FM 6-2

Tactics, Techniques, and Procedures for

FIELD ARTILLERY SURVEY

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HEADQUARTERS, DEPARTMENT OF THE ARMY

Change 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 16 October 1996

Tactics, Techniques, and Procedures for FIELD ARTILLERY SURVEY

FM 6-2, 23 September 1993, is changed as follows:

1. New or changed material is indicated by a star **(★)**.

2. Remove old pages and insert new pages as indicated below.

REMOVE PAGES	INSERT PAGES
i through xiv	i through xiv
1-1 and 1-2	1-1 and 1-2
7-11 and 7-12	7-11 and 7-12
7-15 and 7-16	7-15 and 7-16
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Glossary-1 through -8	Glossary-1 through -9
References-1 through -3	References-1 through -4
Index-1 through -10	Index-1 through -11

3. File this transmittal sheet in the front of the publication for reference.

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Field Manual
FM 6-2

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 23 SEPTEMBER 1993

Tactics, Techniques, and Procedures for FIELD ARTILLERY SURVEY

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DISTRIBUTION RESTRICTION: Approved for public release; distribution is unlimited.

This publication supersedes FM 6-2, 3 November 1986 and rescinds DA Form 3913 (December 1986), DA Form 4009 (December 1986), DA Form 4009a, (December 1986), DA Form 4109 (December 1986), DA Form 4110 (June 1973), DA Form 4168 (October 1973), DA Form 4175 (October 1973), DA Form 4211 (February 1974), DA Form 4212 (February 1974), DA Form 4214 (December 1986), DA Form 4259-R (September 1983), DA Form 4362 (April 1975), DA form 4626 (May 1977), DA Form 5596-R (December 1986), and DA Form 5597-R (December 1986).

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PREFACE

This publications is a guide for commanders, survey officers, and all personnel whose duties include planning, supervising, and performing field artillery (FA) surveys or training in those areas. The material presented herein applies without modification to both nuclear and nonnuclear warfare. This manual provides—

- Doctrine for instruction and employment of survey sections.
- Guidance and reference in survey principles.
- Procedures used in operating and maintaining equipment.

This manual discusses the survey personnel and equipment available to FA units. It describes and discusses—

- Measurement of angles and distances.
- Techniques of recording field data as they are determined.
- Different methods used to extend survey control.
- Basic astronomy and the methods and techniques used in astronomic observation to determine direction.
- Determination of relative locations on a rectangular grid system by using conventional survey methods, the position and azimuth determining system (PADS), and the global positioning system (GPS).
- Survey requirements and techniques used for different FA weapon and fire support systems.
- Survey planning required at all echelons.
- Standardized procedures relevant to survey operations (Appendix A) (denoted in text by a large asterisk [*]).
- Survey standards and specifications (Appendix B).
- Training for the FA surveyor (Appendix C).
- ★]Locally reproducible forms for use with the backup computer system (BUCS), the forward entry device meteorological/survey (FED MSR), and for recording survey control point (SCP) data. (See Appendix D for a list of these forms and the back of this publication for copies of the reproducible forms.)

★ It also includes the ellipsoid and datum tables (Appendix E), a grid zone chart (Appendix F), star cards (Appendix G), and extracts from the standardization agreements (STANAGs) and quadripartite standardization agreement (QSTAG) implemented by this book (Appendix H).

This publication implements the following international agreements:

- ★ STANAG 2934, *Artillery Procedures--AArtyP-1.* (This STANAG combines STANAGs 2865 and 2373.)
- QSTAG 269, *Survey Accuracy Requirements for Surface-to-surface Artillery.*

The proponent of this publication is HQ TRADOC. Send comments and recommendations on DA Form 2028 (Recommended Changes to Publications and Blank Forms) directly to the following:

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Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

CHAPTER 1
MISSION, RESPONSIBILITIES, AND DUTIES

★ *The mission of FA survey is to provide a common grid that will permit the massing of fires, delivery of surprise observed fires, delivery of effective unobserved fires, and transmission of target data from one unit to another to aggressively neutralize or destroy enemy targets. The establishment of a common grid, and the single operational datum within the common grid is a command responsibility.*

> ★**NOTE:** *Common grid* refers to all firing and target-locating elements within a unified command located and oriented, to prescribed accuracies, with respect to a single three-dimensional datum.

1-1. SURVEY PLANNING

a. Field artillery survey must provide indirect fire assets and target-locating assets with a common grid. Common survey control allows the maneuver commander to employ fire support resources with a guarantee of accurate and timely fire support. Survey planning within the force is based on the following tactical considerations:

- The commander's target adjustment policy (that is, if the element of surprise is an important aspect of his tactical plan).
- The requirement for transfer of adjusted target locations to higher and lower echelons.
- The required attack of deep high-payoff targets onto which fire cannot be adjusted (or if surprise is a factor).
- The planned positioning of indirect fire units during each phase of the operation.
- The planned tasking of target acquisition (TA) sensors and the processing of targets to an attack system.

b. The maneuver headquarters (HQ) establishes survey time lines and accuracy requirements in the initial planning stages of an operation. The maneuver commander gives the artillery commander (fire support coordinator [FSCOORD]) targeting priorities and the effects he requires on high-payoff targets. This information translates into survey requirements for the TA sensors and the designated attack systems, which must be on a common grid by the time required. The effects required on the target and inherent system inaccuracies determine the survey accuracy requirement (hasty, fourth-order, or fifth-order survey).

1-2. SURVEY OPERATIONS IN THE AIRLAND BATTLE

AirLand Battle (ALB) doctrine describes the Army's approach to generating and applying combat power at the operational and tactical levels. Surveyors must adapt this doctrine to their mission.

a. AirLand Battle Surveyor. The ALB surveyor understands the principles of all survey methods. His attitude is that some kind of survey is always possible, and some survey is better than no survey at all. He is a thinker with an open mind, an expert in land navigation, and confident in himself and his leaders. He takes the initiative to ensure a successful survey mission. Using initiative and ability, he makes good use of the available time and resources to provide accurate survey control when and where it is needed.

b. Survey Mission Under AirLand Battle. The mission of FA survey-provide a common grid—does not change under ALB doctrine. However, the use of split battery operations, composite units, intelligence and electronic warfare (IEW) sensors, new systems, and greater dispersion and displacements have increased the survey workload. During the first 2 or 3 days of battle, artillery units expect to make many moves. The number of survey points required will depend on the type of unit and the intensity of battle. Prior planning is essential. Before hostilities begin, units should survey a network of artillery positions in their area of operation.

c. AirLand Battle Basic Tenants. The ALB basic tenets of initiative, depth, agility, and synchronization are the foundation of the Army operational concept. Survey leaders and planners must understand how the ALB basic tenets relate to the survey mission.

(1) Initiative equates to the importance of speed. It means making things happen more quickly than the enemy can respond. Early planning enables commanders to take the initiative by ensuring that acquisition and firing units are located by common reference in relation to each other and that the data are timely and to the required accuracy. This provides for the rapid transfer of target data to and between firing elements without degrading accuracy.

(2) Depth is important to the survey planner. It directly relates to the need for accurate and responsive common survey control for deep strikes against the enemy and for accurate fire support in close and rear operations. A combination

of PADS and conventional methods provides the flexibility needed to ensure precise and rapidly extended common survey control to fire support elements (FSEs) in support of the maneuver forces.

(3) Agility is gained through flexible organizations and quick-minded, flexible leaders. For FA survey, agility means having an appropriate mix of equipment and personnel capable of adapting to changing conditions and responsive to leaders who can "think on their feet." The ability to use conventional methods when and where they are advantageous gives the survey section added agility.

(4) Synchronization refers to unity of effort throughout the force. Common survey control ensures this unity at every echelon in the fire support chain when required. Survey planning and cooridnation are, therefore, part of synchronization.

d. Command and Control. Command and control is an important part of ALB doctrine. Planning, communications, and coordination are essential parts of command and control. (Chapter 14, Figure 14-13 outlines the communications network for FA survey.) Field artillery survey planning and coordination begins at the corps artillery survey planning and coordination element (SPCE) with an interface between the topographic (topo) engineers and the SPCE at division artillery (div arty) and FA brigades. Communications is the key to the up, down, and lateral flow of information. The div arty survey officer and FA brigade chief surveyor further coordinate the survey plan down to battalion level with the battalion reconnaissance and survey officer (RSO) and chief surveyor. This type of command and control ensures a successful survey mission.

1-3. FUNDAMENTAL SURVEY OPERATIONS

Successful accomplishment of the mission depends on the fundamental survey operations in Table 1-1.

a. Planning. Survey planning begins with understanding the maneuver commander's intent and receiving the FSCOORD's guidance. Then a thorough map and ground reconnaissance (recon) is conducted. When the PADS is used, ground reconnaissance and survey operations are conducted concurrently. During planning, full consideration is given to the following:

- Artillery commander's concept.
- Priorities.
- Tactical situation.
- ★ Operational datum and survey control available.
- Desired accuracy.
- Number of installations.
- Terrain.
- Weather.
- Personnel.
- Time available.

The commander is responsible for establishing a common grid and, therefore, accomplishing the survey mission. However, survey leaders must keep the commander informed. When the survey plan cannot support the commander's guidance, survey planners must pass the plan to the S3 and the commander. They will review, adjust, and/or approve the plan. Aggressive survey planning that answers **who, where, when, why,** and **how** is absolutely essential to ensure mission success.

b. Coordination. Coordination and planning originate at the corps SPCE located at the tactical operations center (TOC). The corps SPCE is the interface between the topo engineers, division artilleries, and nondivisional units requiring survey control. This coordination and planning effort at div arty is accomplished by the survey officer assigned to div arty headquarters and headquarters battery (HHB). The division survey plan is further coordinated at the battalion level with the battalion RSO. Interface between all echelons of command must be maintained to ensure that common survey control can be provided to units in support of maneuver commanders where and when it is needed. The coordination and synchronization of the survey plan are essential to mission success.

c. Fieldwork. Survey fieldwork is performed by the survey personnel to extend common survey control throughout the area of operations. Fieldwork includes establishing SCPs, measuring distances and horizontal and verticaI angles, making astronomic observations, and accurately recording field data and sketches of SCPs established. The fieldwork must be started immediately on receipt of the commander's orders and be continuously and aggressively pursued until completion of the survey plan.

d. Computations. Survey computations include the use of known data to initiate PADS or conventional operations and the conversion of appropriate elements of field data to usable horizontal and vertical position locations and azimuths. Survey computations and fieldwork are performed at the same time.

1-4. PLANNING RESPONSIBILITIES

a. Each FSCOORD is responsible for ensuring that required survey control, consisting of both horizontal and vertical position location and an orienting line of known direction, is furnished to subordinate units by the time required and to the required accuracy. The FSCOORD must issue orders to the S3 and/or survey officer so that detailed planning and coordiantion may begin. The FSCOORD guidance must provide priorities; accuracies; time to be finished; primary, alternate, and supplementary position requirements; and future plans.

b. The S3 is responsible for the direct supervision of the survey officer. The S3 issues orders and provides guidance based on the FSCOORD's requirements. The S3 coordinates with higher- and lower-echelon staff officers and commanders and advises the commander on any deviations from previous orders.

c. Survey operations must be started as soon as the requirement for survey has been identified. The goal is to establish survey control before occupation by the firing or acquisition elements. All training should point toward this end. The FSCOORD is responsible to coordinate the movement of survey teams with the maneuver commander.

Table 1-1. **Fundamental survey operations**

OPERATIONS	ACTIONS
Planning	Receive artillery commander's guidance. Conduct map end ground reconnaissance. Formulate survey plan, end issue orders detailing the following: • Accuracies. • Time to finish. • PADS requirements. • Alternate plan. • Priorities. • Logistics. • Conventional requirements. • Future requirements.
Coordination	Ensure communications requirements are met and survey data are available where and when needed to include the following: • Higher headquarters. • Adjacent headquarters. • Survey information. • S2 and/or S3. • Commanders. • Lower headquarters.
Fieldwork	Establish and mark survey control points. Provide PADS update points. Provide update points for stabilization reference package/position-determining system (SRP/PDS). Establish position and azimuth for all FA systems requiring survey control. Measure distances and angles. Make astronomic observations. Record and sketch field data. Supervise and/or synchronize PADS-conventional survey interface.
Computations	Compute direction. Compute horizontal and vertical location. Convert to common control. Transform data between grid zones and datums.

d. When survey control is not immediately available, all efforts should be directed toward establishing common directional control in the position area. Recommended methods of establishing direction by priority are as follows:

- Astronomic observation.
- Simultaneous observation with direction established
- the master station by–
  - Astronomic observation (sun or star).
  - Survey instrument, azimuth gyro, lightweight (SIAGL).
  - PADS.
- Directional traverse by using a theodolite.

e. Providing the best available direction and location may take precedence over accuracy of data. In some situations, the commander may have to accept survey accuracies that fall short of the specifications given. This determination is the commander's decision. Survey leaders must advise the commander of the effect of inaccuracies on the guarantee of fire support. For example, in a conventional survey in which the azimuth closure error is excessive, the ability of a fire support unit to accomplish a tire mission on schedule may depend on using the best available data and may require time for adjustment. The use of substandard survey data can affect hitting the target and also could result in friendly casualties. However, these surveys of degraded accuracy should be rerun when the tactical situation and time permit.

f. If the terrain or the tactical situation is such that the survey sections of div arty, HHB, target acquisition battery (TAB), and battalion or battery cannot establish survey control by the time required, hasty methods may be used. The effects of using hasty methods and the guarantee of accurate fire support are shown in Table 1-2. Hasty survey techniques are completely explained in FM 6-50.

Table 1-2. **Hasty survey effect on fire support**

TYPE OF SURVEY	MEANS OF DETERMINING		EFFECTS
	ORIENTATION	*LOCATION*	
Battery hasty	Aiming circle: • Simulteneous observation. • Polaris 2 reticle observation. • Polaris-Kochab observation. Ž Directional traverse.	Graphic resection. Map spot.	1. No common grid. 2. No passage of target records or registration data. 3. No guarantee on unobserved or nonadjusted fire.
Battalion hasty	A scheme in which orientation is initiated by theodolite to an accuracy of 0.3 mil and more than one fire unit is put on common orientation. (Can be passed by simultaneous observation.)	Survey process that puts more than one unit on common grid but not necessarily closely related to the map. Scheme not originated from a known survey control point.	1. Units located in the scheme that includes both orientation and location may pass target records end registration data to each other. 2. No guarantee on nonadjusted or unobserved fire unless the acquisition source is also included in the scheme. Fire can be messed by all units in the scheme after adjustment with one gun.
Divisional hasty	A scheme in which more than one battalion is put on common orientation.	Same as for battalion.	Same as for battalion.
Fifth-order or higher survey	Gyroscopic, astronomic, or equivalent process.	Survey process that originates at known survey control.	1. No restriction on the passage of target records or registration data. 2. Unobserved fire is reliable as long as the acquisition source is in the scheme. 3. Minimizes adjustment.

1-5. RESPONSIBILITIES OF THE ENGINEER TOPOGRAPHIC BATTALION

a. The engineer topo battalion is the primary source of topo support throughout the echelons above corps (EAC). The topo battalion responsibilities to artillery survey are as follows:

- Extend horizontal and vertical control into corps and division areas.
- Provide an SPCE in support of EAC.
- Provide mapping survey control where required.
- Advise on topo matters.
- Assist in lower-level survey to augment FA survey when directed.

b. Topo surveyors establish and recover existing ground control and extend it by third-order or higher conventional survey or satellite methods. Exact positioning of this high-order survey control is coordinated by the corps survey officer. Topo survey support must be provided to multiple launch rocket system (MLRS) units, corps general support (GS) artillery units, and other nondivisional assets in the corps area. The number of SCPs that topo survey must provide for the EAC and corps area depends on the dispersion, amount of movement, and commander's priorities. For example, on the basis of five to seven moves per day, 10 to 20 SCPs will be required every 24 hours to support EAC and corps FA systems that div arty cannot support.

c. Topo surveyors extend survey control into the division area of operations. Initial SCPs must be within 5 kilometers (km) of div arty HQ. Div arty and TAB surveyors will further extend control to the vicinity of weapon systems and target-locating systems. Exact positioning of subsequent SCPs depends on dispersion movement, and priorities. For example, on the basis of five to seven moves per day, 15 to 30 points must be established or data provided from trigonometric (trig) lists every 24 hours. At a minimum, topo support must provide a grid network of high-order SCPs every 30 km throughout the division or corps area. These SCPs must also allow adjacent divisions or corps to be connected by a common grid.

1-6. FA SURVEY ORGANIZATIONS

In the transition from personnel-intensive to equipment-intensive technology, survey organizations were tailored in terms of mission, reliability, equipment, and personnel requirements. The FA survey structure is the key to the transition to new fire support systems, future survey systems, and different unit configurations such as the light infantry division (LID) and composite battalions. See Chapter 14 for more specific guidance on equipment and personnel authorizations.

a. Survey Planning and Coordination Element. At the higher echelons, there is a survey command and control cell called the SPCE. The SPCE is authorized at each corps artillery, div arty, FA brigade, and MLRS battalion. The personnel that man the SPCE are shown in Table 1-3. The SPCE plans and coordinates all of the surveys within its area of responsibility. Survey data collection, evaluation, and dissemination are additional functions of the SPCE.

b. Survey Platoon Headquarters. The survey platoon HQ of FA battalions executes survey planning and coordination. These responsibilities are carried out by an RSO (1LT), and a chief surveyor (SFC). An FA surveyor (SPC) performs survey functions when required and is the radiotelephone operator (RATELO).

Table 1-3. **Survey planning and coordination element**

HEADQUARTERS	RANK	DUTY POSITION
Corps artillery	MAJ	Survey planning and coordination officer
	SFC	Chief surveyor
	SGT	Survey computer
	SGT	Survey computer
	SGT	Survey computer
Division artillery (armored or mechanized)	CPT	Survey officer
	SFC	Chief surveyor
	SGT	Survey computer
	SPC	FA surveyor
	SPC	FA surveyor
Division artillery (light or air assault airborne)	SFC	Chief surveyor
	SGT	Survey computer
	SPC	FA surveyor

Table 1-3. Survey planning and coordination element (continued)

HEADQUARTERS	RANK	DUTY POSITION
Field artillery brigade	SFC SGT SPC SPC	Chief surveyor Survey computer FA surveyor FA surveyor
MLRS battalion	1 LT SFC SPC	Reconnaissance and survey officer Chief surveyor FA surveyor
Patriot battalion	SFC SPC	Chief surveyor FA surveyor

Note. The standards of grade authorizations, duty positions, duty titles, and tasks in AR 611-201 will change upon approval by Department of the Army.

LEGEND:
CPT = captain
1 LT = first lieutenant
MAJ = major
SGT = sergeant
SPC = specialist

c. Survey Section. The survey section for a heavy div arty and a 3 x 8 FA battalion consists of a section chief, one survey team, and two PADS teams. (The duty positions and organization for the survey sections of the different units are shown in Figure l-l.)

(1) Section chief. The section chief (SSG) is responsible for the total survey effort of his section. He must prioritize his personal involvement between the survey team and the PADS team as needed to execute the survey plan.

(2) Survey team. The survey team consists of two FA surveyors led by the section chief. The survey team performs conventional and modified survey methods to—

- Enhance the overall survey effort.
- speed up PADS operations.
- Provide flexibility and agility to the survey operation.

(3) PADS team. The PADS team, also led by the section chief, consists of a PADS team chief and an FA surveyor. The PADS team provides survey control as directed by the section chief.

(4) Survey parties. Conventional survey parties (when authorized) are configured as shown in Table 1-4.

d. Equipment Constraints. Until all PADS are fielded, configure a survey section by using the options below.

(1) No PADS. Use a standard survey platoon HQ and three conventional six-man parties at the div arty or five-man survey parties at the battalion.

Table 1-4, Conventional survey parties

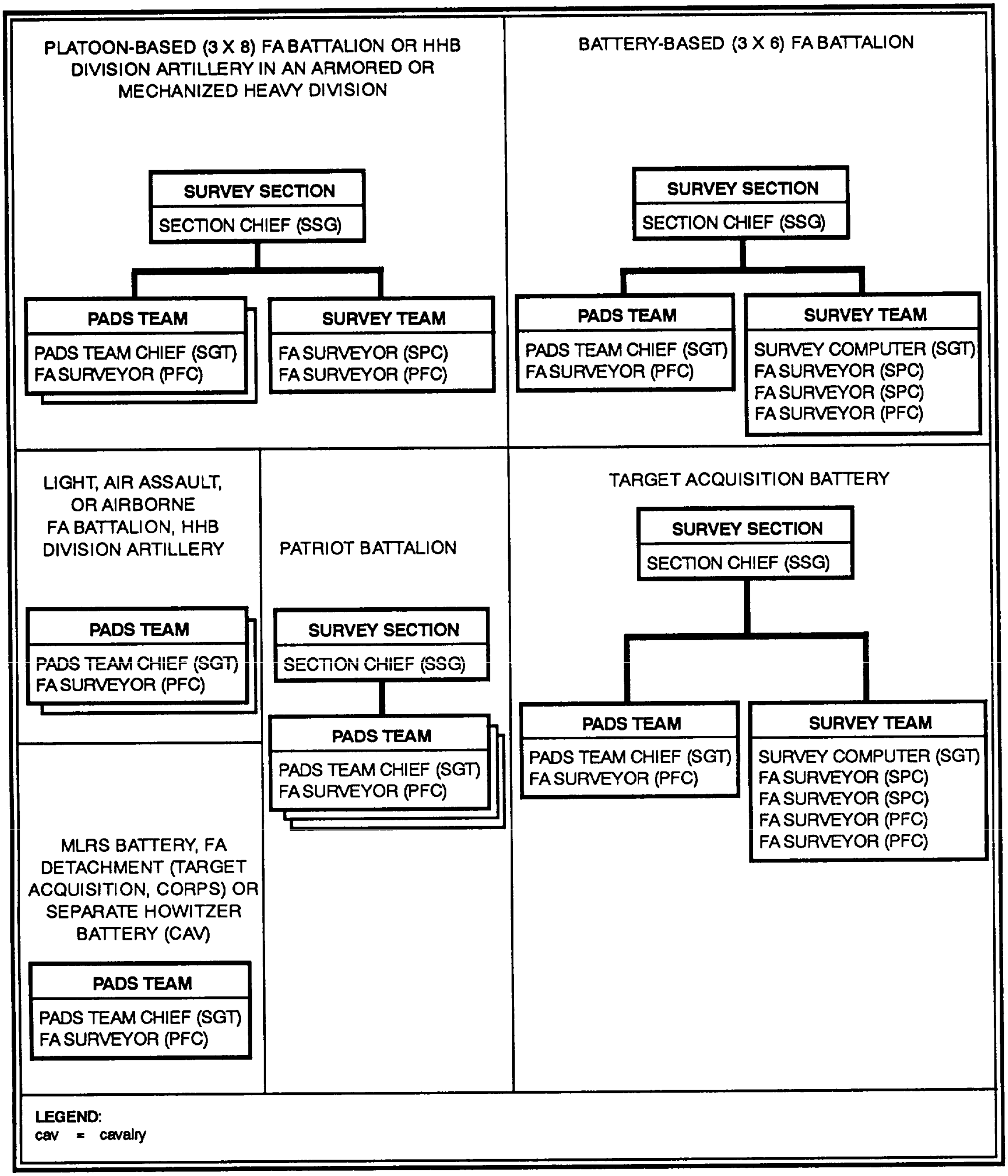
RANK	DUTY POSITION	FIVE-MAN PARTY	SIX-MAN PARTY
SSG	Section chief	1	1
SGT	Survey computer	1	1
SPC	FA surveyor	2	2
PFC	FA surveyor	1	2

LEGEND.
PFC = private first class
SSG = staff sergeant

(2) One PADS. Use a standard platoon HQ, a PADS team, and two conventional six- or five-man parties.

(3) Two PADS but no SEDME-MR. Use a standard platoon HQ, two PADS teams, and one conventional five- or six-man party. Then, when the survey equipment, distance-measuring, electronic (medium-range) (SEDME-MR) is issued, drop three men from the div arty or two men from the battalion conventional party, thus forming the standard survey section–survey section chief, one two-man survey team, and two PADS teams.

Figure 1-1. **Survey sections**



1-7. SURVEY EQUIPMENT

The restructure of the conventional party causes a number of changes in the tables of organization and equipment (TOE). Table 1-5 summarizes the equipment authorized for the five basic elements.

* Table 1-5. **Equipment for survey elements**

EQUIPMENT	SPCE LT	SPCE HVY	PLT HQ[1]	PADS TEAM	SURVEY TEAM
Antenna group OE-254/GRC	1	1	0	0	0
Antenna group OE-303/GRC	1	1	0	0	0
Binoculars	1	1	1	1	1
BUCS Special	1	1	0	0	0
BUCS General	1	1	0	1	2
Cable, reel, MX-10891/G	2	2	2	2	0
Compass, M2	1	1	1	1	1
Digital nonsecure voice telephone TA-1035/U	1	1	1	0	0
Laser range finder AN/GVS-5	0	0	0	1	1
M203 grenade launcher	1	1	1	1	1
M60 machine gun	0	0	0	0	1
GPS manpack/vehicular set (LIN Z46324)[2]	1	1	1	1	1
GPS M998 installation kit (LIN Z69825)[2]	1	1	1	1	1
PADS AN/USQ-70	0	0	0	1	0
Plotting set, artillery fire control	1	1	0	0	0
Radio AN/VRC-88A	0	0	0	0	1
Radio AN/VRC-89A	1	1	1	0	0
Radio AN/VRC-90A	1	1	0	1	1
Reeling machine, cable, hand, RL-39	2	2	2	0	0
Securable remote control unit	1	1	0	0	0
SEDME-MR (LIN S69675)	1	0	1[3]	0	1

★ Table 1-5. **Equipment for survey elements (continued)**

EQUIPMENT	SPCE LT	SPCE HVY	PLT HQ[1]	PADS TEAM	SURVEY TEAM
SIAGL	1[3]	0	1[3]	0	1
Surveying set, artillery fire control, fourth-order[4]	0	0	0	0	1
Survey set, supplementary equipment (PADS)	0	0	0	1	0
Telephone set TA-312/PT	1	1	1	0	0
Theodolite, T16 or T2 with tripod	0	0	0	1[6]	1[5,6]
Trailer, 3/4-ton	1	1	0	0	0
Tripod, surveying: with head extension legs, wood 64" (LIN X31755)	0	0	2[3]	0	0
Vehicle (HMMWV) with winch	1	1	1	1	1
Vehicle (HMMWV) without winch	0	1	0	0	1

[1] The MLRS SPCE will receive the same equipment as listed in the PLT HQ column.

[2] The GPS manpack/vehicular set used by FA survey elements will be either the AN/PSN-8/VSN-8 or the AN/PSN-9/VSN-9. Stock numbers have not yet been assigned.

[3] Indicates light, air assault, and airborne divisions only. This equipment is needed since no conventional team is authorized.

[4] The receiver radio (time signal) (NSN: 5820-01-316-2670) is a component of the surveying set, artillery fire control, fourth order. The time signal receiver is essential to perform astronomic observations. Units not authorized the fourth-order survey set must requisition this item.

[5] TAB and HHB div arty will receive T2 theodolites because of accuracy requirements.

[6] TAB will receive two T2 theodolites.

LEGEND:
HMMWV = high-mobility multipurpose wheeled vehicle
hvy = heavy
LIN = line item number
lt = light
NSN = national stock number
plt = platoon

★ 1-8. DUTIES OF SURVEY PERSONNEL

Individual duties of the various survey personnel by military occupational specialty (MOS) code or area of concentration (AOC) are shown in Table 1-6.

Table 1-6. **Duties of survey personnel**

SURVEY OFFICER, AOC 13D—

- Coordinates and supervises—
  - Training of survey personnel.
  - Field operations.
  - The preventive maintenance program on survey equipment end vehicles.
  - The SPCE, if authorized at his echelon.
- Formulates a survey plan after receiving orders from the S3 or commander and before conducting reconnaissance.
- Issues survey orders and briefs his chief surveyor and team chiefs.
- Conducts reconnaissance.
- Coordinates survey operations with higher, lower, and adjacent HQ.

CHIEF SURVEYOR, MOS 82C40—

- Assists the survey officer and, when directed, performs my or all of the duties of the survey officer.
- Trains his survey section in the performance of reconnaissance, communications, and survey activities. Ensures that section personnel are cross-trained.
- Performs other duties as directed.

SECTION CHIEF OR CHIEF OF PARTY, MOS 82C30—

- Trains his survey party or section.
- Executes his party or section portion of the survey plan.
- Supervises and coordinates field operations of his party or section end PADS team.
- Maintains liaison with the survey officer or chief surveyor during field operations.

SECTION CHIEF OR CHIEF OF PARTY, MOS 82C30— (CONTINUED)

- Supervises preventive maintenance checks and services (PMCS) of section equipment, to include vehicles, communications equipment, and weapns.
- Performs other duties as directed.

SURVEY COMPUTER, MOS 82C20—

- Maintains the required Department of the Army (DA) forms for computation of surveys.
- Performs Independent computations during field operations by using the BUCS.
- Maintains the BUCS.
- Assists in the collection, evaluation, and dissemination of survey data.
- Performs other duties as directed.

PADS TEAM CHIEF, MOS 82C20—

- Performs initialization, operation, and PMCS on the PADS.
- Sets up and operates the theodolite when used to mark and update.
- Directs the assistant PADS operator for autoreflection or plumb bob emplacement over the SCP or other points to be established.
- Records PADS data and maintains the field notebook, ensuring all entries conform with prescribed format.
- Briefs assistant PADS operator and aircraft crew on the survey mission and zero-velocity correction requirements.
- Performs or assists in the transfer and strapping down of the PADS for air assault operations.
- Performs other duties as directed.

FA SURVEYOR, MOS 82C10—

- Instrument Operator—
  - Performs operator PMCS on survey instruments.
  - Operates the instruments during field operations.
  - Verifies the verticality of the range pole before measuring angles during field operations.
  - Reads the measured values to the recorder end checks the recorder by use of a read-back technique.
  - Familiarizes himself with the fieldwork requirements for all survey methods.
  - Helps the tape team maintain alignment during taping operations.
  - Performs other duties as directed.
- Computer-Recorder—
  - Maintains an approved notebook of all surveys performed by the survey team or party.
  - Neatly and legibly records survey starting data and all measured data during field operations.
  - Sketches in the field notebook concise, complete diagrams and descriptions of the principal stations.
  - Checks and means angular data measured by the instrument operator.
  - Checks taped distances by pacing (for fifth-order surveys only).
  - Provides required field data to the survey computers independently.
  - Performs other duties as directed.
- Rodman-Tapeman—
  - Maintains the FA survey set.
  - Assisted by another member of the party and using proper taping techniques, tapes horizontal distances during field operations.

Table 1-6. **Duties of survey personnel (continued)**

FA SURVEYOR, MOS 82C10—(CONTINUED) – Computes an accuracy ratio for double-taped distances as required, – Reports measured distances to the recorder. – Assists In setting up and marking survey stations. – Erects the survey equipment distance-measuring electronic reflector.	– Assists the instrument operator in the care of the instruments. – Operates and maintains communications equipment. – Performs other duties as directed. • Assistant PADS Operator— – Operates and performs maintenance on the PADS vehicle as specified in technical manuals. – Operates and maintains communications equipment.	– Maneuvers vehicle for autoreflection or plumb bob emplacement over the SCP or points to be established under the direction of the PADS operator. – Sets up range poles and establishes survey stations as directed by the PADS operator. Helps the PADS operator in the transfer and strap down of the PADS for air assault operations. – Assists the PADS operator in all his duties. – Performs other duties as directed.

CHAPTER 2
DISTANCE DETERMINATION

In conventional survey operations, a primary requirement of the survey party is to determine distance between two points. The surveyor has many devices available with which to determine distance. These range from the 30-meter steel tape to electronic instruments. Using the solution of geometric figures by methods such as trig traverse is discussed in Chapter 5. Distance measurement is a basic operation that every FA surveyor must be able to perform with the tools available.

Section I

HORIZONTAL TAPING

Horizontal taping is used in conventional FA surveys. In this method, all measurements are made with the tape held horizontally. Measure the horizontal distance between the rear station and the forward station. Usually the distance between stations is more than a full tape length. The taping team determines the distance by measuring successive full tape lengths. When the distance remaining is less than a full tape length, the team measures the partial tape length. The total distance between the stations is determined by multiplying the number of full tape lengths by the length of the tape and adding the partial tape length.

2-1. TAPING TEAM

A taping team consists of two men—a front tapeman and a rear tapeman. The rear tapeman commands the taping team and records all distances in his taping notebook. He is responsible for determining and reporting the measured distance to the recorder. The front tapeman independently computes the distance measured. Then he compares his findings with those of the rear tapeman and records the distance in his notebook. At night, taping requires additional personnel to assist the front and rear tapemen (paragraph 2-18).

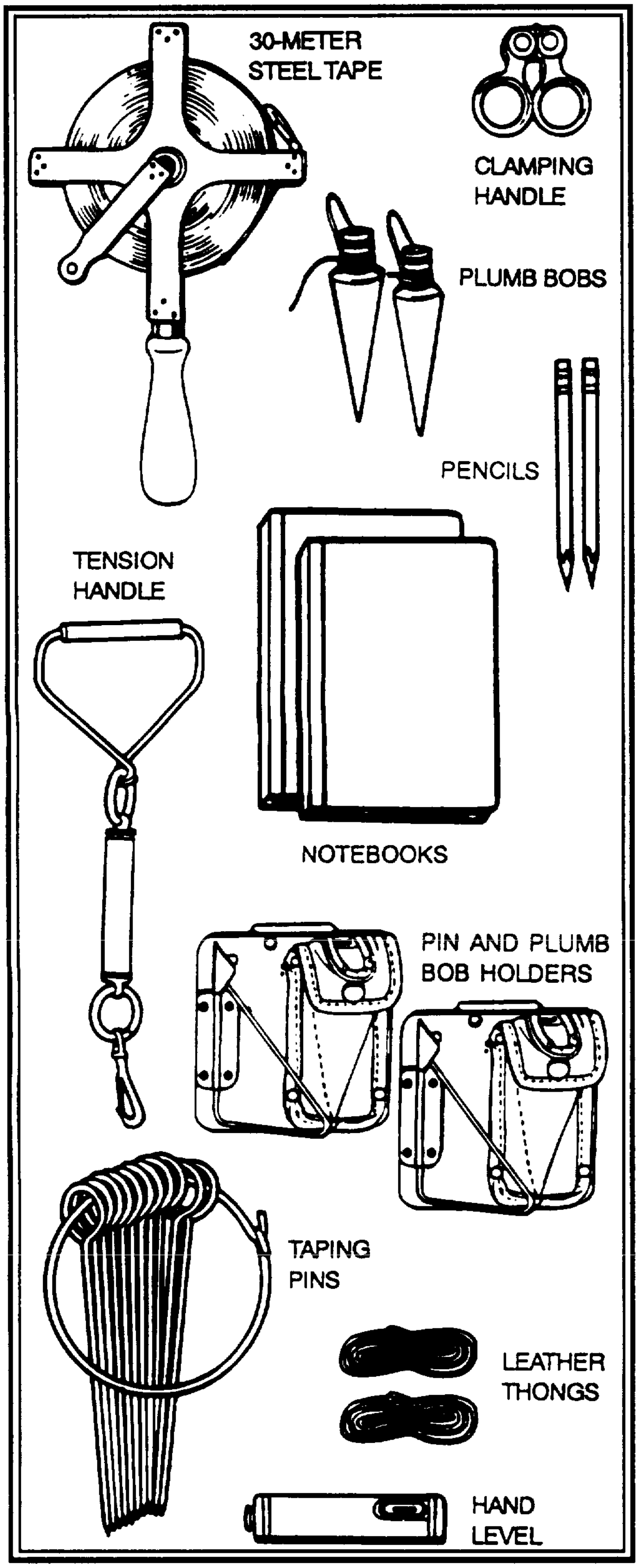
2-2. TAPES AND ACCESSORIES

a. Survey taping teams are equipped with 30-meter steel tapes for measuring linear distances. Tapes are graduated on one side in meters, decimeters (0.1 meter), and centimeters (0.01 meter). The first decimeter is graduated in millimeter (0.001 meter). At each end of the tape is a blank space. Each tape is assigned a number that is used for all records about that specific tape (for example, repairs [paragraph 2-20b]).

b. In addition to a tape, each team is equipped with the following (Figure 2-l):

- One set of taping pins.
- One tension handle.
- One clamping handle.
- Two plumb bobs.
- Two pin and plumb bob holders.
- One hand level.
- Two leather thongs.
- Two notebooks.
- Two pencils.

Figure 2-1. **Taping equipment**



(1) Taping pins. A taping pin is a steel pinpointed on one end with a ring at the other. Use taping pins for marking measured tape lengths on the ground. This will help determine the number of tape lengths measured since the last station. The ring and the upper part of the pin are painted red. The rest of the pin is white. Taping pins are issued in sets of 11 pins each. Properly used, taping pins will prevent a "missed" or "dropped" tape length, a common mistake in distance taping.

(2) Tension handle. The tension handle is used to train taping personnel to recognize when 25 pounds of tension is exerted on a tape. Do not use it in normal everyday surveys. The tension handle has a linear scale graduated in pounds from 0 to 30. Clip it to the tape loop at the end of the tape. Apply tension until the specified reading (25 pounds for artillery survey) appears on the scale.

(3) Clamping handle. This is a mechanical device that grips the flat steel tape without causing a kink in it. When measuring less than a full tape length, the clamping handle permits holding the tape while applying tension.

(4) Plumb bobs. Plumb bobs are used to transfer tape readings to a ground position. This will allow the tape to be read directly above a marked position on the ground.

(5) Pin and plumb bob holders. Each tapeman uses a pin and plumb bob holder to carry taping pins during taping operations. Store the plumb bob in the holder when taping operations are not performed.

(6) Hand level. Use the hand level when taping distances over steep slopes to help keep the tape on a horizontal plane. Use it in normal taping operations to train new tapemen to recognize the required horizontal plane.

(7) Leather thongs. Attach a leather thong to each end of the tape. The leather thongs allow the tapemen to apply tension to the tape.

(8) Notebooks and pencils. Each tapeman keeps a notebook to record distances between stations. These notebooks are in addition to the recorder's notebook.

(9) Other equipment. Often, taping will require the use of other equipment. To get a straight-line clearance between taping points, tapemen may have to clear away vegetation. Useful cutting tools, such as axes, hatchets, or machetes, may be issued to the taping team. Use range poles for aligning the tape from station to station. When measuring distances at night, use flashlights to help align the tape.

2-3. TAPE ALIGNMENT

a. The tapemen must carefully align the tape. The maximum allowable error in both horizontal and vertical alignment is 0.5 meter from one station to the next. The rear tapeman usually makes final alignment by sighting along the tape toward the forward station. The rear tapeman will direct the front tapeman left or right. (See Figure 2-2.) However, if the rear tapeman cannot see the forward station, the front tapeman will make the final alignment. This is done by sighting back on the rear station. The rear tapeman, using preselected reference points aligned with the forward station, can also make the final alignment. The instrument operator, if available, may help in the alignment.

b. The tapemen then level the tape horizontally by holding it parallel to an estimated horizontal plane. If they have trouble keeping the tape level in rough terrain, the tapemen should use the hand level. To use the hand level to set a horizontal plane, the downslope tapeman takes the steps below.

(1) Sight through the level at the upslope tapeman.

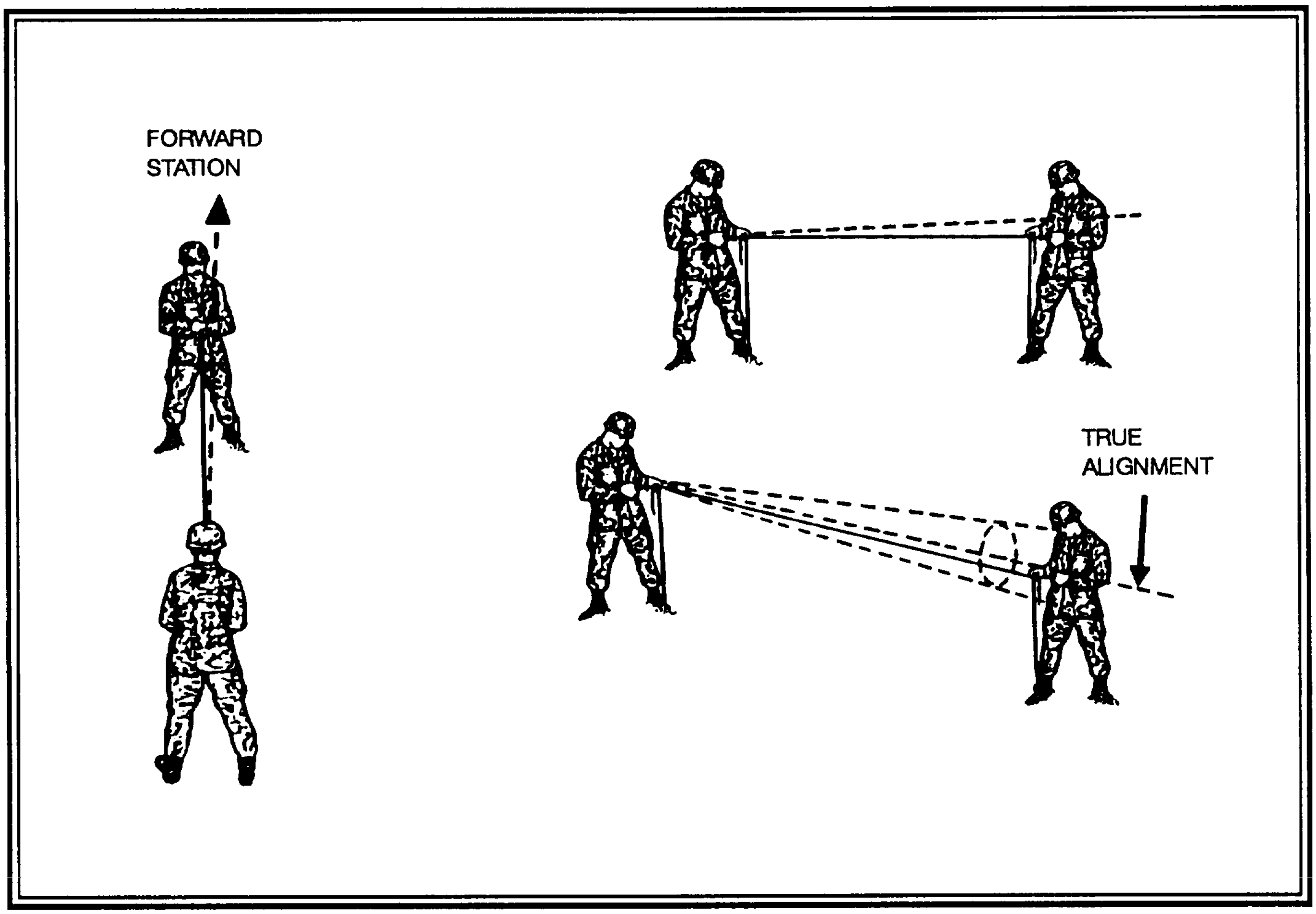
(2) Raise or lower the objective end of the hand level until the image of the level bubble is centered on the horizontal crossline.

(3) Determine the point on the upslope tapeman that is level with the eye. This establishes the horizontal plane.

(4) Tell the upslope tapeman how to hold his end of the tape so that the tape will be parallel to the established horizontal plane. The downslope tapeman must hold the tape no higher than his armpits. Otherwise, the team must use the breaking tape procedure.

c. The tapemen should check the accuracy of the bubble of the hand level when it is first used each day. The upslope tapeman uses the hand level to sight on the downslope tapeman to establish the horizontal plane. The procedure is then reversed to verify the established horizontal plane.

Figure 2-2. **Tape alignment**



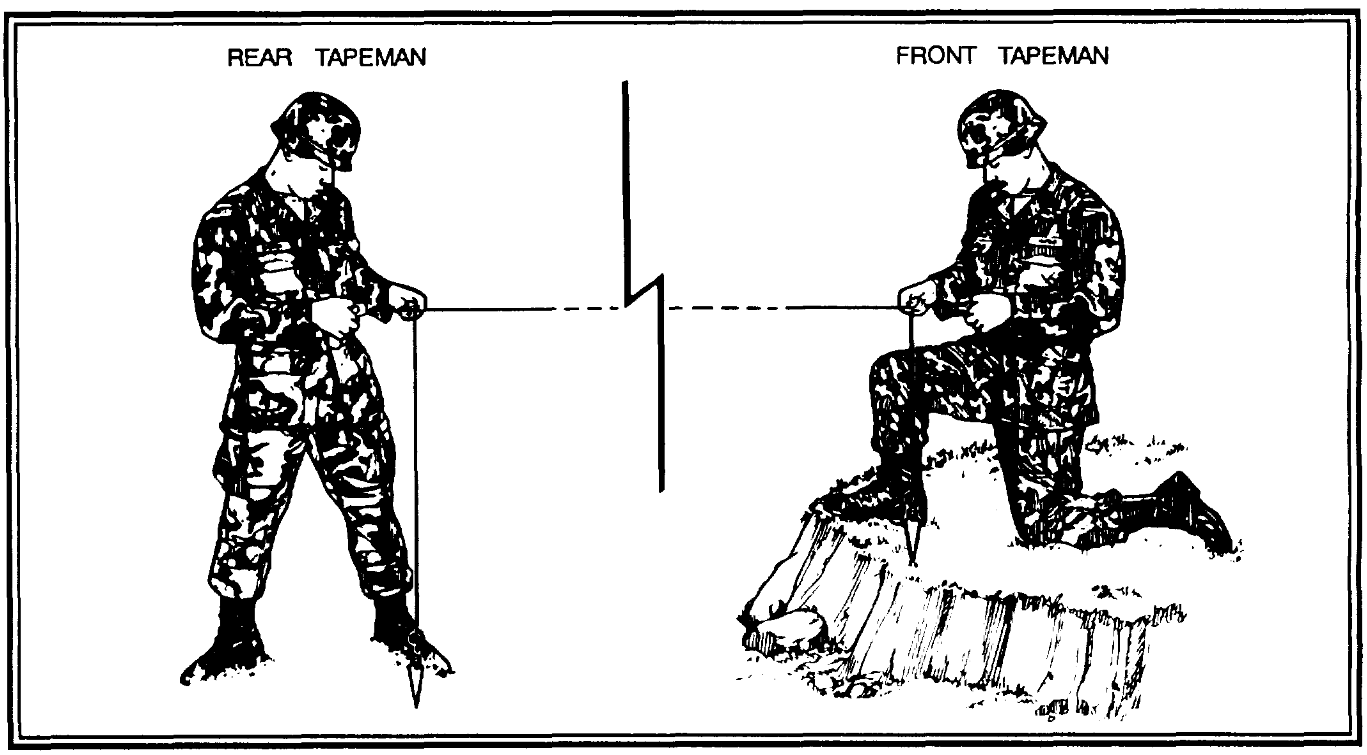
2-4. APPLYING TENSION TO TAPE

a. The tapeman must apply 25 pounds of tension (pull) to each full or partial tape length. He should apply tension to the tape by using his leg muscles and the large muscles of his back. To do this, the tapeman faces across the tape with his shoulders parallel to the length of the tape. He then passes the hand of the arm that is away from the other tapeman through a loop in the thong. Then he places the elbow of that arm tight against some part of his body. (See Figure 2-3.) When the tapeman is standing, he applies tension by bending the knee that is away from the other tapeman. This causes the weight of his body to push against the arm holding the tape. When the tapeman is kneeling, he applies tension by pushing the knee that is away from the other tapeman against the arm holding the tape.

b. The clamping handle is used to hold the tape at arty point other than a tape end. To avoid causing a kink in the tape, the tapeman should hold the clamping handle with the index and middle fingers. Normally, the handle will clamp as he applies tension to the tape. To apply more pressure, the tapeman applies pressure to the outside of the finger grip by using the thumb and ring finger.

c. The front tapeman should use the tension handle until both tapemen become accustomed to the application of 25 pounds of tension.

Figure 2-3. **Applying tension and use of plumb bobs**



2-5. USE OF PLUMB BOBS

a. The tapemen use plumb bobs to project points on the tape to the ground. Each tapeman holds the plumb bob cord on the proper tape graduation using the thumb of one hand on the cord and the forefinger of that hand beneath the tape. (See Figure 2-3.) The front tapeman has the 0-meter graduation and the rear tapeman has the 30-meter graduation. After aligning the tape and applying tension, each tapeman lowers the plumb bob by letting the cord slip across the tape. The tip of the plumb bob should be about 0.25 inch above the desired point. Swinging of the plumb bob is stopped by gently lowering the tape until the plumb bob tip touches the ground and then slowly raising the tape.

b. The rear tapeman uses his plumb bob to position his end of the tape directly over the point from which each tape length is measured.

c. The front tapeman establishes the point on the ground to which each tape length is measured by dropping his plumb bob. If necessary, the front tapeman should clear high grass or other debris in the immediate ground area near the point to be established. This will ensure a true plumb over the point and help the rear tapeman in moving forward. After establishing the point with the plumb bob, the tapeman marks the point with a taping pin.

2-6. USE OF TAPING PINS

The front tapeman must use the taping pins to mark points on the ground for each full or partial tape length. The front tapeman marks the point struck by the tip of the plumb bob by sticking a pin into the ground at exactly that point. The shaft of the pin is placed at an angle of about 45° to the ground and perpendicular to the length of the tape. When moving forward, the tapeman should not pull the tape through the loop of the taping pin. In taping over a hard surface, it may be necessary to mark the point struck by the plumb bob in an identifiable fashion (point of taping pin). The point of the pin is laid at the point struck by the plumb bob, perpendicular to the line of direction of the tape.

2-7. MEASURING THE FIRST FULL TAPE LENGTH

Measure the first full tape length as discussed below.

a. The front tapeman gives 1 taping pin to the rear tapeman and keeps 10 pins. The pin given to the rear tapeman represents the first full tape length. The front tapeman moves toward the forward station with the zero end of the tape.

b. As the end of the tape reaches the rear station, the front tapeman stops, either on his count of paces or on the command **TAPE** given by the rear tapeman. The rear tapeman aligns the front tapeman by sighting first toward the forward station and then in an estimated horizontal plane. Align the tape within 0.5 meter of the line of sight from one station to the next and within 0.5 meter of the horizontal plane.

c. Each tapeman places a leather thong on his wrist and the plumb bob cord on the proper graduation on the end of the tape. The rear tapeman aligns his plumb bob roughly over the rear station and commands **PULL.** The tapemen exert a pull of 25 pounds on the tape.

d. After the tapemen have properly aligned and applied tension to the tape, the rear tapeman plumbs his end of the tape exactly over the rear station and commands **STICK.** At this command, the front tapeman drops his plumb bob and then marks the point of impact by inserting a taping pin into the ground. Insert the pin perpendicular to the line of measurement at an angle of about 45° to the ground. This allows accurate plumbing for the next measurement. After the pin is firmly placed, the front tapeman announces **STUCK.** This is the command for the rear tapeman to move forward to the pin position. The front tapeman advances 30 paces to measure the next tape length.

2-8. MOVING FORWARD

a. The front tapeman should select a landmark (rock, bush, or such) in line with the forward station. Use this technique as a guide in moving forward. The front tapeman should keep his eyes on the forward station. He should determine his pace count for one tape length. He can stop without signal from the rear tapeman when he has moved forward a tape length.

b. By moving forward to a point 2 or 3 meters forward of the rear end of the tape, the rear tapeman usually can locate the taping pin before the front tapeman has stopped. If the taping pin is not readily visible, the front tapeman may have to wait until the rear tapeman arrives at his position. Then he moves forward to make the next measurement.

c. When using an instrument at either the forward or the rear station, the tapeman must remain as clear of the line of sight as possible.

2-9. MEASURING SUCCEEDING FULL TAPE LENGTHS

Succeeding full tape lengths are measured as described in paragraph 2-7 except as discussed below.

a. The front tapeman should get his approximate horizontal alignment by sighting back along the tape toward the last pin position and the rear station. This will allow him to move right or left until the tape is about on line.

b. The rear tapeman plumbs the end of the tape exactly over the point at which the taping pin enters the ground.

c. After the front tapeman commands **STUCK,** the rear tapeman pulls the taping pin from the ground and then moves forward to the next pin position. If a taping pin is lost during the measurement of the distance, the tapemen must tape the entire distance again rather than complete the taping from a recovered pinhole.

2-10. BREAKING TAPE

When the tape alignment is unobtainable within 0.5 meter of a horizontal plane because of the slope of the ground, the tapemen use a special procedure known as breaking tape. (See Figure 2-4.) The procedure for breaking tape is discussed below.

a. The front tapeman pulls the tape forward a full length. He then drops it about on line and then walks back along the tape until he reaches a point at which a partial tape length can be measured. When the tape is held level, it should be no higher than the armpits of the downslope tapeman. At that point, the front tapeman selects any convenient full meter graduation. The tapemen then measure the partial tape length, aligning the tape and applying the full 25-pound tension. Clamping handles are used at any holding point between ends of the tape.

b. After he has placed the taping pin into the ground, the front tapeman announces **STUCK.** He then waits until the rear tapeman comes forward. The front tapeman tells the rear tapeman which full meter graduation was used; for example, **HOLDING 25.** The rear tapeman repeats **HOLDING 25.** The front tapeman receives a pin from the rear tapeman and moves forward. Tapemen repeat this procedure until they reach the zero mark on the tape.

c. When holding a point on the tape other than the zero graduation, the front tapeman must receive a pin from the rear tapeman before moving forward.

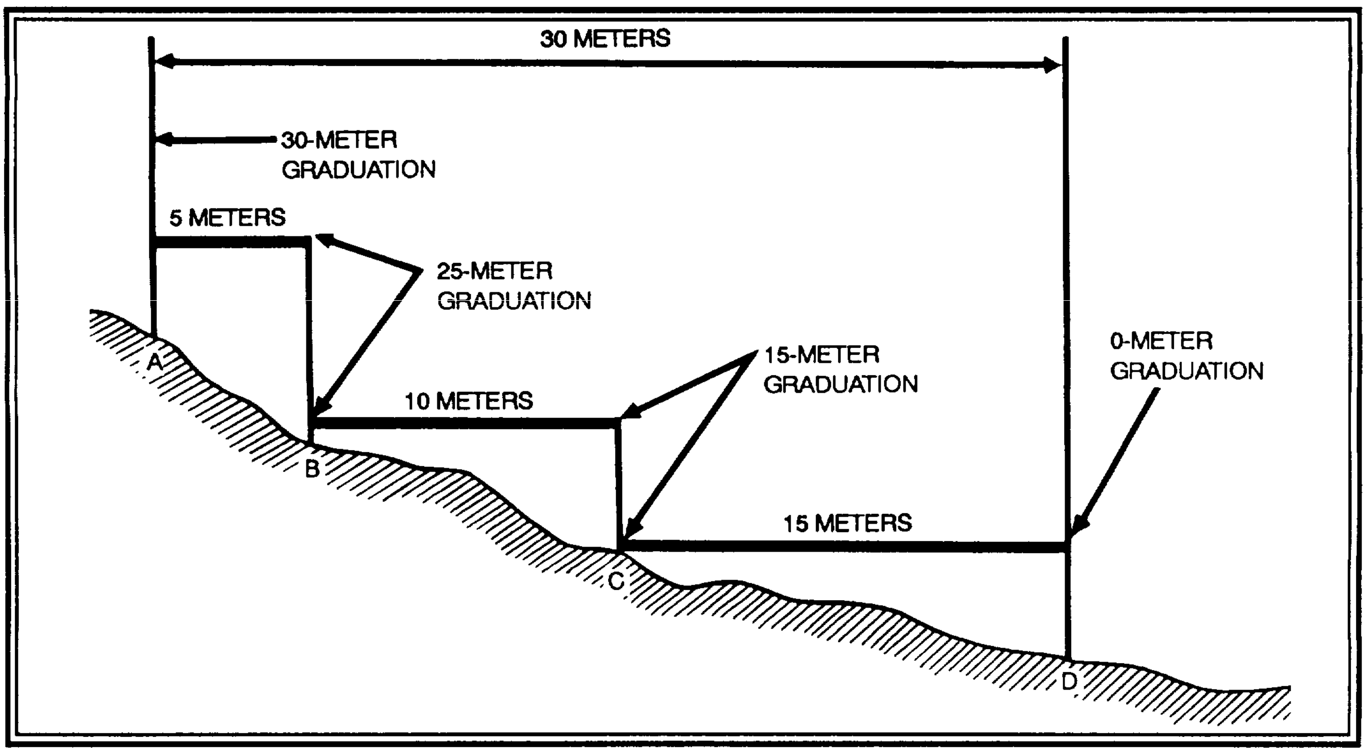
2-11. MEASURING DISTANCES MORE THAN 10 TAPE LENGTHS

To measure a distance longer than 10 full tape lengths, the tapemen use the procedures described in paragraphs 2-3 through 2-9 except as discussed below.

a. When the front tapeman has set his last pin in the ground, he has established a point that is 10 full tape lengths from the rear station. The front tapeman waits at the last pin position until the rear tapeman comes forward.

b. Both tapemen count the pins to be sure that none are lost. (One pin in the ground will not be counted. The rear tapeman should have 10 pins.)

Figure 2-4. **Breaking tape**



c. The rear tapeman gives the front tapeman the 10 pins.

d. Both tapemen record 10 tape lengths (300 meters) and then continue taping.

2-12. MEASURING PARTIAL TAPE LENGTHS

To measure the partial tape length between the forward station and the taping pin representing the last full tape length, the tapemen use the procedure discussed below.

a. The front tapeman moves to the forward station and places the plumb bob cord on the zero graduation of the tape. The rear tapeman moves forward along the tape to the taping pin.

b. To gain slack, the front tapeman commands **SLACK.** The rear tapeman allows the tape to move forward. When the front tapeman is ready, he commands **PULL.** The rear tapeman exerts a pull of 25 pounds on the tape, using a clamping handle to hold the tape. Then the rear tapeman slides his plumb bob cord along the tape until the plumb bob is exactly over the pin.

c. When the zero graduation is exactly over the forward station, the front tapeman commands **READ.** The rear tapeman reads the graduation marked by his plumb bob cord and announces the measurement of the partial tape length to the nearest 0.01 meter.

d. The front tapeman repeats the reading aloud, and both tapemen record the measurement.

e. If the survey party has a nonstandard tape that is graduated in millimeters (mm) from the zero end to the 1-meter mark and in decimeters from the l-meter mark to the 30-meter mark, or in any other combination, use the procedure discussed below.

(1) The front tapeman holds the plumb bob on zero.

(2) The rear tapeman, using a clamping handle to hold the tape, places his plumb bob cord on the first whole meter mark behind the last pin in the ground.

(3) The rear tapeman commands **PULL,** and the front tapeman exerts a pull of 25 pounds on the tape. The rear tapeman should give slack until his plumb bob is exactly over the last pin. The front tapeman slides his plumb bob cord along the tape until the plumb bob is over the forward station.

(4) When the rear tapeman's plumb bob (which he holds on a whole meter mark) is exactly over the pin, the rear tapeman commands **READ.** The front tapeman reads the graduation marked by his plumb bob cord and announces his partial meter reading. The rear tapeman announces the whole meter mark that he was holding.

(5) Computing independently, both tapemen subtract the front tapeman's partial meter reading from the rear tapeman's whole meter reading. After verifying the amputations by comparison, both tapemen record the distance.

EXAMPLE

Rear tapeman holding	20.00 meters
Front tapeman partial meter reading	-0.47 meter
Partial distance from last pin to forward station	19.53 meters
Full tape lengths measured = 7 (7 x 30)	+210.00 meters
Total measured distance	229.53 meters

f. When a taping team is making a measurement at a station occupied by an instrument, the tapeman can make the measurement at the plumb bob cord of the instrument. The tapeman must use extreme care not to disturb the instrument.

2-13. DETERMINING TAPED DISTANCE

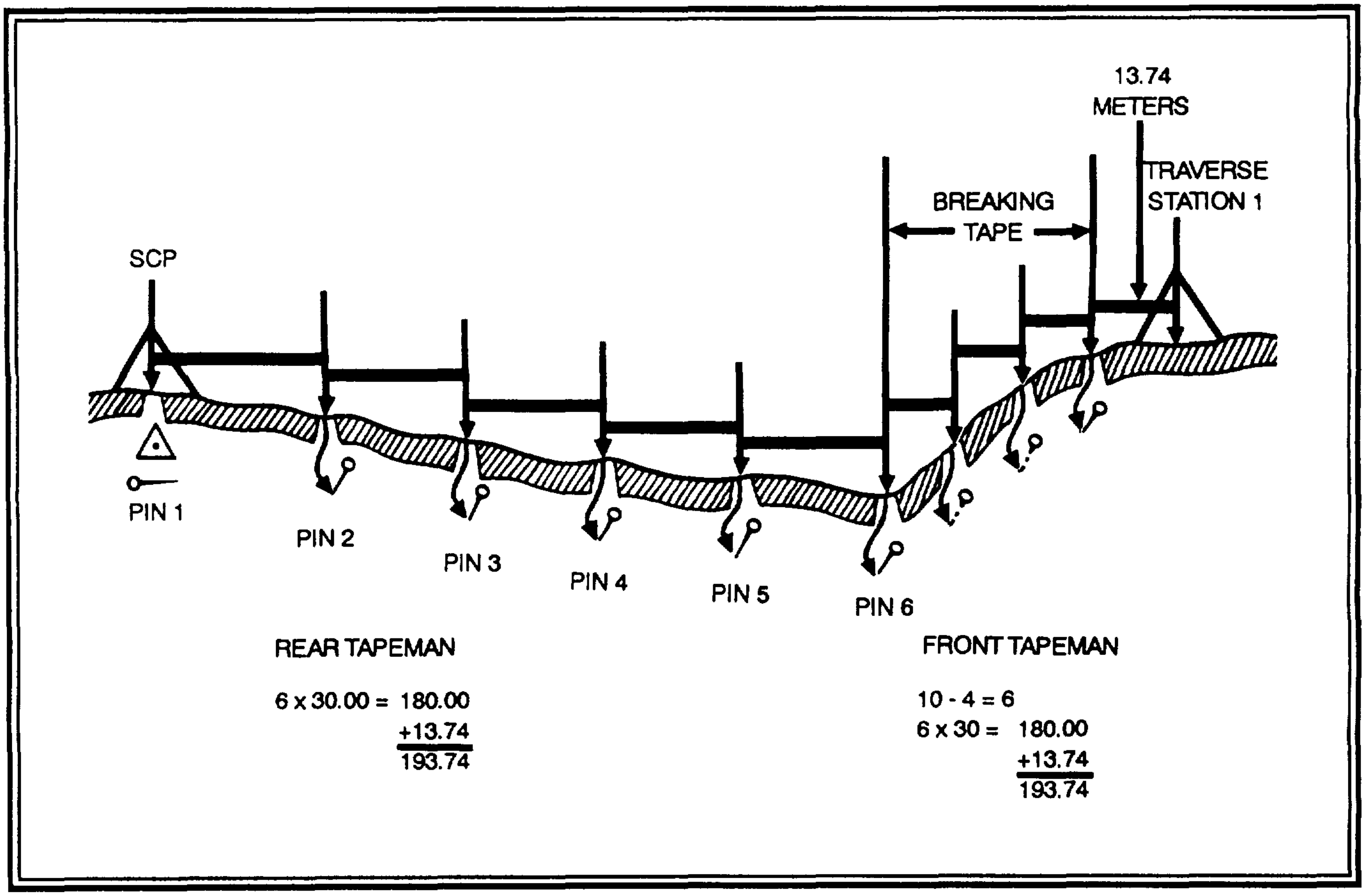
The tapemen determine and check the distance measurement (Figure 2-5) as discussed below.

a. Each tapeman counts the number of pins he has. (The pin in the ground at the last full tape length is not counted.)

b. The rear tapeman determines the distance measurement. He does this by multiplying the length of the tape (30 meters) by the number of pins in his possession and adding the partial length read from the tape.

c. The front tapeman independently checks the distance measurement. He does this by first subtracting the number of pins in his possession from 10, then multiplying by 30, and adding the partial tape distance.

Figure 2-5. **Determining taped distance**



2-14. USE OF TWO TAPING TEAMS

When two taping teams measure the distance between two stations, one taping team uses a pin to establish a starting station one-half tape length (15 meters) from the rear station. In this case, the front tapeman does not give a pin to the rear tapeman. The taping pin marking the half tape length represents one full tape length plus 15 meters. After establishing the starting station a half tape length from the rear station, the taping procedures are the same as those described earlier except that each tapeman adds 15 meters to the distance measurement. This procedure prevents both teams from placing their taping pins in the same hole.

2-15. COMPARATIVE ACCURACY FOR DOUBLE-TAPED DISTANCES

a. When the distance between two stations has been determined by double-taping, the two measurements are compared and the comparative accuracy of the two measurements is determined. The comparative accuracy is expressed as a ratio between the difference in the measurements and the mean of the measurements. The ratio is expressed with a numerator of 1; for example, 1/1000 or 1:1,000. The denominator is determined by dividing the mean of the measurements by the difference in the measurements. After the comparative accuracy is computed, the denominator of the fraction is reduced to the next lower hundred.

b. When the double-taped distance does not meet the required comparative accuracy, the distance must be taped a third time. Then the third measurement is compared with each of the first two measurements to determine if a satisfactory comparative accuracy can be achieved, with one or the other, The unsatisfactory distance is discarded.

EXAMPLE

Distance measurement by taping team 1	357.84 meters
Distance measurement by taping team 2	357.76 meters
Difference between measurements	0.08 meter
Mean of the measurements	357.80 meters
Comparative accuracy	$= \frac{\text{Mean}}{\text{Difference}} = \frac{+\,357.80}{0.08}$
	$= \frac{1}{4472.5}$ or $\frac{1}{4400}$

2-16. TAPING ACCURACIES

To achieve the various degrees of accuracy in survey, distances must be determined accurately to certain specifications, depending on the method of survey used. Prescribed accuracies for the different methods of survey are listed in Appendix B.

2-17. ERRORS

Horizontal taping errors fall into three groups-systematic errors, accidental errors, and errors caused by blunders.

a. Systematic Errors. Systematic errors are errors that accumulate in the same direction. They can be measured and normally are constant in each tape length.

(1) The systematic errors in horizontal taping cause distance to be measured longer or shorter than the true length. The main causes of systematic errors are as follows:

- Failure to align the tape properly.
- Failure to apply enough tension to the tape.
- Kinks in the tape.
- Tape of incorrect length (a little short or a little long).

(2) Eliminate systematic errors by strict adherence to proper procedures and techniques. Tapemen should be especially careful to keep the tape horizontal when taping on a slope and should break tape when necessary. They should avoid the tendency to hold the tape parallel to the slope. When taping in strong winds, tapemen must be especially careful to apply the proper tension to the tape. Tapes should be checked often for kinks. One of the chief causes of kinked tapes is improper use of the clamping handle.

(3) Systematic errors can be due to improper tape repair (repaired too long or too short). This causes taped distances to be longer or shorter than the true distances.

b. Accidental Errors. Accidental errors involve probability and may accumulate in either direction. Usually, these errors are minor and tend to offset each other. Small errors in plumbing cause the principal accidental error. Tapemen should be careful in plumbing over points. When taping in strong winds, they must be especially careful to reduce swinging of the plumb bob. The tapeman does this by keeping the plumb bob close to the ground and shielding the plumb bob as much as possible with his leg.

c. Errors Caused by Blunders. Blunders are major errors made by poorly trained or careless soldiers. A blunder may be an error in any direction. Correct this by remeasuring the distance.

(1) The main blunders made by tapemen are as follows:

- Incorrect exchange of taping pins.
- Errors in reading the tape.
- Omission of the half tape length when two teams are double-taping.
- Loss of a taping pin.
- Failure of front and rear tapemen to compare distance measured.

(2) Blunders are detected and eliminated by strict adherence to correct taping procedures.

2-18. TAPING AT NIGHT

During night operations, three additional men are added to each taping team. One man goes with each tapeman as a light holder. The third man places the taping pin in the ground. When the rear tapeman comes forward to the taping pin, the third man walks the length of the tape and frees the tape from any obstacles. This procedure is repeated for each full or partial tape length. A piece of white cloth may be tied to each end of the tape to help the tapemen follow and locate the tape. Light holders must observe light discipline when using their lights.

2-19. MAINTENANCE OF STEEL TAPES

a. Steel tapes are accurate surveying instruments, and you must handle them with care. Although steel tapes are of durable construction, they can be easily damaged through improper care and use. Never let a vehicle run over a tape.

b. When a steel tape is used, it should be completely removed from its reel and kept straight to prevent kinking or breaking. The tape should never be pulled around an object that will cause a sharp turn in the tape. Care should be taken to avoid jerking or stepping on the tape. Applying tension with a loop in the tape may cause the tape to kink or break. Before applying tension, the tapemen must be sure there are no loops in the tape.

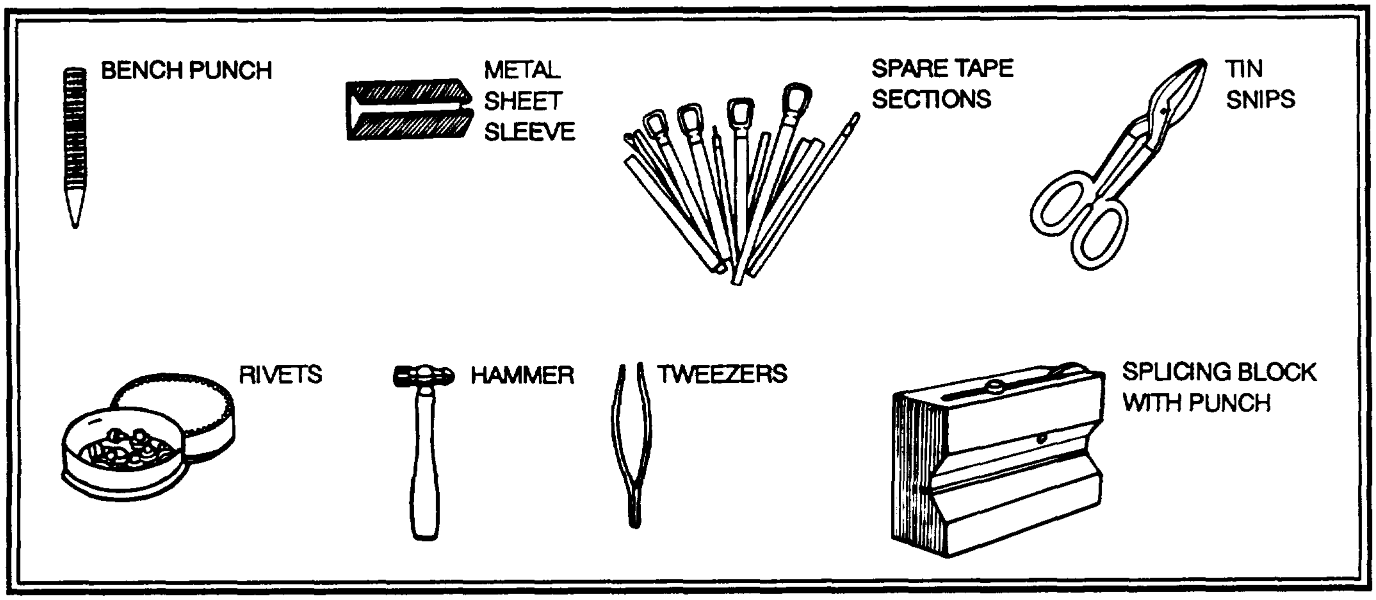
c. The tape should be wiped clean and dry and oiled lightly after each use. The tape is oiled by running it through an oily rag while rewinding the tape on its reel. The tape should be loosely wound on its reel when not in use. When rewinding the tape, the tapeman should insert the end of the tape with the 30-meter graduation into the reel and wind the tape so the numbers are facing the axle of the reel.

2-20. REPAIR OF BROKEN TAPE

a. You can protect tapes and maintain them. However, at one time or another, you may have to repair one in the field to avoid delay in the work. For this reason, every survey party should have a tape repair kit. This kit contains a pair of small snips, tape sections of proper size and graduations, and a hand punch or bench punch with block. Also included are an assortment of small rivets, a small container of sheet metal sleeves, a pair of tweezers, and a small hammer. (See Figure 2-6.) When repairing a broken tape, first square the broken ends. Next, align the broken tape ends over the spare tape section so the graduations are the correct distance apart. Select a spare tape section long enough to span the distance between the squared ends and to overlap each end not less than 3 centimeters. When using rivets, rivet each overlap so the edges of all parts of the points are snug. To do this, place the rivets near (about 3 mm from) the squared ends. A broken tape can also be repaired by fitting a sheet metal sleeve over the broken ends of the tape. The sleeve is coated on the inside with solder and flux. When the sleeve is hammered down tightly and heat is applied, the solder securely binds the broken ends of the tape within the sleeve. You can use an ordinary match to heat the solder. Repair of tapes with rivets is considered a permanent repair. A repair with metal sleeves is considered a temporary repair.

b. Compare the repaired tape with another tape to ensure proper joining of the tape ends and that the tape gives a true measurement. Any discrepancy between the two tapes is recorded in the taping notebook and is referenced to the tape number mentioned earlier.

Figure 2-6. **30-meter steel tape repair kit**



★Section II

SURVEY EQUIPMENT, DISTANCE-MEASURING, ELECTRONIC (MEDIUM-RANGE)

Survey sections equipped with the SEDME-MR can measure distances in minimum time. The SEDME-MR is a compact, lightweight, economical, and simple-to-operate instrument that is especially suitable for short- and medium-range survey operations. Measuring distances from 30 to 7,000 meters takes about 18 seconds measuring time under average conditions.

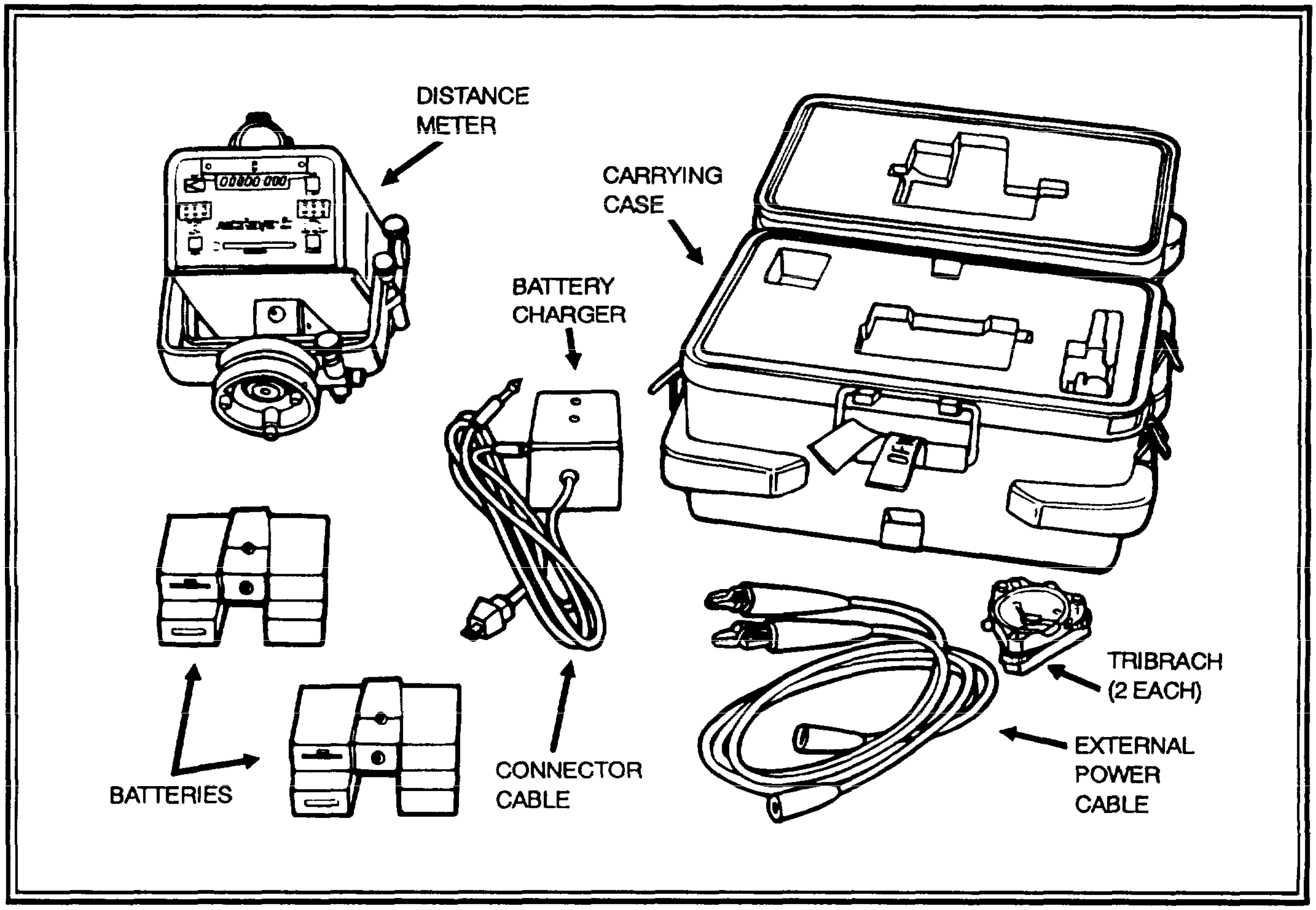
2-21. DESCRIPTION OF COMPONENTS

The SEDME-MR consists of the distance meter and the retroreflector prisms. These units mount on any universal tripod. The distance meter and the retroreflectors are packaged and transported in separate carrying cases—the distance meter case and the restoreflector cases.

a. Distance Meter Case. The distance meter case (Figure 2-7) contains the items of equipment discussed below.

(1) ***Distance meter.*** The distance meter is the electronic package of the system. This instrument generates and sends a modulated signal and receives the reflected signal from

Figure 2-7. **Distance meter case contents**



the prism. The calculated slope distance is in meters and appears on the numerical display.

(2) Batteries. Issued with each system are two nickel-cadmium (NICAD) batteries. You can make about 750 continuous measurements with each battery before recharging is necessary.

(3) Battery charger. A battery charger comes with the system and is used to recharge fully discharged batteries.

(4) Connector cable. The connector cable allows simultaneous charging of both batteries.

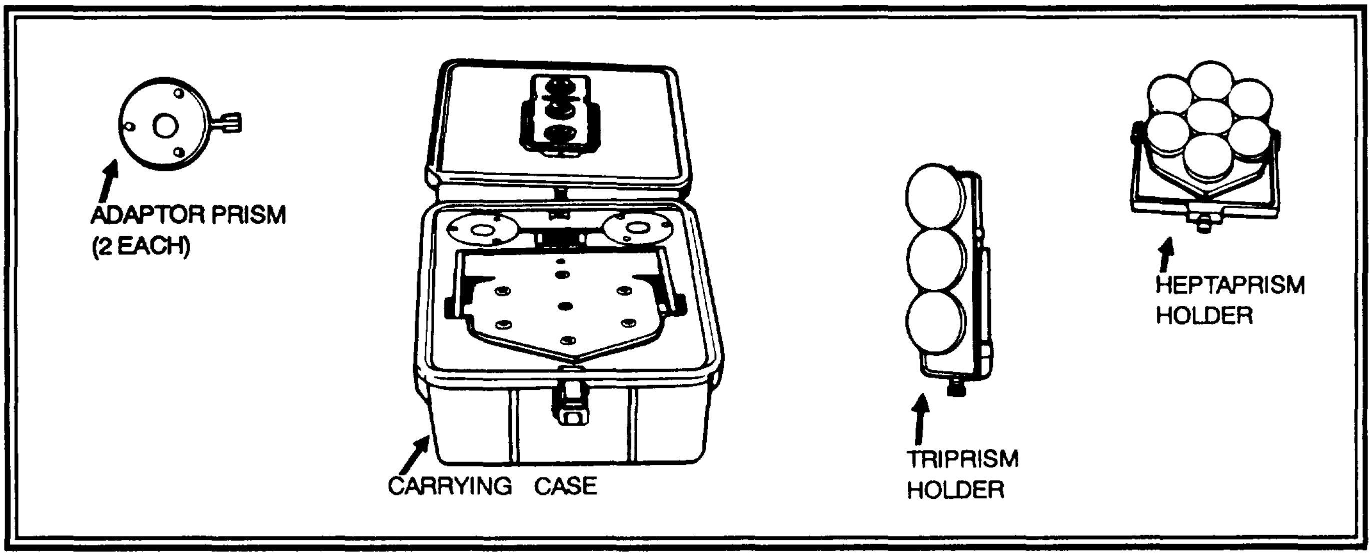
(5) External power cable. The external power cable permits the distance meter to connect to and get power from an external 12-volt battery.

(6) Tribrach. The tribrach adapts the distance meter and retroreflectors to the tripod.

Note. Carrying case design reduces the chance of damage to the instrument and the accessories in transport. Pack all equipment properly in the carrying case before transporting.

b. Retroreflector Case. Two sets of retroreflectors come with each SEDME-MR. A set of retroreflextors consists of a three-prism cluster (triprism) and a seven-prism cluster (heptaprism). (See Figure 2-8.) The triprism is used for distances up to 3,000 meters. The heptaprism normally is enough for a maximum distance of 7,000 meters under average conditions. Average atmospheric conditions are considered to be light haze with visibility of about 15 km or moderate sunlight with light heat waves.

Figure 2-8. **Retroreflector case contents**



2-22. SETTING UP THE SEDME-MR

The setup procedure for the SEDME-MR uses issued tribrachs and/or the theodolite tribrach for the distance meter and prism. After measuring the station angle, follow the steps below. Refer to Figure 2-9 for the location of controls and indicators of the distance meter.

a. Remove the theodolite from the tribrach by using the tribrach clamp. Replace and secure the theodolite in its case.

b. Mount the distance meter on the tribrach and lock it in place by using the tribrach clamp. Check the tribrach leveling bubble, and relevel if necessary.

c. Adjust the vertical lock and horizontal lock firmly enough to allow holding action.

d. When using the NICAD battery, place the battery pack onto the instrument power connector.

e. When using the auxiliary cable, connect the power cable to the power connector. Connect the red clip lead of the power cable to the positive terminal of the 12-volt direct current (v DC) power source, and connect the black clip lead to the negative terminal of the DC power source.

f. Set the parts per million (PPM) switches to 00 (atmospheric correction not used in artillery survey).

g. Set the OFFSET switch to the instrument offset correction. (An instrument offset correction is stamped onto the instrument offset plaque located at the bottom left corner of the instrument.)

h. Accurately set the retroreflector up over the point to which you are making the distance measurement. Align the retroreflector on the line of sight to the instrument. (See Figure 2-10.)

2-23. OPERATING PROCEDURES

a. Test. An automatic test function is built into the instrument. The test provides a quick check of the internal microcomputer and display circuits. To test, press the PWR switch to turn on the instrument. The instrument enters the test mode automatically. The numerical display should sequence from all 0s to all 9s and then display 0000.

Figure 2-9. **SEDME-MR controls and indicators**

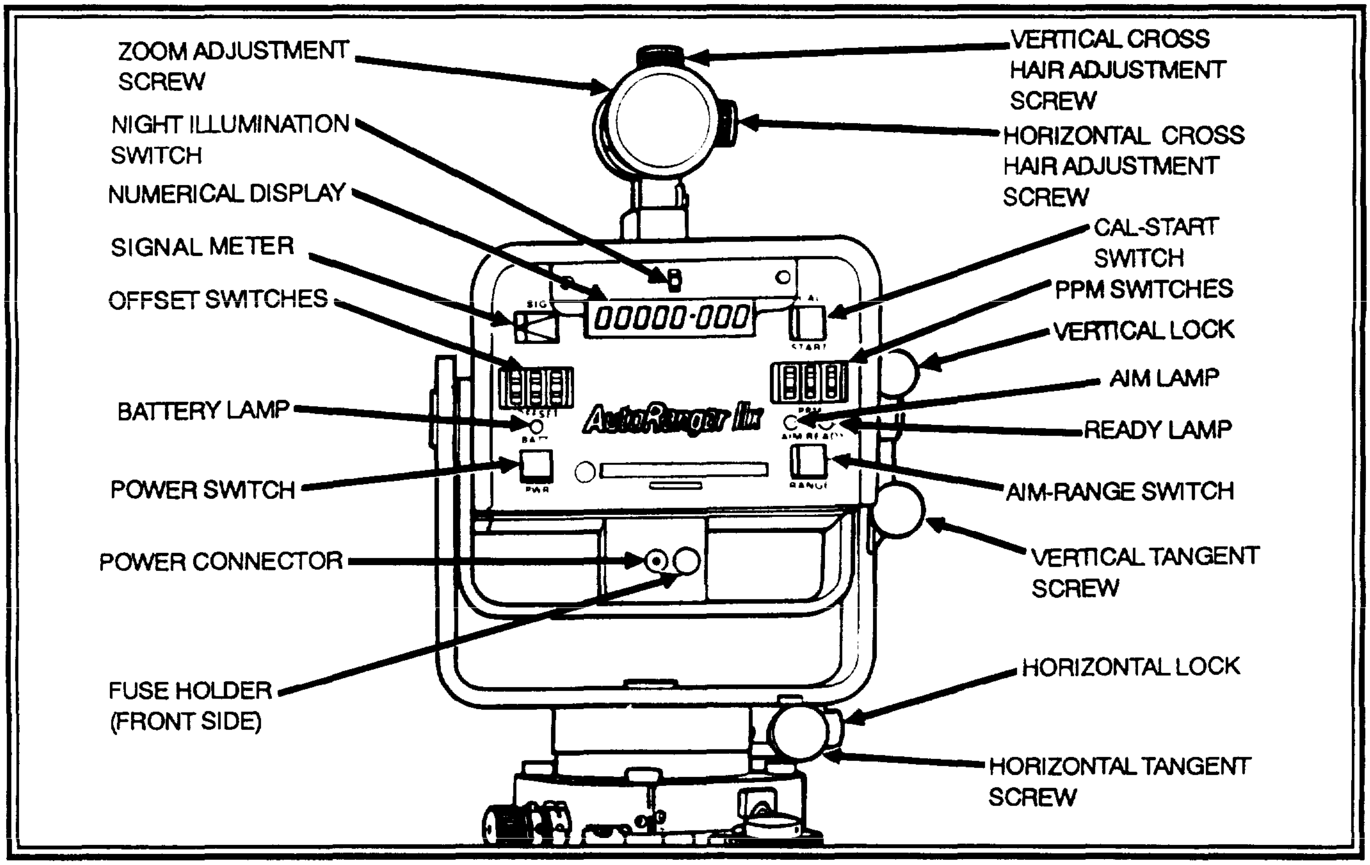
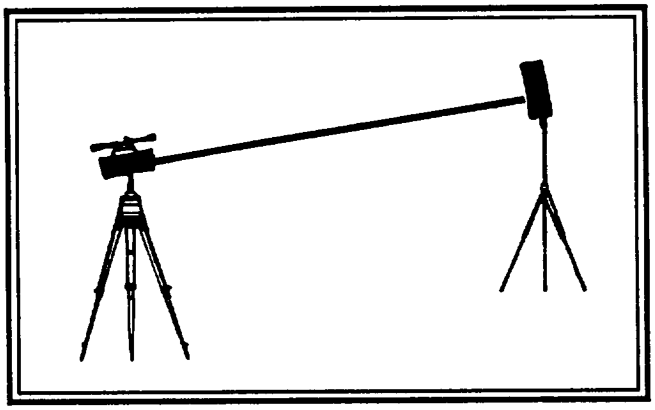


Figure 2-10. **Prism alignment**



b. Retroreflector Acquisition. After completion of the test function, the SEDME-MR is ready for alignment on the retroreflector.

CAUTION

Do not aim the SEDME-MR directly at the sun. The optical system of the SEDME-MR is designed for infinity focus. You may damage the sensitive detector located at the focal point of the receiver optics.

(1) Using the vertical and horizontal tangent screws, position the sighting scope reticle on the prism. For shorter distances, the sighting point should be 4.5 inches above the retroreflector. When the retroreflector is first acquired and a return signal is received, an audio tone will sound for about 2 seconds and then go off. The audio tone will sound again each time the return signal falls below a predetermined level after initial acquisition.

(2) While squiring the retroreflector, note the indication on the signal (SIG) meter. Carefully adjust the vertical and horizontal tangent screws to maximize the SIG meter indication.

(3) If the pointer of the SIG meter runs up against the upper stop because the signal level is too great, press the CAL-START switch. The READY lamp should light, and the meter pointer should automatically move to about midscale before the vertical and horizontal tangent screws are adjusted further. Near the maximum range of the instrument, the meter pointer may indicate below center; however, if the READY lamp is on, measurements can be made.

(4) Repeat steps (2) and (3) above until the SIG meter indicates no further increase.

Note. To achieve maximum range accuracy, correctly sight the Instrument on the retroreflector.

(5) As the last step in the acquisition procedure, press the CAL-START switch and wait for the READY light to come on. When the READY light comes on, the SEDME-MR is ready for distance measurement.

c. Ranging. After sighting the instrument on the retroreflector and maximizing the return signal, the operator performs the steps below.

(1) Press the AIM-RANGE switch. Be very careful not to move the instrument. The AIM light should go out. The SEDME-MR will begin to cycle automatically. A slight clicking sound will indicate that the measurement is occurring. In about 6 seconds, the measured distance will appear on the numerical display.

(2) Read aloud the displayed distance to the recorder. Ensure the recorder reads back the distance correctly. If the recorder repeats the distance incorrectly, immediately announce **CORRECTION** and repeat the correct distance measurement.

(3) The instrument will continue to make distance measurements automatically and will update the range indication on the numerical display every 6 seconds as long as the instrument remains in the range mode. Read and record two more distance measurements.

(4) Check the recorded distances to be sure that there is no variation among the three readings of more than 0.010 meter from the mean. If any of the readings is outside this limit, take another reading to replace it.

(5) To stop the range sequence, press the AIM-RANGE switch to select the aim mode or press the PWR switch to turn off the instrument.

Note. The audio tone will not function in the range mode of operation.

d. Slope Distance Conversion. The mean of the three distances is a slope distance and must be converted to a horizontal distance. There are two different means of converting the slope distance to a horizontal distance.

(1) To compute the required distance, use the formula D = cos V x S. In this formula, D is horizontal distance, V is the vertical angle between the distance meter and the

reflector, and S is slope distance. These computations may be made with logarithms or with the BUCS. The horizontal distance determined from this computation meets the accuracy requirements for field artillery.

(2) The horizontal distance can also be determined by using Program 2 (Traverse) of the BUCS survey module and DA Form 5591-R (Computation of Coordinates and Heights From Azimuth, Distance, and Vertical Angle (BUCS)). (A reproducible copy of this form is at the back of this book.) When using the BUCS to convert the distance, perform the following steps:

Step 1. Call Program 2.

Step 2. Press the END LINE key at the TRAVERSE prompt.

Step 3. Bypass the E OCC STA: 0.00 prompt by pressing the END LINE key.

Step 4. Bypass the N OCC STA: 0.00 prompt by pressing the END LINE key.

Step 5. Bypass the HT OCC STA. 0.0 prompt by pressing the END LINE key.

Step 6. Bypass the AZ TO REAR: 0.000 prompt by pressing the END LINE key.

Step 7. Respond to the prompt MN SCH LEG (Y/N) by entering Y or N.

Step 8. Bypass the prompt HZ FWD: 0.000 by pressing the END LINE key.

Step 9. At the prompt VA (+/-): 0.000, enter the vertical angle.

Step 10. Respond to the prompt RECIP VA (Y/N) by entering Y or N.

Step 11. At the prompt ˆDIST FWD (-:SL/+:HZ), press the END LINE key. When the screen becomes blank, enter the slope distance. Remember to enter the distance as a negative number.

Step 12. At the next step, BUCS will display the horizontal distance.

2-24. CARE AND MAINTENANCE

a. Packing and Transporting. Pack the SEDME-MR in the molded carrying case with the foam inserts provided. The SEDM-MR should be packed for transport or when it is not in use.

b. Condensation. Taking an instrument from a cold to a warm environment can cause condensation on the instrument. Leave the instrument in its carrying case for several hours under such conditions. This allows a gradual temperature change.

c. Lens Care. Use care in cleaning dust or moisture from lenses. Do not touch lenses with fingers. Do not use coarse cloth, paper, or other material that might scratch the lenses. Use antistatic optical cleaning cloth, lens tissue, and a camel‘s-hair brush. Use a mild soap and water solution to remove smudge marks, when needed. To further protect lens, keep lens cover on when not in use.

d. Nickel-Cadmium Battery. A NICAD battery was selected for use in the power unit. A NICAD battery, with proper care, performs good over an extended lifetime. To charge the battery, follow the instructions in (1) through (5) below.

CAUTION

Do not try to charge a battery that is not fully discharged. Ensure each battery is fully discharged by using it until a distance can no longer be measured due to the lack of power. Trying to charge a partially charged NICAD battery will shorten the life of the battery.

(1) Plug the battery charger into an alternating current (AC) power outlet that is continuously supplied with power. The battery charger is designed to operate from a nominal 110-volt, 50/60-hertz (Hz) power supply. When only a 220-volt, 50/60-Hz source is available, use the 220/110-volt adapter supplied with the unit.

CAUTION

Before plugging the battery charger into an AC power outlet, make certain that the rating of the battery charger matches the rating of the available AC power source.

(2) Plug the connector end of the battery charger cable into the power connector unit. On a battery charger that has a red charge light, the light should come on. This indicates that the unit is taking a charge.

(3) Allow about 16 hours to completely recharge a fully discharged battery with the supplied battery charger.

(4) Leaving the battery unit plugged into the battery charger will not cause overcharging. However, during prolonged periods of inactivity, disconnect the charged battery from the power unit and store it.

(5) To prevent possible damage to the NICAD battery, never charge it in an area where the temperature falls below 5 degrees Celsius (C) (40 degrees Fahrenheit [F]) or exceeds 27°C (90°F).

> **Note.** While the battery unit is charging, the battery charger may become warm to the touch and may emit a buzzing sound. This is normal. It is not an indication of a malfunction In the battery charger.

e. Sighting Telescope Alignment. Adjust the alignment of the sighting telescope as discussed below.

(1) Place a single-prism or triple-prism cluster with only the center prism uncovered at a distance of 30 to 50 meters from the SEDME-MR.

(2) Using the vertical and horizontal tangent screws, position the telescope cross hairs on the center of the uncovered prism.

(3) Turn the instrument power on, and select the aim mode. If there is no signal indication, search the area near the prism until the signal is squired. Use the tangent screws to maximize the signal.

(4) Remove the covers from the vertical and horizontal cross hair adjustment screws.

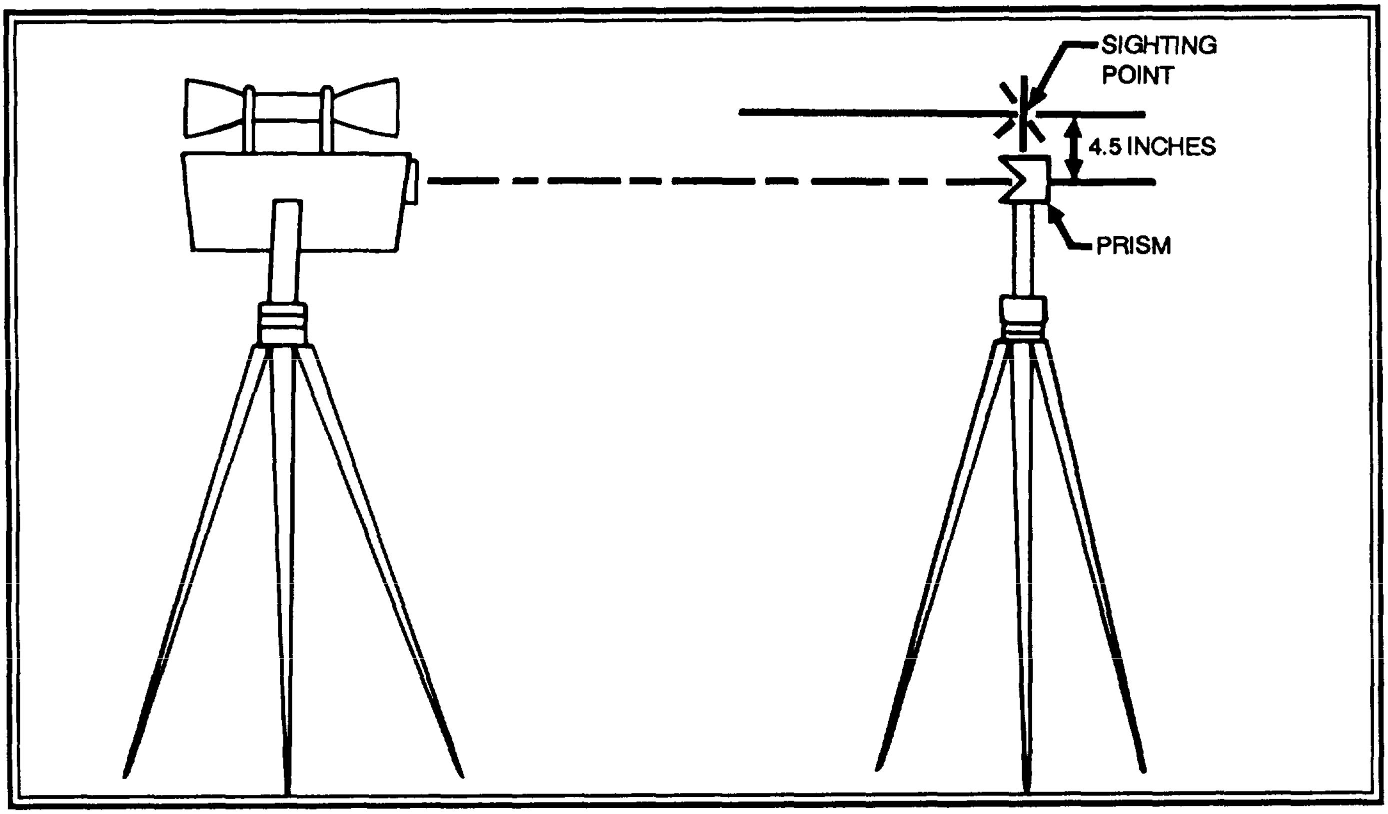
(5) Using the horizontal adjustment screw, position the vertical cross hair to the center of the prism.

(6) Using the vertical adjustment screw, move the horizontal cross hair to a point 4.5 inches above the center of the prism. (See Figure 2-11.)

(7) After adjustments, use the tangent screws to obtain maximum strength and ensure proper alignment. Replace covers on the adjustment screws.

f. Power Fuse. The power fuse protects the power circuits of the SEDME-MR against overload. If the power fuse fails, power is no longer applied to the internal circuits. If you see no response when operating the PWR switch, check or replace the fuse. If repeated fuse failures occur, turn the SEDME-MR in for repair.

Figure 2-11. Telescope alignment



g. BATT Light. Flashing of the BATT light indicates a low battery. The instrument operator can still make reliable range measurements with the light flashing. However, the instrument will go into an automatic power-off mode when battery voltage falls below a preset limit. At that point, the BATT light will glow brightly and steadily. Connection of a recharged battery unit or an auxiliary source to the instrument will permit resumption of normal operation.

> **Note.** In low ambient light conditions, a faint glow may be observed. This is normal end does not indicate low battery voltage.

CHAPTER 3

ANGLE DETERMINATION

An FA survey operation consists of many tasks. One task is the measurement of horizontal and vertical angles. Field artillery surveyors use two angle-measuring instruments—the T16 and the T2 theodolites.

Section I

T16 THEODOLITE

The T16 and T16-84 theodolites (Figure 3-1) are compact, lightweight dustproof, optical-reading, directional-type instruments equipped with a fixed reticle (Figure 3-2) in the telescope and a horizontal circle (repeater) clamp. Surveyors use these theodolites to measure horizontal and vertical angles for artillery fifth-order survey. The horizontal and vertical scales of the theodolite are enclosed and are read through a built-in optical system. The scales, graduated in mils, are read directly to 0.2 mil (m) and by estimation to the nearest 0.1 mil. Illumination of the scales is provided by either sunlight or artifical light.

3-1. ACCESSORIES

Accessories issued with the T16 include the following:

- Canvas accessory kit, which contains the following:
  - Eyepiece prisms.
  - Sun filters.
  - Two jeweler's screwdrivers.
  - Two adjusting pins.
  - Camel's-hair brush.
  - Lubricant.
  - Plastic instrument head cover.
  - Circular compass.
  - Two operation and service manuals.
- Battery case with lighting devices and three spare bulbs.
- Universal tripod with plumb bob, plug-in sleeve, and tripod key in a leather pouch attached to the tripod.

In addition to the accessories issued with the older model T16, the T16-84 accessories include a GST20 tripod and an eye prism. The fixing screws on all Wild tripods have the same threads. This allows both theodolites to mount on any Wild tripod.

Note. For detailed information on the T16 theodolite, see TM 5-6675-200-14 or TM 5-6675-270-15.

3-2. PREPARING THE T16 THEODOLITE FOR USE

a. Set up the tripod as discussed below.

(1) Upend the tripod, place the tripod head on the toe of your boot, and unbuckle the restraining strap.

(2) Loosen the leg clamp thumbscrews, and extend the tripod legs to the desired length. Tighten the leg clamp thumbscrews. Do not force the thumbscrews.

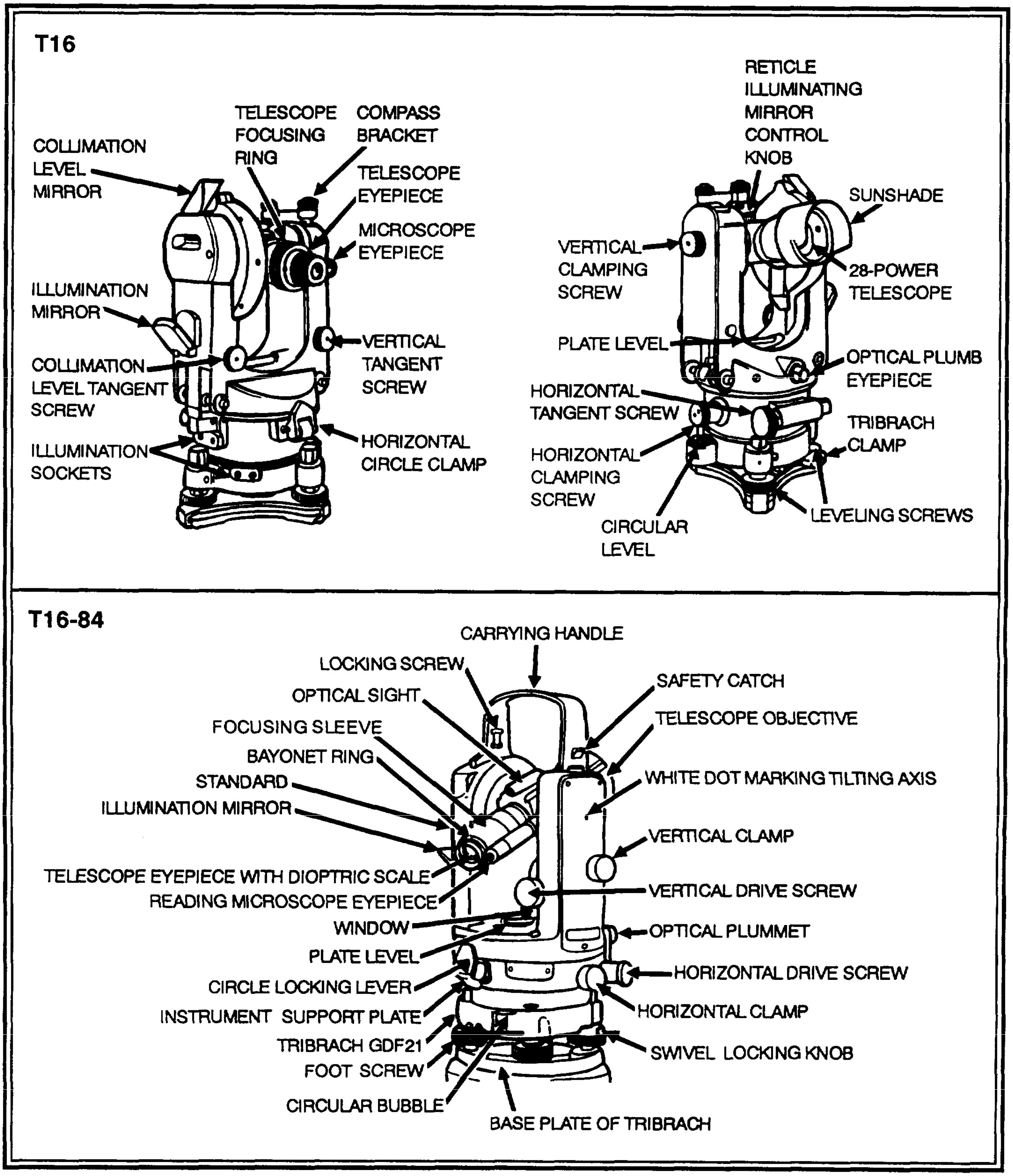
(3) Spread the legs, and place the tripod over the occupied station with one leg bisecting the angle(s) to be measured. Set up the tripod head so that the telescope will be at a convenient height for the operator.

(4) Insert the plug-in sleeve of the plumb bob into the instrument fixing screw. The plumb bob should hang about 1 inch above the station. Center the tripod approximately over the station.

(5) Firmly embed the tripod legs in the ground. Be sure the plumb bob is within 0.5 inch (laterally) of center of the station. The tripod head should be approximately level when the legs are embedded.

(6) Remove the tripod head cover.

Figure 3-1. **T16 and T16-84 theodolites**



b. Remove the theodolite from its case as discussed below.

(1) Grasp the carrying strap with both hands just above the two clamping levers. Pull outward to release the clamping levers from the base assembly.

(2) Lift the dome-shaped cover directly off the instrument, and lay it to one side.

(3) Pull upward on the two base clamping levers that secure the theodolite to the base assembly. Grasp the theodolite by the standard on which the trademark is inscribed, and lift the theodolite off the base assembly. Handle the theodolite by this standard only.

Note. The carrying handle is used to lift the T16-84 theodolite off the base assembly.

(4) Attach the instrument to the tripod head by screwing the fixing screw snugly into the base of the tribrach.

(5) Replace the cover on the carrying case to keep dust and moisture from entering the case. Move the case away from the tripod to provide a working area for the instrument operator.

c. Plumb and level the T16 theodolite as discussed below.

(1) Loosen the fixing screw slightly, and carefully move the instrument around on the tripod head to center the point of the plumb bob exactly over the station.

(2) Tighten the fixing screw. Be sure the point of the plumb bob remains centered over the station. Remove the plumb bob, and return it to its case.

CAUTION

Excessive tightening of the fixing screw will bend the slotted arm and damage the tripod head.

(3) Loosen the horizontal clamping screw, and rotate the instrument until the axis of the plate level is parallel to any two of the three leveling screw knobs. This is the first position. Center the bubble by using these two leveling screw knobs. Grasp the leveling screw knobs between the thumb and forefinger of each hand. Turn the knobs simultaneously so the thumbs of both hands move either toward each other or away from each other. (See Figure 3-3.) This movement tightens one screw as it loosens the other. The bubble always moves in the same direction as the left thumb.

(4) Rotate the instrument 1,600 mils. This second position places the axis of the tubular level at a right angle to the first position. Using the third leveling screw knob only, center the bubble. (See Figure 3-4.)

(5) Return the instrument to the first position (Figure 3-3), and again center the bubble.

(6) Return the instrument to the second position (Figure 3-4), and again center the bubble.

(7) Repeat (5) and (6) above until the bubble remains centered in both positions.

Figure 3-2. **Telescope reticle**

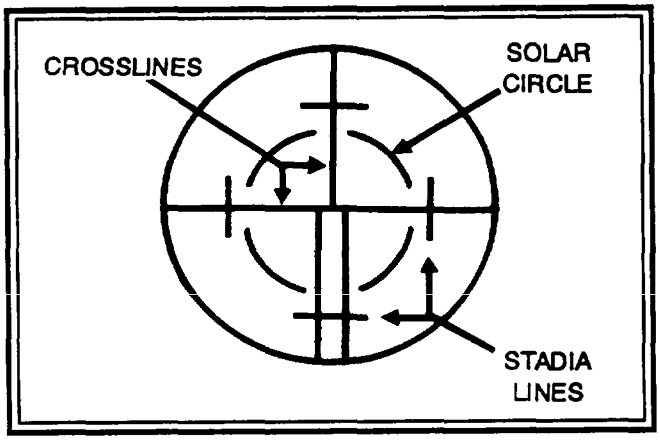


Figure 3-3. **Leveling the theodolite-first and third positions**

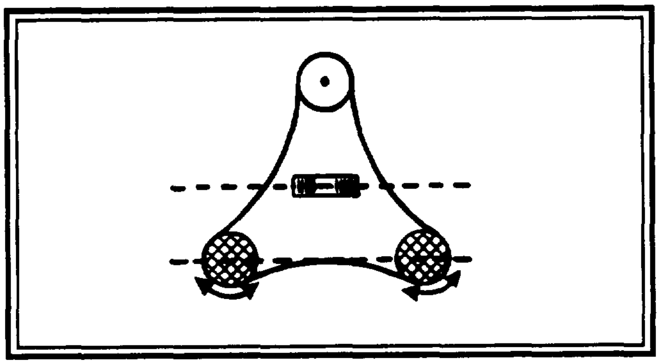
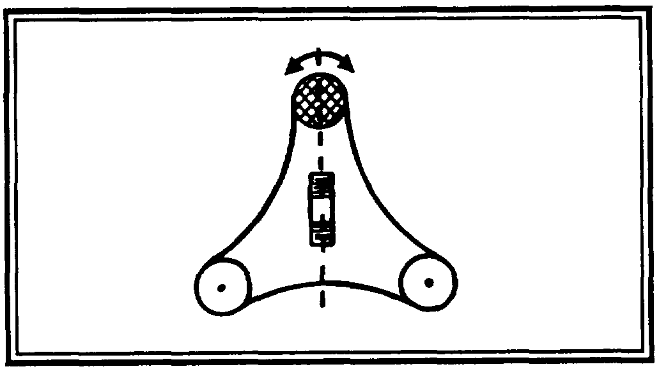


Figure 3-4. **Leveling the theodolite-second and fourth positions**



(8) Rotate the instrument 3,200 mils from the first position (Figure 3-3) so the axis of the tubular level vial is on a line parallel with the first position. If the bubble remains centered in this position, rotate the instrument 3,200 mils from the second position. (See Figure 3-4.) If the bubble remains centered in this position, rotate the instrument throughout 6,400 mils. The bubble should remain centered. If the instrument remains centered, it is level.

(9) Rotate the instrument 3,200 mils from the first position ((8) above). The level vial is out of adjustment if it does not remain centered. If time permits, perform a plate level adjustment. If the situation does not allow time for a plate level adustment, perform the following. To compensate, with the instrument in this position (Figure 3-3), move the bubble halfway back to the center of the level vial by using the same two leveling screw knobs used for the first position. Rotate the instrument 3,200 mils from the second position, and move the bubble halfway back to the center of the level vial by using the one remaining leveling screw knob. Rotate the instrument through 6,400 mils. If the bubble does not move more than one graduation, the instrument is considered level. If the bubble moves more than one graduation, repeat the leveling procedure. If the bubble continues to move more than one graduation, turn the theodolite in to the supporting maintenance unit for repair.

(10) After the instrument is level, cheek the optical plumb to ensure that the instrument is centered exactly over the station. If it is not, center the instrument over the station by loosening and shifting it on the tripod head. Check the level of the instrument. If necessary, repeat the leveling process, and again check the optical plumb. Repeat this process until the instrument is level and centered over the station.

Note. A valid check with the optical plumb can be made only if the optical plumb is in proper adjustment.

3-3. TAKING DOWN THE T16 THEODOLITE

After completing observations at a station, march-order the theodolite and tripod as discussed below.

a. Remove the dome cover from the carrying case.

b. Place the telescope in a vertical position with the objective lens down, and lightly clamp the vertical clamping screw.

c. Turn the leveling screws halfway down and to the same height.

d. Position the horizontal clamping screw directly over one of the leveling screws, and lightly clamp it.

Note. On the T16-84, place the optical plumb over any one of the leveling screws.

e. Close the illumination mirror, and turn the hinge to the top.

f. Hold the instrument by its right standard, and unscrew the instrument-fixing screw. Lift the theodolite from the tripod, and secure it in the carrying case. Replace the dome-shaped cover.

g. Replace the tripod head cover, collapse the tripod, and strap the tripod legs together.

3-4. READING AND SETTING HORIZONTAL AND VERTICAL CIRCLES WITH THE T16

a. With the T16 theodolite prepared for observing as described in paragraph 3-2, open the illumination mirror. Adjust the light so both the horizontal and vertical circles are uniformly illuminated when viewed through the circle-reading microscope. When operating at night with unfavorable lighting, attach lighting devices and connect them to the battery pack. Adjust the focus of the circle-reading microscope until the numbers on the horizontal and vertical scales are sharp and clear.

b. When viewed through the circle-reading microscope (Figure 3-5), the vertical circle (marked "V") appears above the horizontal circle (marked "AZ"). Both circles are graduated from 0 to 6,400 mils with a major graduation each 10 mils. Unit mils and tenths are viewed on an auxiliary scale graduated in 0.2-mil increments from 0 to 10 mils. Circle readings are estimated to the nearest 0.1 mil. The scale reading is taken at the point where the major (10-mil) graduation (gauge line) is superimposed on the auxiliary scale. When the telescope is not in a horizontal position, the scales will appear tilted. The amount of tilt depends on the inclination of the telescope.

> **Note.** The horizontal circle of the T16-84 theodolite (Figure 3-6) is yellow and marked "HZ."

c. All horizontal angle measurements with the T16 theodolite begin with an initial circle setting of 0001.0 mil on the horizontal circle. This practice prevents working with a negative mean of direct (D) and reverse (R) readings on the rear station. To set this value on the horizontal circle, release the horizontal clamping screw and rotate the instrument until the major graduation 0 appears on the horizontal circle. Tighten the horizontal clamping screw, and use the horizontal tangent screw to set the 0 gauge line directly over the 1.0-mil graduation on the auxiliary scale. Engage the horizontal circle clamp by setting it to the locked position (down). The horizontal circle is now attached to the alidade of the instrument. The reading of 0001.0 mil will remain on the horizontal circle as long as the horizontal circle clamp is engaged.

Figure 3-5. **T16 theodolite scales viewed through the circle-reading microscope**

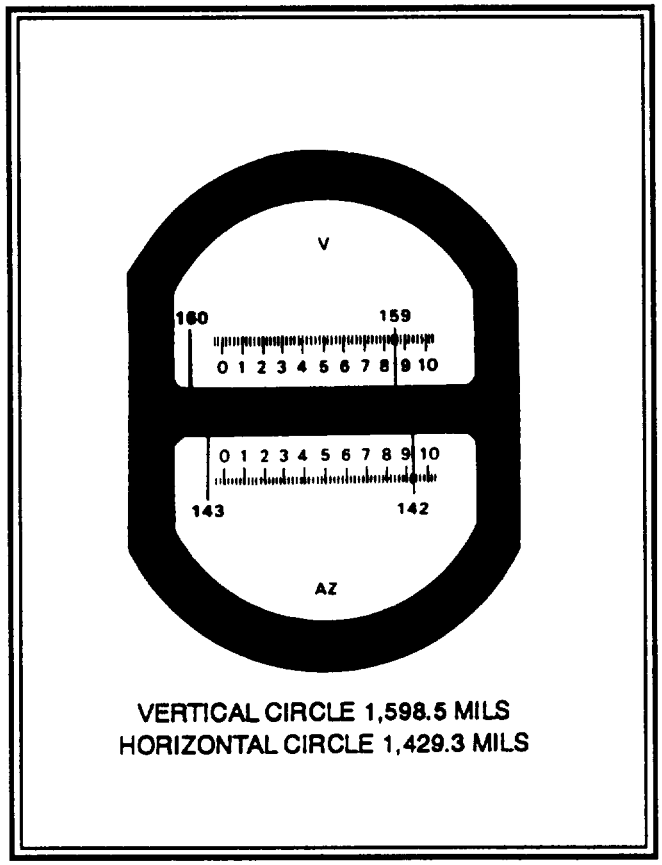
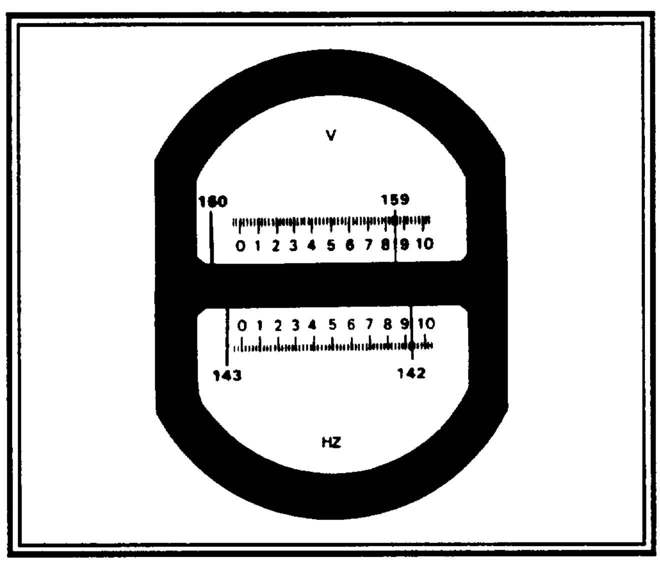


Figure 3-6. **T16-84 scales viewed through the circle-reading microscope**



3-5. FOCUSING THE TELESCOPE TO ELIMINATE PARALLAX

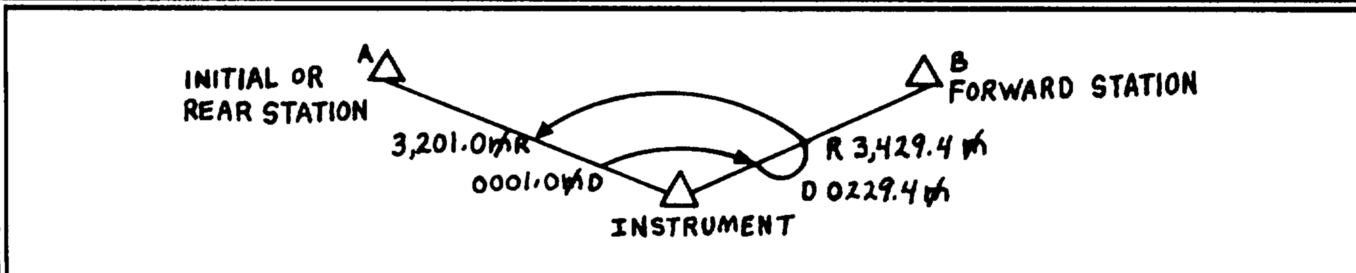
Before using the theodolite to measure angles, focus the telescope to eliminate parallax. Parallax is eliminated by bringing the focus of the eyepiece and the focus of the objective lens to the plane of the reticle (crosslines). To do this, first point the telescope toward the sky or a neutral background. Rotate the knurled ring on the telescope eyepiece until the reticle cross lines are distinct lines. When doing this, be very careful to focus your eyes on the crosslines, not on the sky. Next point the telescope toward a well-defined distant point. While focusing on the crosslines, bring the distant point into a clear, sharp image by rotating the knurled focusing ring on the telescope. Use the horizontal tangent screw to center the vertical crossline on the point. To check for parallax, move your eye horizontally back and forth across the eyepiece. If parallax is eliminated, the crossline will remain fixed on the object as you move your eye. If all parallax is not eliminated, the crossline will appear to move back and forth across the object. To eliminate any remaining parallax, change the focus of the eyepiece slightly to bring the crosslines into sharper focus and refocus the telescope accordingly until there is no apparent motion. Each time an angle is measured, the telescope should be focused to eliminate parallax. Accurate pointings with the instrument are not possible if parallax exists.

3-6. MEASURING HORIZONTAL ANGLES WITH THE T16

a. In artillery survey, the T16 theodolite is used as a directional-type instrument. The horizontal circle clamp is used only to set the initial circle setting (0001.0 roil) on the horizontal circle before making a pointing on the initial station. Measuring horizontal angles consists of determining, at the occupied station, the horizontal circle readings to each observed station, beginning with an initial (rear) station. The angle between two observed stations is the difference between the mean (inn) horizontal circle readings determined for each of the observed stations. The mean horizontal circle readings used to determine the angles are determined from two pointings (circle readings) on each observed station. (See Figure 3-7.)

b. The direct and reverse pointings on each station should differ by 3,200 roils, plus or minus the amount of horizontal spread (twice the actual error in horizontal collimation) in the instrument. No value can be specified as the maximum allowable spread for an instrument however, it should be small (1.0 mil or less) for convenient in meaning of the pointings. The amount of the spread should be constant; otherwise, there are inconsistencies in operating the instrument. If the mean spread of an instrument exceeds 1.0 mil, the instrument should be adjusted at the first opportunity.

Figure 3-7. **Field notebook extract and sketch of pointings in measuring horizontal angles**



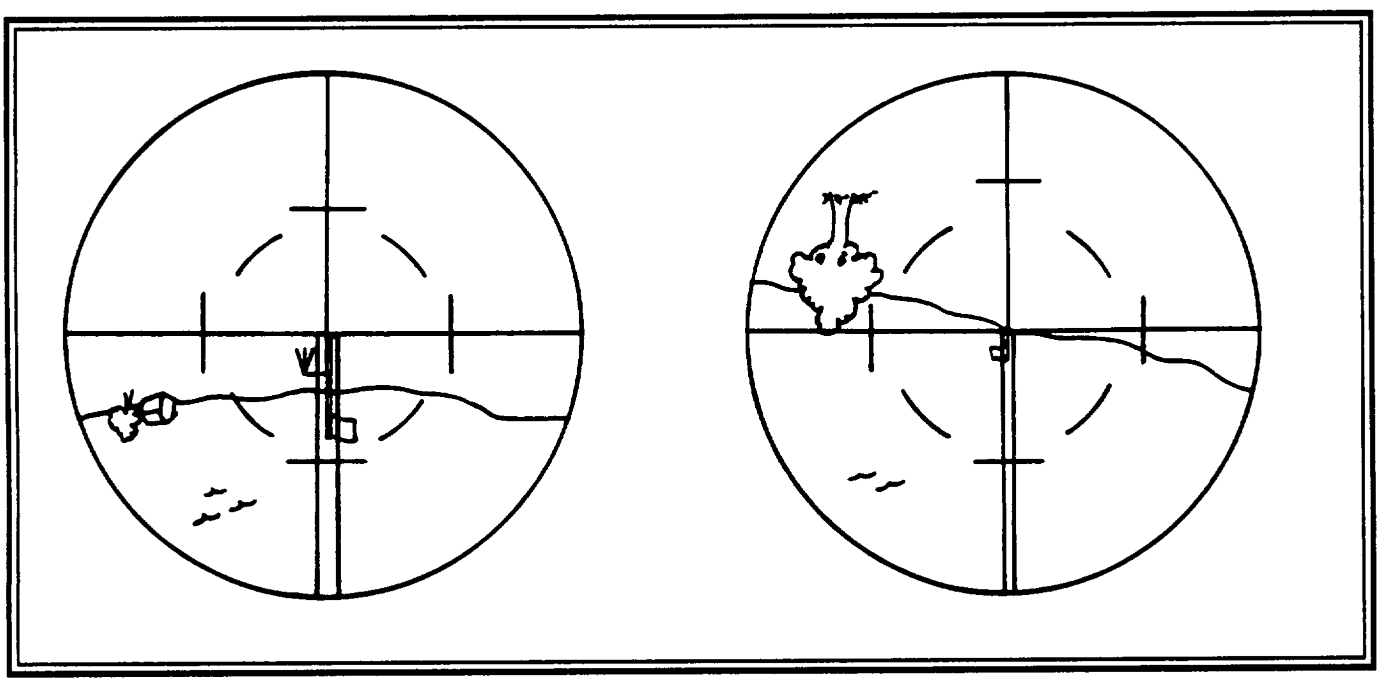
STATION	T	HORIZ ∡	MEAN	VERT READING	VERT ∡
A	D	0001.0			
	R	3201.0	0001.0		
INSTRUMENT	MN ∡	0228.4			+1.4
B	D	0229.3		1598.5	+1.5
	R	3429.4	0229.4	4801.4	+1.4

c. With the telescope in the direct position, the initial circle setting of 0001.0 mil on the horizontal circle, and the horizontal circle clamp engaged (down), make a pointing on the initial, or rear, station at the lowest visible point. This establishes the direction of the station at 0001.0 mil with respect to the horizontal circle. Record in the field notes (Figure 3-7) the value of the direct reading on Station A. Release (lift) the horizontal circle clamp. This causes the horizontal circle to detach itself from the alidade and remain in its fixed position. Then make a pointing on each station around the horizon in a clockwise direction. After making a pointing to the last station, plunge the telescope to the reverse position (by rotating the telescope to an upside down position). Make a pointing on each station in a counterclockwise direction, beginning with the last station and ending with the initial station. This sequence of operations is defined as a one-position angle.

d. In making pointings, the horizontal and vertical clamping screws are used to place the crossline approximately on the object marking the station. After placing the crosslines approximately on the target, tighten the horizontal and vertical clamping screws. Then use the horizontal and vertical tangent screws to plain the crosslines exactly on the lowest visible point of the station. (See Figure 3-8.) The final rotation of the tangent screws must be in a clockwise direction.

> **Note.** The view through the T16-84 is the same as the T16 except that the view is not inverted.

Figure 3-8. **Crosslines on the lowest visible point**



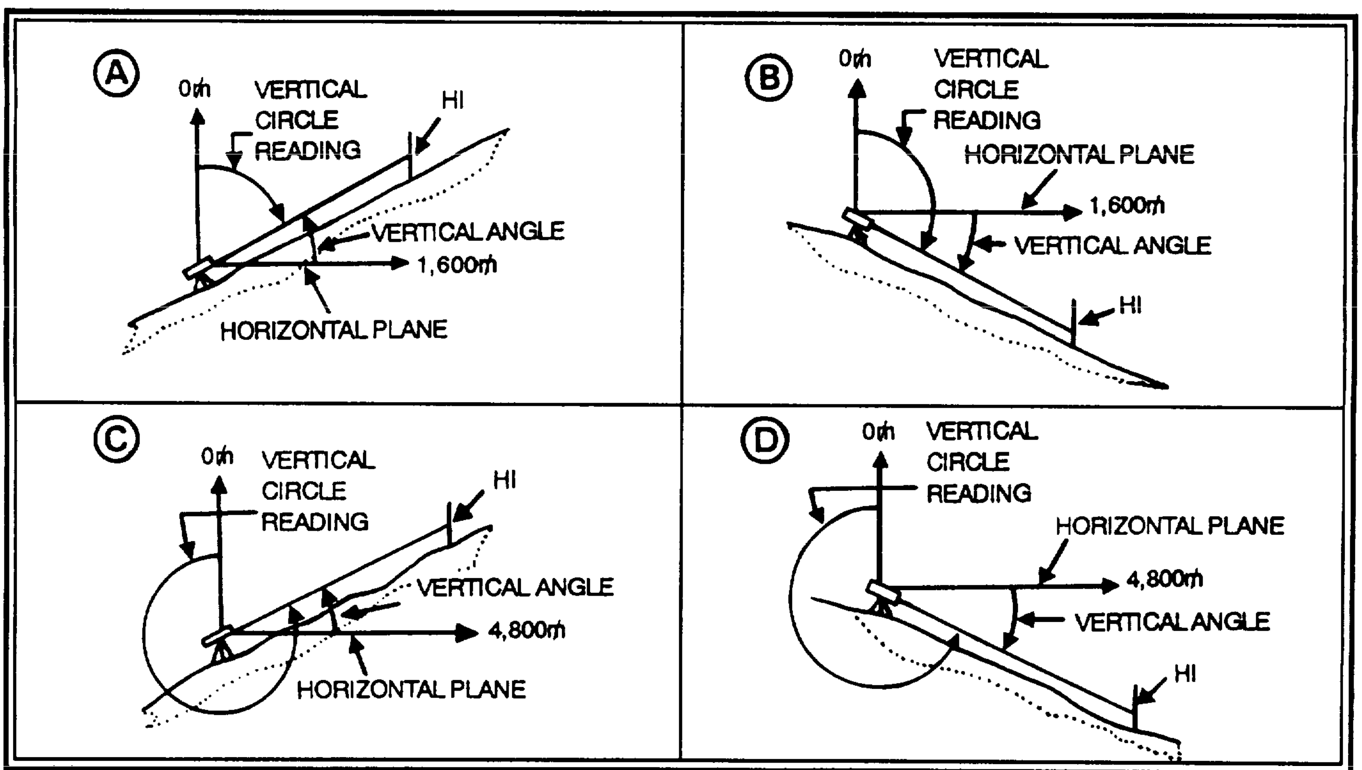
c. After making the reverse pointing on the initial station and recording the horizontal circle reading, plunge the telescope to the direct position. Then make a direct pointing on the initial station. Although zeroing the instrument is not a part of the angle measurement it will save time in setting the initial circle setting for the angle measurement at the next station.

3-7. DETERMINING VERTICAL ANGLES WITH THE T16

a. Normally, each time a horizontal angle is measured, a vertical angle to the forward station is determined. If possible, measure vertical angles to the height of the instrument.

b. Vertical angles cannot be measured directly with the theodolite. The vertical circles of the theodolite reflect readings of 0 mils at the zenith (straight up), 1,600 mils horizontal direct, 3,200 mils at the nadir (straight down), and 4,800 mils horizontal reverse. Hence, values read from the vertical circle are not vertical angles but are zenith distances that are converted to vertical angles. When the collimation level bubble is centered, vertical circle readings are taken from what is, in effect, an upward extension of the plumb line of the theodolite. (See Figure 3-8.) One value of the vertical angle is computed from the vertical circle reading made with the telescope in the direct position arid pointed at the station. With the telescope in the direct position, a vertical circle reading of less than 1,600 mils indicates that the station observed is above the horizontal plane of the theodolite and the vertical angle is positive. A vertical circle reading greater than 1,600 mils indicates that the station observed is below the horizontal plane of the theodolite and the vertical angle is negative. To determine the value of a positive vertical angle, subtract the vertical circle reading from 1,600 mils. (See Figure 3-9, (A).) Determine the value of a negative vertical angle by subtracting 1,600 mils from the vertical circle reading. (See Figure 3-9, (B).) A second value of the vertical angle is computed from the vertical circle reading made with the telescope in the reverse position and pointed at the station. With the telescope reversed, a vertical circle reading greater than 4,800 mils indicates a positive vertical angle, and a vertical circle reading less than 4,800 mils indicates a negative vertical angle. Determine the value of a positive vertical angle by subtracting 4,800 mils from the vertical circle reading, (See Figure 3-9, (C).) Determine the value of a negative vertical angle by subtracting the vertical circle reading from 4,800 mils. (See Figure 3-9, (D).) Mean the two values by adding them together and dividing the result by two. The result is the vertical angle to the observed station.

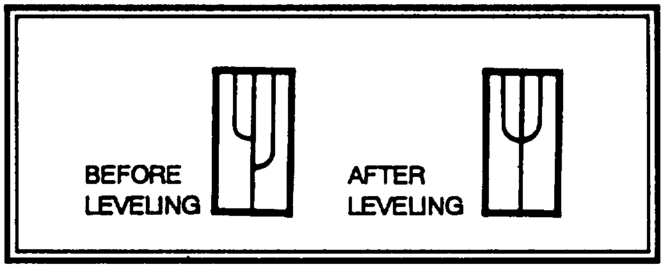
Figure 3-9. **Relation of vertical circle readings and vertical angle**



c. After placing the crosslines on the station, elevate or depress the telescope until the horizontal crossline is exactly on the point to which the vertical angle is desired. After positioning the telescope on the station, center the bubble of the collimation level (split bubble) on its vial by rotating the collimation level tangent screw until the images of the ends of the bubble coincide. (See Figure 3-10.) Then read the vertical circle reading in the circle-reading microscope. The T16-84 has an automatic vertical index.

> **Note.** If the T16-84 instrument is so off level that the automatic index is no longer within its working range, a red warning screen appears on the vertical circle scale. If a red screen appears, relevel the instrument.

Figure 3-10. **View of collimation level**



3-8. COMPUTING HORIZONTAL AND VERTICAL ANGLES

After making the direct and reverse pointings and recording the horizontal and vertical circle readings in the field notes (Figure 3-7), determine the size of each angle.

a. To determine the horizontal angle between Stations A and B (Figure 3-7), first determine the mean of the pointings on each station. Do this by mentally adding 3,200 mils to, or subtracting 3,200 mils from, the reverse reading and taking the mean of the direct and reverse readings. Enter the results in the field notes in the proper column. Then determine the horizontal angle between the stations by finding the difference in the mean circle readings. In Figure 3-7, the mean pointing on Station A is 0001.0 mil; on Station B, 0229.4 mils. Therefore, the horizontal angle from Station A to Station B is 0228.4 mils (0229.4-0001.0 = 0228.4).

b. In the field notes in Figure 3-7, the direct pointing on *Station* B resulted in a vertical circle reading of 1,596.5 mile, or a vertical angle of +1.5 mils. With the telescope revered, the vertical circle reading on Station B was 4,601.4 mils, or a vertical angle of +1.4 mils. The mean vertical angle from the instrument to Station B is +1.4 mils (1.5 + 1.4 + 2 = 1.45 rounded to the nearest even 0.1 mil =1.4.

3-9. CARE OF THE T16 THEODOLITE

The T16 theodolite is a delicate instrument. Take care not to drop it or bump it against any object. If the instrument gets wet, dry it before storing it in the carrying case. As soon as possible, place the instrument in a dry room or tent. Remove it from the carrying case so it can dry completely. If left in the closed carrying case, it will absorb the humidity in the air if there is an increase in temperature. Should the temperature drop later, the moisture will condense on the inside of the instrument and may render the instrument inoperable. A man on foot may carry the instrument mounted on the tripod from station to station. Always carry the theodolite in an upright position. Clamp all motions with the telescope in the vertical position. For transport over rough terrain, the instrument should be in its carrying case. When transported in a vehicle, the theodolite should be in the carrying case and the case should be in the padded box, For short distances in vehicles, the instrument operator may hold the carrying case in an upright position on his lap.

3-10. CLEANING THE T16 THEODOLITE

Keep the theodolite clean and dry. During use, as necessary, and after use, clean the instrument as discussed below.

a. Wipe painted surfaces with a clean cloth.

b. Clean the lenses only with a camel's-hair brush and lens tissue. Clean the lenses first with the brush to remove any dust or other abrasive material and then with the lens tissue. Remove any smudge spots remaining after using lens tissue by slightly moistening the spot and again cleaning with lens tissue. Be careful not to scratch the lenses or remove their coating. The coating reduces glare for the observer.

c. Clean all metal parts of the tripod with a cloth moistened with an approved cleaning solvent. Then wipe them dry. Clean the wooden parts with a soft cloth moistened with water, and dry the parts thoroughly. Clean the leather strap with a suitable leather cleaner.

3-11. REPAIR OF THE T16 THEODOLITE

Theodolites in need of major adjustment or repair should be turned in to the engineer unit responsible for providing maintenance service.

3-12. TESTS AND ADJUSTMENTS OF THE T16 THEODOLITE

a. Keep the T16 theodolite in correct adjustment to obtain accurate results. There are four tests and adjustments of the T16 theodolite that the instrument operator must make. He makes these tests and adjustments in the following sequence:

Ž Plate level test and adjustment.

Ž Optical plumb teat and adjustment.

Ž Horizontal collimation teat and adjustment.

Ž Vertical collimation test and adjustment.

When a test indicates that an adjustment is necessary, the operator makes the adjustment and retests the instrument for accuracy before making the next test in sequence.

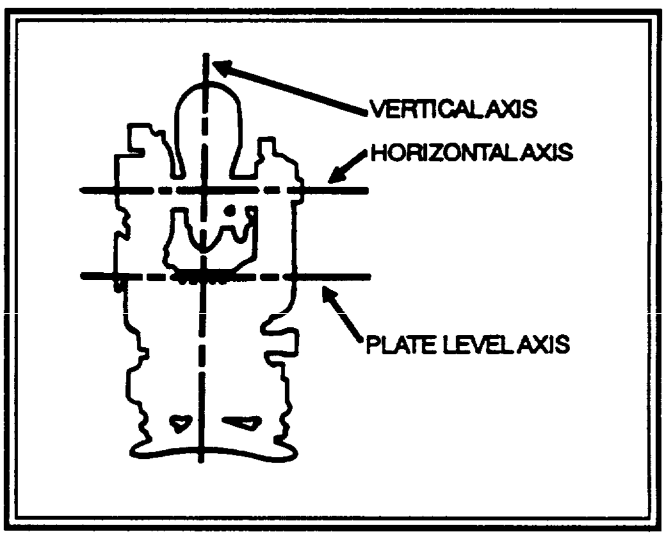
b. The four tests and adjustments of the theodolite are made with the instrument mounted on its tripod. For these tests and adjustments, set the instrument up in the shade on firm ground with the head of the tripod as nearly level as possible. Also protect the theodolite from the wind.

c. If handled properly, an instrument will remain in adjustment indefinitely. Needless and excessive movement of the adjusting screws will cause them to become worn and the instrument will not hold an adjustment.

3-13. T16 PLATE LEVEL TEST AND ADJUSTMENT

a. Purpose. The purpose of the plate level adjustment is to make the vertical axis of the theodolite truly vertical when the bubble of the plate level is centered in the vial. (See Figure 3-11.)

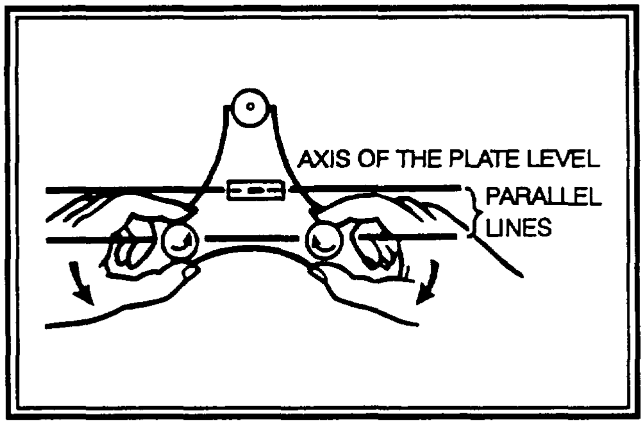
Figure 3-11. **Plate level adjustment**



b. Test.

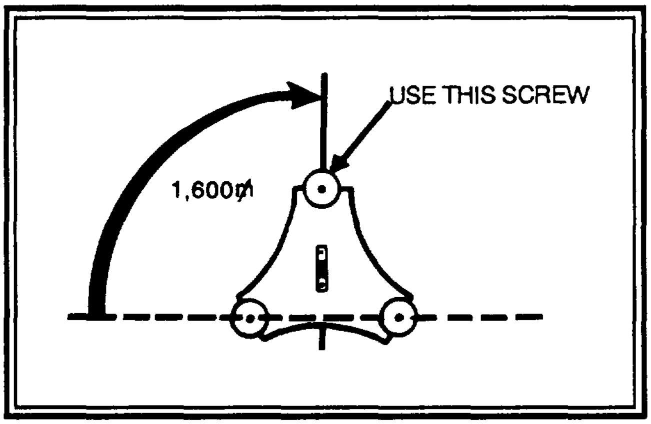
Step 1. Test the adjustment of the plate level by placing the axis of the plate level bubble parallel to any two of the three leveling screws. (See Figure 3-12.)

Figure 3-12. **Plate level adjustment, step 1**



Step 2. With these two leveling screws, center the bubble in its vial. Rotate the instrument 1,600 mils, and align the plate level with the third leveling screw. (See Figure 3-13.)

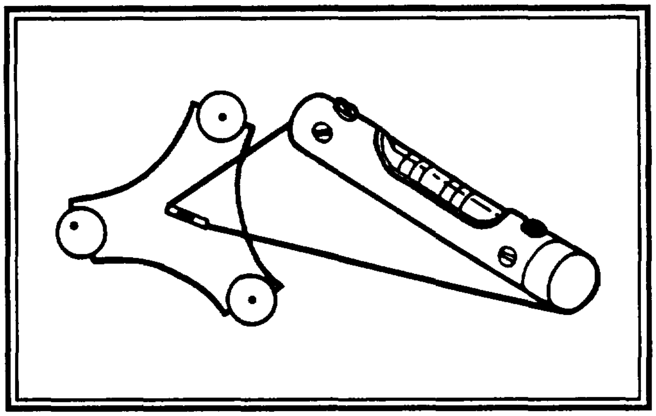
Figure 3-13. **Plate level adjustment, step 2**



Step 3. Center the bubble in this position by using the third leveling screw. Rotate the instrument back to the first position, and see if the bubble remains centered. Repeat leveling in these two positions until the bubble remains centered in both positions.

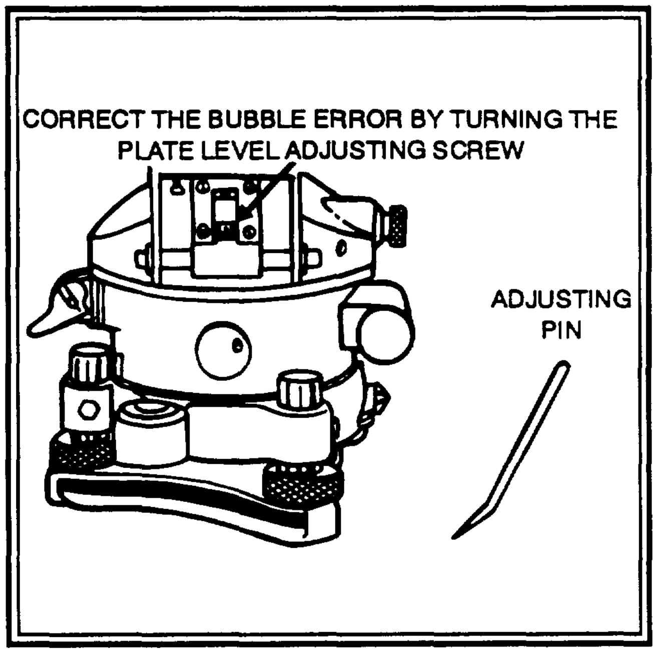
Step 4. Carefully rotate the instrument 3,200 mils from the first position. If the bubble does not remain centered within one graduation, an adjustment is required. The discrepancy noted between the position of the bubble and the center position is the apparent error, or twice the actual error of the plate level. The level vial has graduated lines used to determine the apparent error. (See Figure 3-14.)

Figure 3-14. **Plate level adjustment, apparent error**



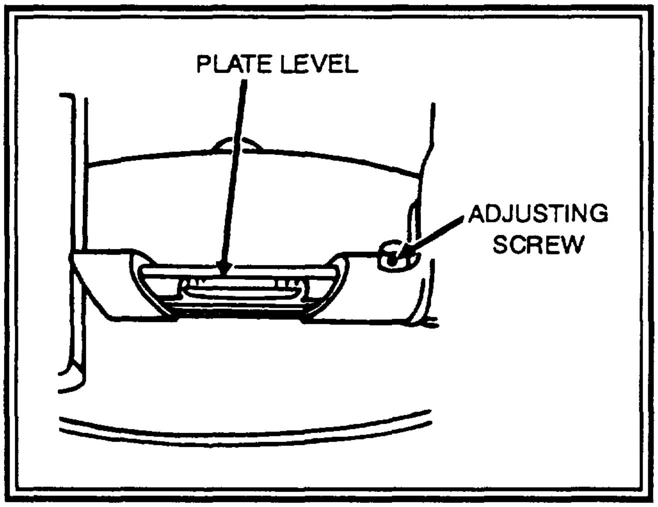
c. Adjustment. To adjust the plate level, use the adjusting pin from the accessory case. With the instrument 3,200 mils from the first position insert the adjusting pin into the hole of the capstan screw and remove one-half of the apparent error (actual error) by turning the capstan adjusting screw. On the T16 theodolite, the plate level adjusting screw is about 1.5 inches above the horizontal clamping screw on the right standard. (See Figure 3-15.) After adjusting, repeat the plate level test and adjust as necessary to correct any error remaining in the plate level bubble. The plate level is in proper adjustment when the bubble remains centered throughout 6,400 mils rotation.

Figure 3-15. **Plate level adjusting screw and adjusting pin**



Note. On the T16-64, the plate level adjustment screw is on the top right of the plate level vial. (See Figure 3-16.)

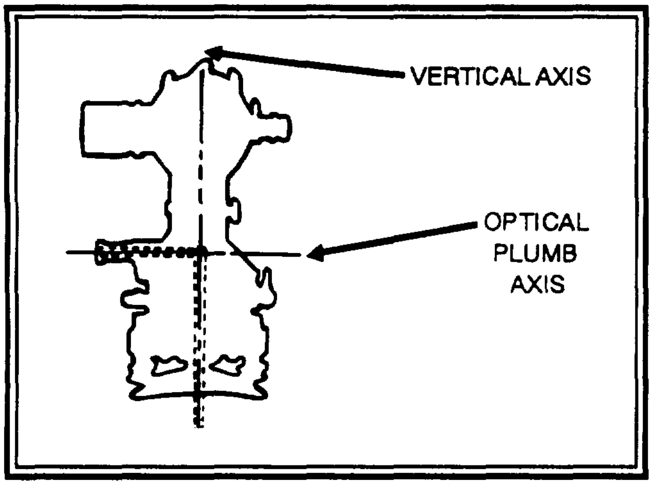
Figure 3-16. **Plate level adjusting screw (T16-84)**



3-14. T16 OPTICAL PLUMB TEST AND ADJUSTMENT

a. Purpose. The purpose of the optical plumb adjustment is to make the vertical axis of the theodolite pass through the station mark when the theodolite is properly leveled and the station mark is centered in the reticle of the optical plumb. (See Figure 3-17.)

Figure 3-17. **Optical plumb adjustment**



b. Test.

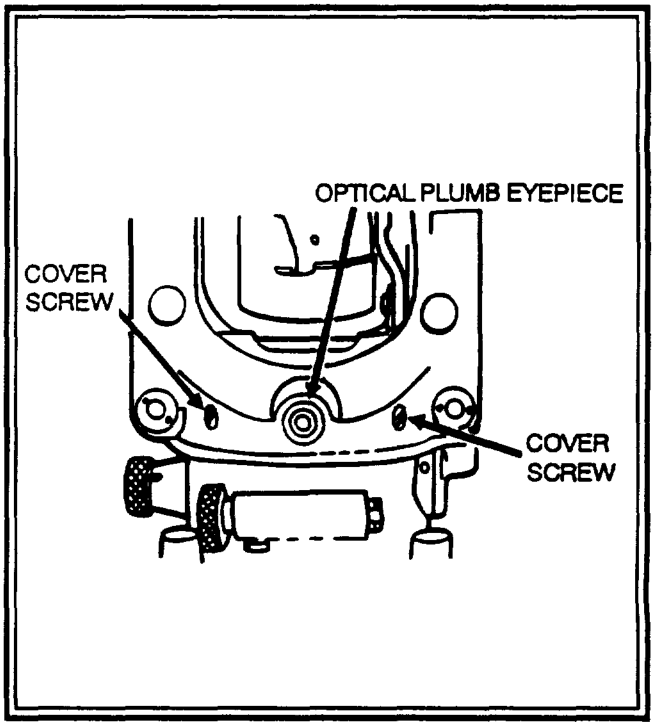
Step 1. To test the optical plumb, set up the theomdolite over a station that is clearly marked by a cross or other well-defined point. Accurately plumb and level the instrument. The image of the point should be centered exactly in the center of the optical plumb. This is accomplished by recentering and releveling as necessary.

Step 2. When the instrument is leveled and the image of the point is centered, rotate the alidade 6,400 mils about its vertical axis. If the image of the point does not remain centered in the reticle, an adjustment is required. The amount of displacement is the apparent error, or twice the actual error, of the optical plumb. Position the instrument at the point where the displacement is farthest from the point.

c. Adjustment.

Step 1. To adjust the optical plumb, correct one half of the displacement (actual error) by turning the two optical plumb adjusting screws. The adjusting screws are 1.25 inches to the right and left of the optical plumb eyepiece. To gain access to the adjusting screws, remove the cover screws. (See Figure 3-18.)

Figure 3-18. **Optical plumb eyepiece and cover screws**



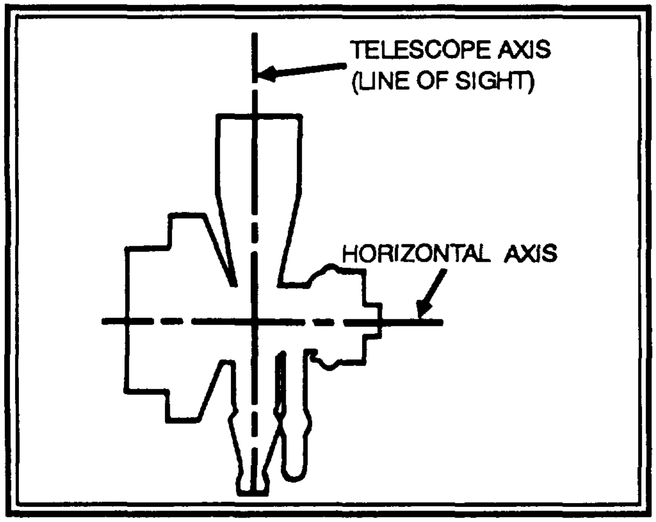
Step 2. Use the screwdriver from the accessory case to turn the adjusting screws. Loosen the adjusting screw on the side opposite the side to which the reticle must be moved. Tighten the other screw, and the reticle moves as the screw is tightened. Move the reticle image one-half the distance to the station mark by moving first one screw and then the other in small increments. The last movement of both adjusting screws must be clockwise. This compresses a counterspying positioned under each screw and holds the optical system stationary.

Step 3. Check the adjustment again by centering the instrument over the station mark and leveling it. Rotate the instrument through 6,400 mils. If the image of the reticle remains centered on the station mark throughout the full circle, the optical plumb is in adjustment. If the image of the reticle does not remain centered on the station mark throughout the full circle, repeat the adjustment until the image of the reticle remains centered. After the adjustment is complete, replace the cover screws.

3-15. T16 HORIZONTAL COLLIMATION TEST AND ADJUSTMENT

a. Purpose. The purpose of the horizontal collimation adjustment is to make the line of sight perpendicular to the horizontal axis of the telescope. (See Figure 3-19.)

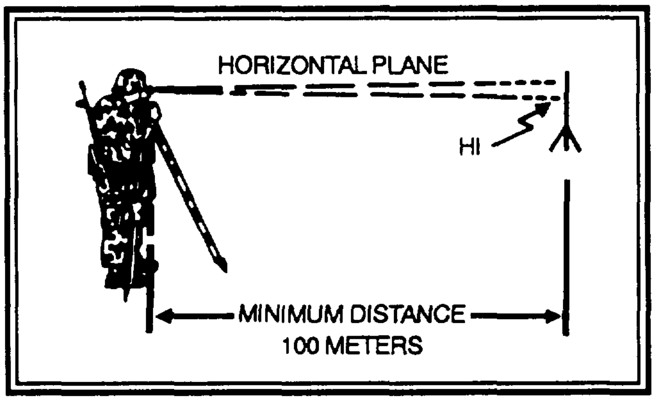
Figure 3-19. **Horizontal collimation adjustment**



b. Test.

Step 1. To test the horizontal collimation, select a well-defined point at least 100 meters (m) from the instrument and at about the same height as the instrument. (see Figure 3-20.)

Figure 3-20. **Horizontal collimation adjustment, step 1**



Step 2. With the telescope in the direct position, center the vertical crossline on the selected point. Read the horizontal circle reading to the recorder. For illustration purposes, assume your direct reading is 0001.0 mil.

Step 3. Plunge the telescope to the reverse position, and give the recorder a second reading to the same point. Assume the reverse reading is 3,202.6 mils.

Note. Only one sat of direct and reverse readings is required. Be very careful, therefore, to prevent pointing or reading errors.

Step 4. The difference between the direct and reverse readings should be exactly 3,200 mils. Assuming you did not make any error in the pointings or readings, the discrepancy between the actual difference in the two readings and 3,200 mils is the apparent horizontal collimation error, or twice the actual horizontal collimation error. If the apparent horizontal collimation error exceeds the initial circle setting (0001.0 mil for the T16), you should perform the horizontal collimation adjustment.

EXAMPLE

Direct reading to selected point	**0001.0**
Reverse reading to the same point	**3202.6-3200 = 0002.6**
Spread (0002.6 -0001 .0)	**1.6**
Apparent horizontal collimation error	**1.6 mils**
Actual error (apparent error divided by 2) (1.6 + 2)	**0.8 mil**

c. Adjustment.

Step 1. With the telescope sighted on the point in the reverse position and using the horizontal tangent screw, set the circle to the mean value of the direct and reverse pointings. (Mean reverse reading: 3202.6- 0.8= 3201.8) This will move the vertical crossline of the telescope reticle off the point.

Step 2. Move the vertical crossline back to the point by turning the two pull-action capstan adjusting screws that are arranged horizontally and on opposite sides of the telescope near the eyepiece. To move the crosslines to the left, loosen the right screw first and tighten the left screw. If the adjusting screw is tightened too much, it will cause the reticle to get out of adjustment later. Do not try to make the entire adjustment in one step. Loosen and tighten the opposite screws in small amounts. Do this until the crossline is centered exactly on the sighted point.

> **Note.** On the T16-84, the cover on the telescope eyepiece must be removed to expose the capstan adjusting screws.

Step 3. Perform the test again, and make additional adjustments until the difference is less than 0.2 mil.

> **Note.** It is preferred that the adjustment be made with the theodolite in the reverse position. This adjustment also can be made with the telescope in the direct position and by using the mean value for the direct pointing (0001.0+0.8 = 0001.8).

3-16. T16 VERTICAL COLLIMATION TEST AND ADJUSTMENT

a. Purpose. The purpose of the vertical collimation adjustment is to make the line of sight horizontal when the vertical circle reading is 1,600 mils with the telescope in the direct position (4,800 mils with the telescope in the reverse position) and the ends of the collimation level bubble in alignment. (See Figure 3-21.)

b. Test.

Step 1. To test the vertical collimation, select a well-defined point at least 100 meters from the instrument and about on a horizontal plane with the theodolite. (See Figure 3-22.)

Step 2. With the telescope in the direct position, give the recorder a direct vertical circle reading to the point. Be sure to precisely align the collimation level bubble.

Step 3. Plunge the telescope to the reverse position. Give the recorder a reverse circle reading to the same point. Be sure the collimation level bubble is precisely aligned before you read the vertical circle. Check the alignment after you take your reading.

Figure 3-21. **Vertical collimation adjustment**

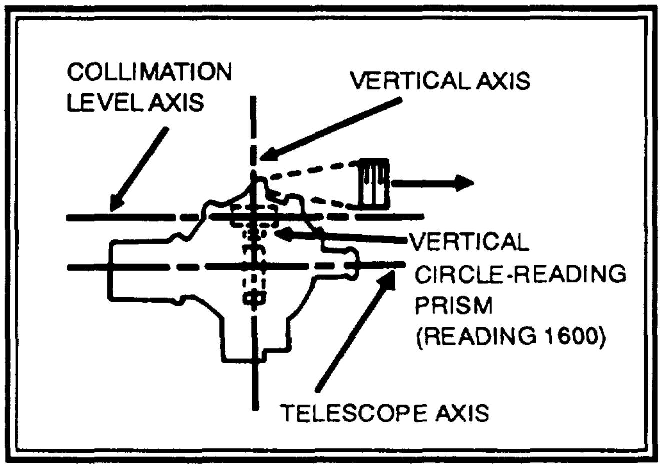
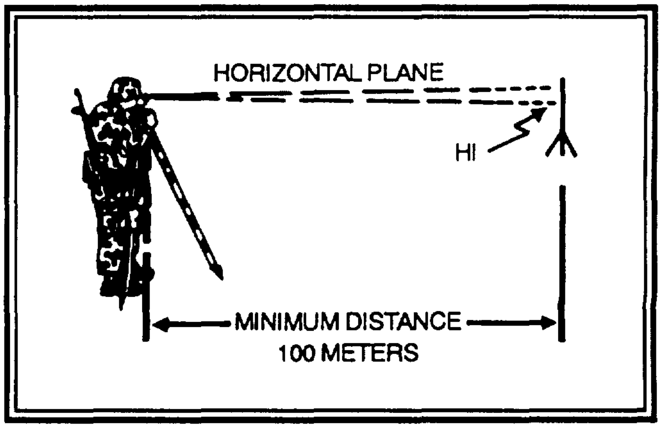


Figure 3-22. **Vertical collimation adjustment, step 1**



> **Note.** Only one set of direct and reverse readings is required. Be very careful, therefore, to prevent pointing or reading errors.

c. Adjustment. The sum of the direct and reverse readings should be 6,400 mils. Any difference between the sum of the two readings and 6,400 mils is the apparent vertical collimation error, or twice the actual error. If the difference exceeds 0001.0 mil for the T16 theodolite, the vertical collimation level should be adjusted. To compensate for the error, you must compute the correct vertical pointing by using the two vertical readings. If the sum of the two readings is greater than 6,400 mils, determine the difference between the sum and 6,400 mils. Then subtract one-half the difference from your reverse reading to obtain a corrected reading. If the sum of the two readings is less than 6,400 mils, find the difference between the sum and 6,400 mils. Add one-half of the difference to the reverse vertical reading.

EXAMPLE

Direct reading	1603.4
Reverse reading	+4797.8
Sum	6401.2
	-6400.0
Apparent error	1.2 mils
Actual error (1.2 + 2)	0.6 mil
Corrected reverse vertical reading (4797.8 - 0.6)	4,797.2 mils

EXAMPLE

Direct reading	1594.6
Reverse reading	+4804.2
Sum	6398.8
Apparent error (6400 - 6398.8)	1.2 mils
Actual error (1.2 + 2)	0.6 mils
Corrected reverse vertical reading (4804.2 + 0.6)	4,804.8 mils

Step 1. With the instrument in the reverse position and the telescope sighted on the selected point, use the collimation level tangent screw to place the corrected vertical reading on the vertical circle scale. The collimation level bubble will not be centered.

Step 2. Remove the cover from the collimation level bubble, and use the capstan adjusting screw to center the collimation bubble. Rotate the single adjusting screw to align the images of the collimation bubble. On the T16-84, slacken the screw located 1/2 inch above the illumination mirror and open the cover. The adjustment screw for the vertical index is now seen. Turn the adjustment screw carefully until the correct vertical reading is set, then close the cover.

Step 3. Continue the test and adjustments until the difference between the direct and reverse readings is less than 0.2 mil.

Note. It is preferred that the adjustment be made with the theodolite in the reverse position. This adjustment also can be made with the telescope in the direct position b using the corrected direct vertical reading to adjust the instrument.

3-17. TESTS AND ADJUSTMENTS OF THE T16-64 THEODOLITE

a. There are five tests and adjustments on the T16-84 theodolite that are made by artillery survey personnel. The tests and adjustments are performed in the following order:

- Ž Plate level adjustment.
- Ž Circular bubble test and adjustment.
- Ž Optical plumb test and adjustment.
- Ž Horizontal collimation test and adjustment.
- Ž Vertical collimation test and adjustment.

The procedure for tests and adjustments on the T16-84 are very similar to those of the T16. Perform the plate level, horizontal collimation, and vertical collimation tests and adjustments by following the procedures outlined for the T16 theodolite in paragraphs 3-13, 3-15, and 3-16 respectively.

b. Always perform the tests and adjustments in the sequence in which they are listed. After you make an adjustment, perform the test again to check for accuracy before you go to the next teat and adjustment. When making adjustments, do not force the movement of the adjusting screws or exert too much pressure. The screws could be damaged and render your instrument unserviceable. A correctly adjusted theodolite is essential in obtaining accurate survey results.

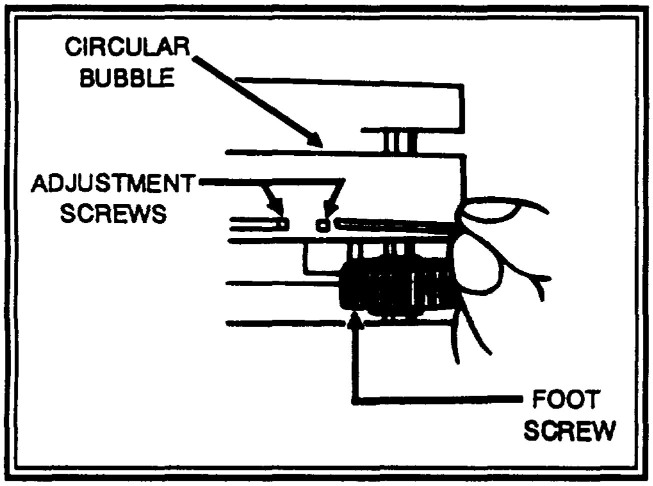
3-18. T16-84 CIRCULAR BUBBLE TEST AND ADJUSTMENT

a. Purpose. The purpose of the circular bubble adjustment is to make the circular bubble center of its setting circle when the plate level is in adjustment.

b. Test. Level the instrument by using the plate level. The circular level should be center of its setting circle. If not, it must be adjusted.

c. Adjustment. To adjust the circular bubble, tighten and/or loosen the two small adjustment screws in the side of the level holder (Figure 3-23) until the level is centered in its setting circle.

Figure 3-23. **Circular level adjusting screws**



3-19. T16-84 OPTICAL PLUMB TEST AND ADJUSTMENT

a. Purpose. The purpose of the optical plumb adjustment is to make the vertical axis of the theodolite pass through the station mark when the theodolite is properly leveled and the station mark is centered in the reticle of the optical plumb.

b. Test.

Step 1. Place a piece of paper on the ground under the instrument. Accuratel y plumb the instrument by using the plumb bob, and mark the point on the paper. Label the mark “Point l.”

Step 2. Remove the plumb bob, and bring the point into focus. Turn the leveling screws to set the cross hairs of the optical plumb exactly on Point 1. Move the eye slightly to ensure there is no parallax between the cross hairs and Point 1. If there is parallax, adjust the focus.

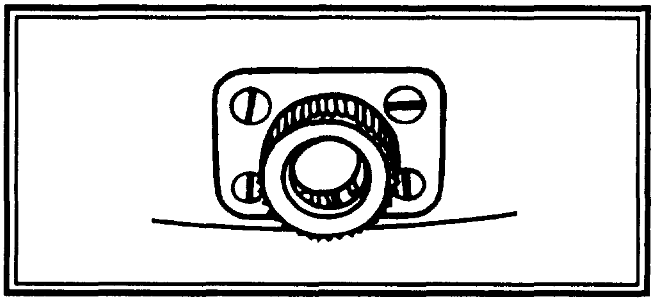
Step 3. Rotate the alidade 3,200 mils, and carefully mark the position of the cross hairs on the paper as Point 2. If Points 1 and 2 coincide, the optical plumb is in adjustment. If not, it must be adjusted.

c. Adjustment.

Step 1. Mark a point (Point 3) halfway between points 1 and 2. Using the leveling screws, set the cross hairs of the optical plumb on Point 3.

Step 2. Loosen the four screws in the plate around the optical plumb eyepiece until the optical plumb and plate can just move. (See Figure 3-24.)

Figure 3-24. **Optical plumb**



Step 3. Move the plummet and plate carefully until the cross hairs are exactly on Point 1. Tighten the four screws. Repeat the test, and if necessary, repeat the adjustment.

Note. In the procedure described above, the plate level has no influence and must be ignored.

CAUTION

It may be difficult for you to remember where the various adjusting screws are located when you need to make adjustments on the theodolite. You should always refer to the technical manual published for each type of theodolite.

3-20. CARE AND USE OF THE TRIPOD

The tripod should be used and cared for as discussed below.

a. Turn the tripod to its upright position. Test the adjustment of the tripod legs by elevating each leg, in turn, to a horizontal position and then releasing it. If properly adjusted, the leg should fall to about 800 mils and stop. If it does not, adjust the tripod leg by tightening or loosening the tripod clamping nut. Repeat the test until it is successful.

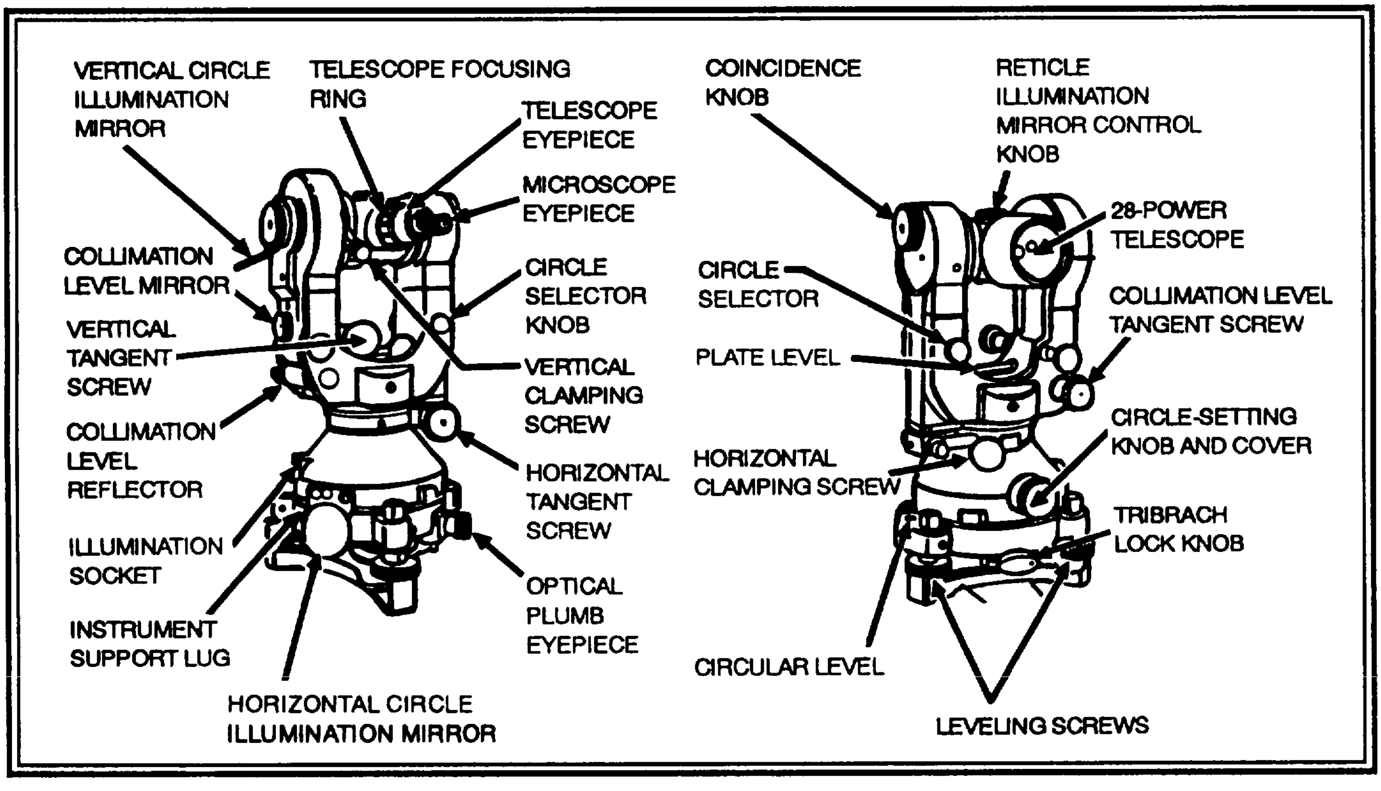
b. Clean the wooden parts with a soft cloth moistened with water, and dry them thoroughly. Clean the leather strap with a suitable leather cleaner.

Section II

T2 THEODOLITE

The T2 theodolite (Figure 3-25) is the authorized angle-measuring instrument for artillery fourth-order survey. The theodolite is a directional-type instrument and is used to measure horizontal and vertical angles. It has interior scales, which are read by means of a built-in optical system. The scales, graduated in mils, can be read directly to 0.002 mil and by interpolation to the nearest 0.001 mil. The scales may be illuminated by sunlight or by means of a built-in wiring system using artificial light. All parts of the instrument that can be seriously damaged by dust or moisture are enclosed. The T2 theodolite is issued with a canvas accessory case containing the following:

Figure 3-25. **T2 theodolite**



- An instructional pamphlet.
- Diagonal eyepieces for the telescope and reading microscope.
- A sun filter.
- A jeweler's screwdriver.
- Two adjusting pins.
- A camel's-hair brush.
- A plastic instrument cover.
- Two lamp fittings for artificial illumination.

Also issued with the T2 is a battery case containing lighting devices and spare bulbs and a universal tripod with a plumb bob, plug-in sleeve, and tripod key in a leather pouch attached to the tripod. The accessories of some models of the theodolite are stored in the base of the carrying case.

> **Note.** For detailed information on the T2 theodolite, see TM 5-6675-205-20P, TM 5-6675233-20P, and TM 5-6675-296-14.

3-21. PREPARING AND TAKING DOWN THE T2 THEODOLITE

a. Setting Up the Tripod. The tripod used with the T2 theodolite is similar to that used with the T16 theodolite. The procedure for setting up this tripod is the same as that for setting up the T16 theodolite tripod (paragraph 3-2).

b. Removing the Theodolite From Its Case. The T2 theodolite is removed from its case in the same manner as the T16 theodolite (paragraph 3-2) except that the T2 theodolite is fastened to the base by three supports with locking devices.

c. Plumbing and Leveling the Theodolite. The procedure for plumbing and leveling the T2 theodolite is the same as that for the T16 theodolite. (See Figures 3-3 and 3-4.)

d. Focusing the Telescope to Eliminate Parallax. The telescope of the T2 theodolite is the same as the telescope of the T16 theodolite. It is focused to eliminate parallax in the same manner (paragraph 3-5).

e. Taking Down the T2 Theodolite. The procedure for taking down the T2 theodolite is discussed below.

(1) Remove the dome cover from the carrying case, and prepare the case to receive the theodolite by opening the locking devices.

(2) Place the telescope in a vertical position with the objective lens down, and lightly clamp the vertical clamping screw.

(3) Turn the leveling screws about halfway down and to the same height.

(4) Lightly clamp the horizontal clamping screw.

(5) Close the illumination mirrors, and turn the hinges to the top.

(6) Hold the instrument by its right standard, and unscrew the instrument-fixing screws. Lift the theodolite from the tripod, and secure it in the carrying case. Replace the dome-shaped cover.

(7) Replace the tripod head cover, collapse the tripod, and strap the legs together.

3-22. CIRCLE READINGS WITH THE T2

a. A system of lenses and prisms permits the observer to see small sections of either the horizontal circle or the vertical circle. The circles are viewed through the circle-reading microscope eyepiece located alongside the telescope. The observer selects the circle to be viewed by turning the circle selector knob on the right standard. The field of view of the circle-reading microscope contains two small windows. (See Figure 3-26.) The upper window shows images of two diametrically opposite parts of the circle (horizontal or vertical). One image of the circle is inverted and appears above the other image. The lower window shows an image of a portion of the micrometer scale.

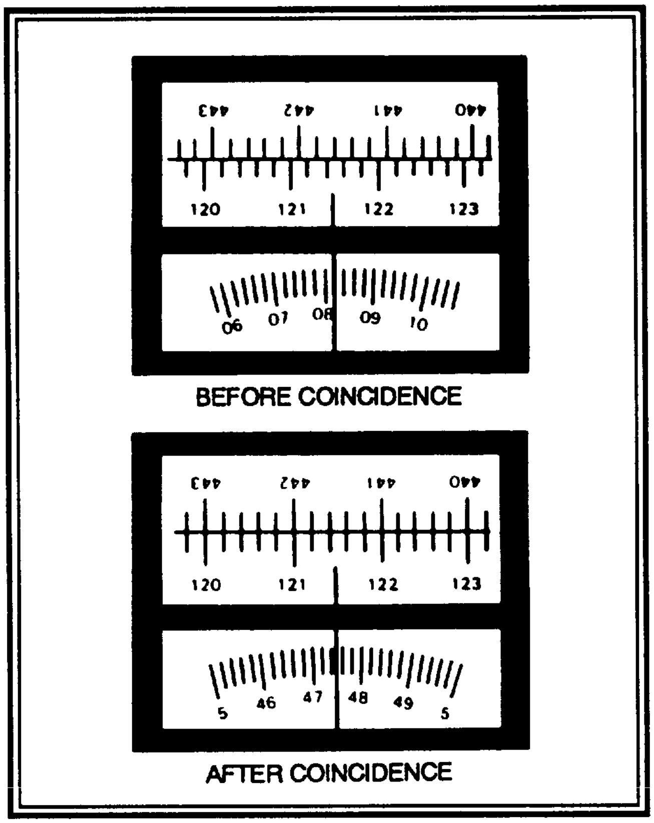
b. The micrometer coincident knob on the side of the right standard is used in conjunction with the micrometer scale to obtain readings for either of the circles. Optical coincidence is obtained between diametrically opposite graduations of the circle by turning the micrometer coincidence knob. When this knob is turned, the images of the opposite sides of the circle appear to move in opposite directions across the upper window in the circle-reading microscope. The image of the micrometer scale in the lower window also moves. The graduations of the circle (upper window) are brought into coincidence so they appear to form continuous lines across the dividing line. The center of the field of view in the upper window is marked by a fixed vertical index line. The final coincidence adjustment should be made between circle graduations near this index line.

3-23. HORIZONTAL CIRCLE READINGS WITH THE T2

A reading on the horizontal circle is determined as discussed below.

a. Rotate the circle selector knob until the black line on the face of the knob is horizontal.

Figure 3-26. **T2 theodolite scales viewed through the circle-reading microscope**



b. Adjust the illuminating mirror so both windows in the circle-reading microscope are uniformly lit.

c. Focus the microscope eyepiece so the graduations of the circle and the micrometer scale are sharply defined.

d. Observe the images in the microscope eyepiece. Bring the circle graduations into coincidence at the center of the upper window by turning the coincidence knob.

e. Read the horizontal circle and the micrometer scale.

3-24. STEPS IN CIRCLE READING

On the T2 theodolite, the main scale (upper window) is graduated in 2-mil increments (Figure 3-26). Each fifth graduation is numbered with the unit digits omitted. For example, 10 mils appears as 1; 250 mils, as 25; and 3,510 mils, as 351. The micrometer scale (lower window) is graduated from 0.000 mil to 1.000 mil. Each 0.002 mil is marked with a graduation and each fifth graduation is numbered (hundredth of a mil). The scale may be read to 0.001 by interpolation. The steps in reading the circles are discussed below.

a. With the circle graduations in coincidence (Figure 3-26), determine the first erect numbered graduation to the left of the index line that marks the center of the upper window. This numbered graduation indicates the value of the circle reading in tens of mils. In Figure 3-26, this graduation is 121.

b. Locate on the inverted scale the graduation for the number opposite 121 (the number +320). In Figure 3-26, this number is 441 (viewed as Ɩᔭᔭ). The inverted number normally is to the right of the index line that marks the center of the field of view. Both values always end in the same number—in this case, the number 1. When the unit mil of the circle reading is zero, coincidence is obtained when the circle reading and its diametrically opposite number are in coincidence with each other.

c. Count the number of spaces between graduations from 121 to the inverted 441. Each of these spaces represents 1 mil. There are five spaces, representing 5 mils.

d. Convert 121, which is tens of mils, to 1,210 mils. To this value, add the unit mils determined in paragraph c above (1,210 + 5 = 1,215 mils, the angular value obtained from the main scale).

e. On the micrometer scale (lower window), the index line that marks the center of the field of view also indicates the value to be read from the micrometer scale. In Figure 3-26, this value is 0.475 mil.

f. Add the values determined in paragraphs d and e above (1215 + 0.475= 1,215.475 mils, the angular value displayed in Figure 3-26).

3-25. VERTICAL CIRCLE READINGS WITH THE T2 THEODOLITE

To view the vertical circle, turn the circle selector knob to the vertical position (the black line on the face of the knob is vertical.) Adjust the vertical circle illuminating mirror so both windows in the circle reading microscope are uniformly lit. The vertical circle is read in the same manner as the horizontal circle. Before reading the vertical circle, center the vertical collimation level (split bubble) by using the procedures described in paragraph 3-7, and bring the images of the vertical circle into coincidence by using the procedures described in paragraph 3-22.

3-26. SETTING THE HORIZONTAL CIRCLE

There are two situations in which it is necessary to set the horizontal circle.

a. The first instance is when the initial circle setting of (0000.150 ± 0.100 mil) is used.

(1) Point the instrument at the rear station.

(2) Using the coincidence knob, place a reading of 0.150 on the micrometer scale.

(3) Using the circle-setting knob, zero the main scale as accurately as possible, ensuring that the numbered lines, which are 3,200 mils apart (the erect 0 graduation and the inverted 320 graduation), are touching each other. Ensure that the circle-setting knob cover is closed when this step is finished.

(4) With the coincidence knob, bring the main scale graduation into precise coincidence.

(5) Read the horizontal circle. The reading should be 0000.150 ± 0.100 mil).

b. The second instance is when it is desired to orient the instrument on a line of known direction from a reference direction (or to measure a predetermined angle).

(1) Sight the instrument on the station for which the reference direction is provided, and read the circle.

(2) Add the angular difference between the reference direction and the desired direction (or the predetermined angle) to the circle reading. The result is the circle reading for the instrument when it is pointed in the desired direction.

(3) Using the coincidence knob, set the micrometer scale to read the fractional portion of the desired circle reading to the nearest thousandth of a mil.

(4) Using the horizontal clamping screw and the horizontal tangent screw, rotate the alidade to obtain coincidence on the main state at the roils value corresponding to the reading obtained in (2) above. When coincidence is obtained, the instrument is pointing in the desired direction.

3-27. MEASURING HORIZONTAL ANGLES WITH THE T2

a. Since the T2 theodolite is a directional-type instrument, the values of horizontal angles are determined by differences in circle readings. The procedures for measuring and determining horizontal angles (Figure 3-27) are discussed below.

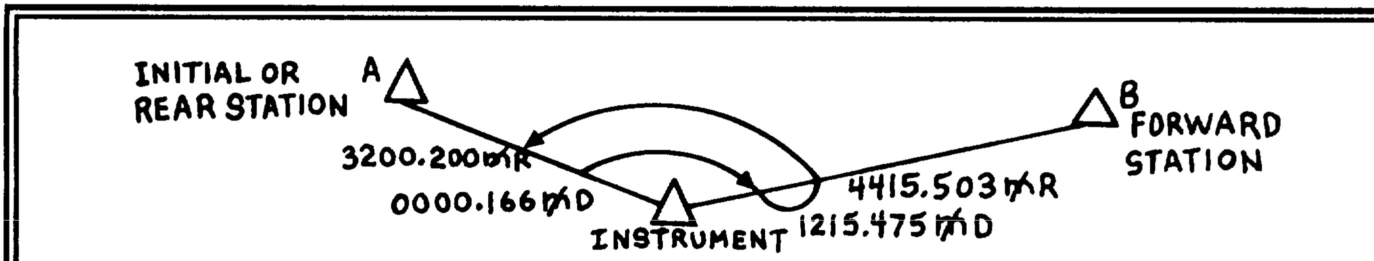
(1) With the telescope in the direct position, point to the rear station (Station A). Set and record the initial circle setting (0000.166 mil).

(2) With the telescope in the direct position, point to the forward station (Station B). Record the horizontal circle reading (1,215.475 mils).

(3) Plunge the telescope to the reverse position, and point to Station B. Record the circle reading (4,415.503 mils).

(4) With the telescope in the reverse position, point to Station A. Record the circle reading (3,200.200 mils).

Figure 3-27. **Method of recording and sketch of pointings in measuring horizontal angles, T2 theodolite**



STATION	T	HORIZ ∡	MEAN	VERT READING	VERT ∡
A	D	0000.166			
	R	3200.200	0000.183		(+28.624)
INSTRUMENT	MEAN ∡	(1215.306)			
B	D	1215.475		1571.384	+28.616
	R	4415.503	1215.489	4828.631	+28.631

(5) Subtract 3,200 mils from the reverse pointing on Station A. Mean the remainder with the direct pointing on Station A (0000.183 mil).

(6) Subtract 3,200 mils from the reverse pointing on Station B. Mean the remainder with the direct pointing on Station B (1,215.489 mils).

(7) Subtract the mean pointing on Station A from the mean pointing on Station B to determine the horizontal angle from Station A to Station B (1215.489-0000.183= 1,215.306 mils).

> **Note.** Steps (1) through (7) above constitute one direct and one reverse pointing on each station, which is referred to as one position.

b. When it is necessary to measure the angle to more than one station, make a pointing on the initial station with the telescope in the direct position and then on each station around the horizon in a clockwise direction. After getting a direct reading on the last station, reverse the telescope and make a pointing at each station in a counterclockwise direction, ending with the initial station. One set of direct and reverse pointings on all of the observed stations constitutes one position.

c. The direct and reverse pointings on each station should differ by 3,200 mils, plus or minus the amount of horizontal spread (twice the actual error in horizontal collimation) in the instrument. No value can be specified as the maximum allowable spread for an instrument however, it should be small (0.150 mil or less) for convenience in meaning the pointings. The amount of the spread should be constant; otherwise, there are inconsistencies in operating the instrument. If the mean spread of an instrument exceeds 0.150 mil, the instrument should be adjusted at the first opportunity.

d. In FA survey, one position is normall y observed for traverse.

e. It may be necessary, as in fourth-order triangulation, to measure two positions. The second position is measured in the same manner as the first position, except that the second position is measured with the telescope in the reverse position for the initial pointing on each station. The initial circle settings should be as follows: first position, 0000.150 (+ 0.100) mil; second position (reverse), 4,800.150 mils (+ 0.100) mil.

f. Determine the angle between two observed stations by measuring and meaning the horizontal circle reading to each station and computing the difference between the mean circle readings. When two positions are taken, determine the value of the angle by taking the mean of the values of the angle as determined from each of the two positions.

g. When two positions are observed, if the two observed values for any angle differ by more than 0.050 mil, these observed values should be rejected. If the observed values are rejected, the angles) must be remeasured.

3-28. DETERMINING VERTICAL ANGLES WITH THE T2

a. The procedure for determining vertical angles with the T2 theodolite is the same as that for the T16 theodolite (paragraph 3-7).

b. After sighting on the observed station and with the circle selector knob in the vertical position, make the vertical circle reading in the same manner as the horizontal circle reading.

3-29. TESTS AND ADJUSTMENTS OF THE T2 THEODOLITE

a. The T2 theodolite must be kept in correct adjustment if accurate results are to be obtained. There are five tests and adjustments of the T2 theodolite that the instrument operator must make in the following sequence:

- Ž Plate level test and adjustment.
- Ž Optical plumb test and adjustment.
- Ž Verticality test and adjustment.
- Ž Horizontal collimation teat and adjustment.
- Ž Vertical collimation teat and adjustment.

When a test indicates that an adjustment is necessary, the operator makes the adjustment and retests the instrument for accuracy before making the next test in sequence.

b. The Eve tests and adjustments of the theodolite are made with the instrument mounted on its tripod and accurately leveled. For these tests and adjustments, the instrument is set up in the shade on firm ground with the head of the tripod as nearly level as possible. The theodolite should also be protected from the wind.

c. If handled properly, an instrument will remain in adjustment indefinitely. Needless and excessive movement of the adjusting screws should be avoided, as it will cause the screws to time worn, and the instrument will not hold an adjustment.

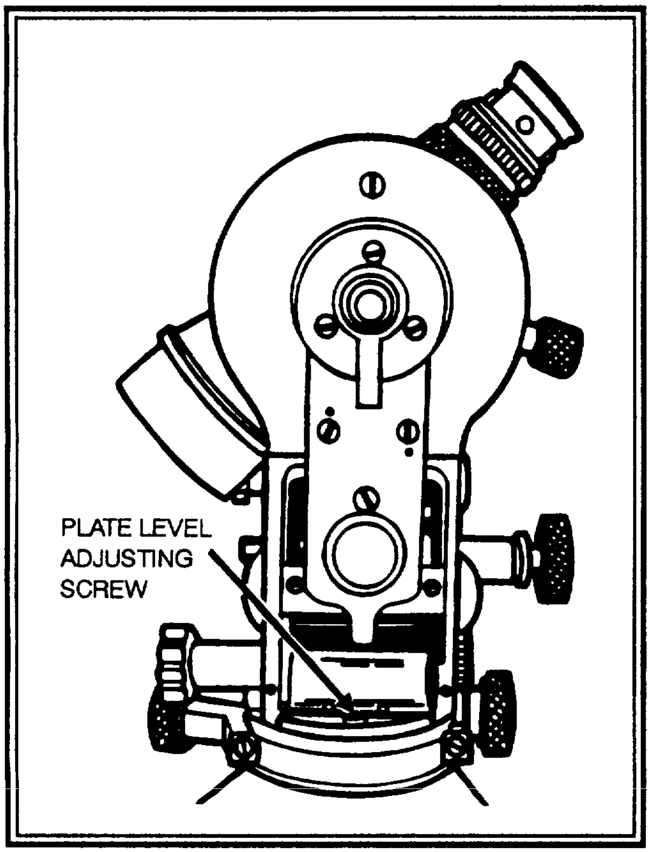
3-30. T2 PLATE LEVEL TEST AND ADJUSTMENT

a. Purpose. The purpose of the plate level adjustment is to make the vertical axis of the theodolite truly vertical when the bubble of the plate level is centered in its vial.

b. Test. The plate level adjustment test for the T2 theodolite is the same as that for the T16 theodolite. See paragraph 3-13 for the steps in this test.

c. Adjustment. To adjust the plate level, use the adjusting pin from the accessory case. Insert the adjusting pin into the hole of the capstan screw, and remove one-half of the apparent error (actual error) by turning the capstan adjusting screw. The capstan adjusting screw is located on the lower portion of the large standard of the T2 theodolite, directly below the collimation level bubble reflector. (See Figure 3-28.) After adjusting, repeat the plate level test to detect and adjust for any error remaining in the plate level bubble. The plate level is in proper adjustment when the bubble remains centered throughout 6,400 mils rotation.

Figure 3-28. **Location of plate level adjusting screw**



3-31. T2 OPTICAL PLUMB TEST AND ADJUSTMENT

a. Purpose. The purpose of the optical plumb adjustment is to make the vertical axis of the theodolite pass through the station mark when the theodolite is properly leveled and plumbed.

b. Test.

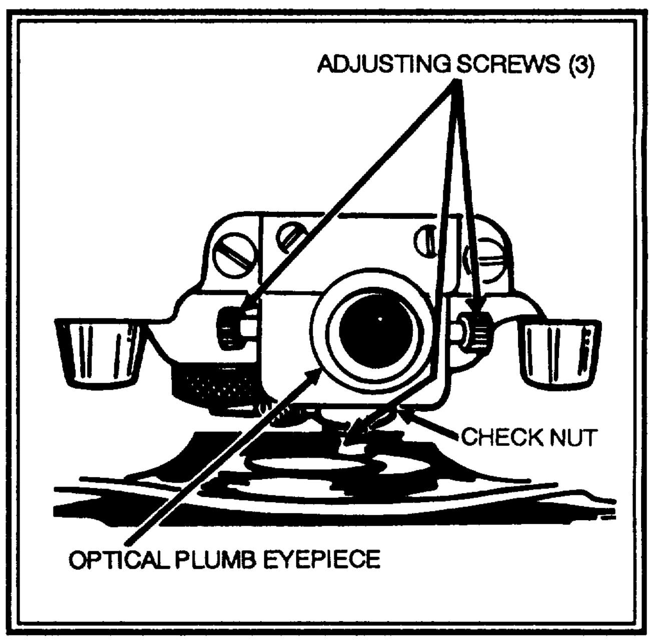
Step 1. To test the optical plumb, set up the theodolite over a station that is clearly marked by a cross or other well-defined point.

Step 2. Suspend the plumb bob from the instrument. Move the instrument until the plumb bob is suspended directly over the well-defined point. Accurately level the instrument.

Step 3. Remove the plumb bob from the instrument, and check to ensure that the instrument is accurately leveled (that the vertical axis is truly vertical). Look into the eyepiece of the optical plumb. If it is in correct adjustment, the mark on the ground will be centered in the reticle.

c. Adjustment. If the point on the ground is not centered in the optical plumb reticle, center the point by using the three adjusting screws located near the optical plumb eyepiece. Two of these adjusting screws are on opposite sides of the eyepiece, and the third adjusting screw is below the eyepiece. The bottom adjusting screw is locked in place by a check nut, which is located immediately above the head of the adjusting screw. (See Figure 3-29.)

Figure 3-29. **Location of adjusting screws for optical plumb adjustment**



Step 1. With an adjusting pin, loosen the check nut. Raise or lower the reticle by turning the bottom adjusting screw to move the reticle image along the axis of the optical plumb in the same direction that the screw travels.

Step 2. Use two adjusting screws on each side of the eyepiece to move the image of the reticle in the opposite direction that the screws travel. If it is necessary to use these screws, they should be rotated an equal amount in opposite directions. It is usually necessary to loosen the screw below the eyepiece slightly to adjust the screws on the side.

Step 3. When the adjusting is complete, the two opposed adjusting screws must be fairly tight. Lock the bottom adjusting screw in place by tightening the check nut.

3-32. T2 VERTICALITY TEST AND ADJUSTMENT

a. Purpose. The purpose of the verticality adjustment is to make the vertical crossline of the reticle lie in a plane that is perpendicular to the horizontal axis of the telescope.

> **Note.** The newer model T2 theodolites (64 series or newer) require no verticality adjustment at the operator or organizational maintenance level.

b. Test.

Step 1. To teat the verticality of the vertical crossline, select a well-defined distant point as near the horizontal plane of the instrument as possible. Center the vertical crossline on the selected point.

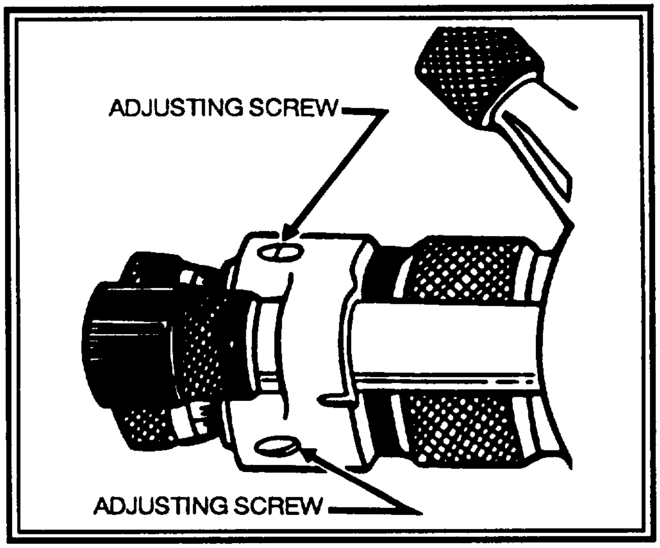
Step 2. Elevate and depress the telescope by using the vertical tangent screw. If the vertical crossline does not continuously track on the point as the telescope is elevated and depressed, an adjustment is necessary.

c .Adjustment. To adjust the vertical crossline and make it truly vertical, use the three adjusting screws on the enlarged portion of the telescope housing between the eyepiece and the knurled focus ring. The two screws on the right side are slant screws (Figure 3-30), which change the vertical position of the crossline. Loosen one slant screw and tighten the other one an equal amount to adjust the verticality of the crossline. The adjusting screw on the left side moves the crossline horizontally.

3-33. T2 HORIZONTAL COLLIMATION TEST AND ADJUSTMENT

a. Purpose. The purpose of the horizontal collimation adjustment is to make the line of sight perpendicular to the horizontal axis of the telescope.

Figure 3-30. **Location of adjusting screws for verticality adjustment**



b. Test.

Step 1. To test the horizontal collimation, select a well-defined point at least 100 meters from the instrument and at about the same height as the instrument.

Step 2. With the telescope in the direct position, center the vertical crossline on the selected point and read the horizontal circle reading to the recorder. For illustration purposes, assume your direct reading is 0000.202 mil.

Step 3. Plunge the telescope to the reverse position, and take a reverse reading to the same point. Assume the reverse reading is 3,200.802 mils.

> **Note.** Only one set of direct and reverse readings is required for horizontal collimation. Be very careful, therefore, to prevent pointing and reading errors.

Step 4. The difference between the direct and reverse readings should be exactly 3,200 mils. Assuming you do not make any error in the pointings or readings, the discrepancy between the actual difference in the two readings and 3,200 mils is the apparent horizontal collimation error, or twice the actual horizontal collimation error. If the apparent horizontal collimation error exceeds the initial circle setting (0000.150 mil for the T2), you should perform the horizontal collimation adjustment.

EXAMPLE

Direct reading to selected point	0000.202
Reverse reading to the same point (3200.802-3200)	0000.802
Spread (0000.802 - 0000.202)	0.600 mil
Apparent horizontal collimation error (0.600 mil + 2)	0.300 mil

c. **Adjustment.**

Step 1. With the telescope on the point in the reverse position, set the mean value of the direct and reverse pointings (reverse= 3200.502) on the micrometer scale by using the coincidence knob.

Step 2. Bring the main scale into coincidence by using the horizontal tangent screw. This moves the vertical crossline of the telescope off the point by the amount of the actual horizontal collimation error.

Step 3. You must align the vertical crossline on the selected point by lateral movement of the reticle within the telescope. Newer models of the T2 have two pull-action capstan adjusting screws arranged horizontally and on opposite sides of the telescope. To align the vertical crossline, loosen one screw and tighten the opposite one an equal amount. The crossline will move laterally toward the screw that you tighten. Do not try to make the entire adjustment in one step. Loosen and tighten the opposite screws in small amounts. Proceed in this reamer until the crossline is aligned on the station.

> **Note.** On the older-model T2 (63 series or older), the adjusting screws are those used for verticality adjustment. To move the vertical crossline, loosen (tighten) the two adjusting slant screws on the right side of the telescope equally, and tighten (loosen) the single adjusting screw on the left side of the telescope. The adjusting screw or screws on one side of the telescope must be loosened before you tighten the screw or screws on the opposite side. Continue the lateral movement of the vertical crossline until it is aligned precisely on the selected point.

Step 4. Perform the test again, and make additional adjustments until the difference between the direct and reverse pointings is less than 0.050 mil.

> **Note.** It is referred that the adjustment be made with the theodolite in the reverse position. This adjustment also can be made with the telescope in the direct position by using the mean value for the direct pointing (000.202 + 0.300 = 0000.502).

3-34. T2 VERTICAL COLLIMATION TEST AND ADJUSTMENT

a. Purpose. The purpose of the vertical collimation adjustment is to make the line of sight horizontal when the vertical circle reads 1,600 mils with the telescope in the direct position (4,800 mils with the telescope in the reverse position) and the ends of the collimation level bubble aligned.

b. Test.

Step 1. To test the vertical collimation, select a well-defined point at least 100 meters from the instrument and approximately on a horizontal plane with the theodolite.

Step 2. With the telescope in the direct position give the recorder a direct vertical circle reading to the point. Be sure that the collimation level bubble is precisely aligned.

Step 3. Plunge the telescope to the reverse position, and give the recorder a reverse vertical circle reading to the same point. Ensure the collimation level bubble is precisely aligned before you read the vertical circle, and check it after you take your reading.

> **Note.** The T2 adjustment for vertical collimation requires only one set of direct and reverse readings. Be very careful, therefore, to prevent pointing and reading errors.

c. Adjustment. The sum of the direct and reverse readings should be 6,400 mils. Any difference between the sum of the two readings and 6,400 mils is the apparent vertical collimation error, or twice the actual error. If the difference exceeds 0.150 mil for the T2 theodolite, the vertical collimation level should be adjusted.

Step 1. With the telescope in the reverse position and accurately sighted on the selected point, use the coincidence knob to set the fractional part of the corrected reading on the micrometer scale. The corrected reading is the reverse reading with one-half of the apparent error (actual error) applied. Then apply the actual error to determine the corrected vertical reading. In the example below, the actual error must be added. So, add 0.100 mil to 4,804.607 mils to determine the corrected reading of 4,808.707 mils. Set the fractional part of the corrected reading (0.707 mil) on the micrometer scale by using the coincidence knob.

EXAMPLE

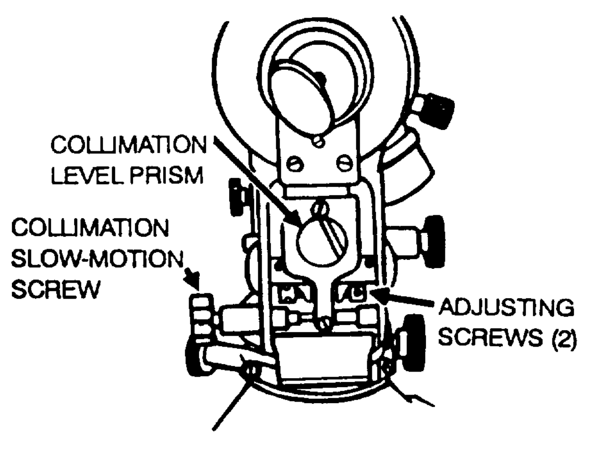
Direct reading	**1595.193**
Reverse reading	**<u>4804.607</u>**
Sum	**6399.800**
Apparent error (6400 - 6399.800)	**0.200 mil**
Actual error (0.200 + 2)	**0.100 mil**

Note. If the sum of the two readings was greater than 6,400 mils, then the actual error would be subtracted from the reverse reading to determine the corrected vertical reading.

Step 2. Obtain coincidence on the main scale at the correct vertical reading by using the collimation level tangent screw. With the telescope sighted at the selected point and the corrected reading on the vertical scale, the collimation level bubble will not be aligned.

Step 3. Align the images of the ends of the collimation level bubble by rotating the two capstan adjusting screws located directly below and to the right and left of the collimation level mirror (prism). Adjust the bubble images by loosening one adjusting screw and tightening the other by an equal amount. Figure 3-31 shows the location of the adjusting screws. Continue the test and adjustment procedures until the vertical collimation error is less than 0.050 mil.

Figure 3-31. **Location of adjusting screws for vertical collimation adjustment**



Note. It is preferred that the adjustment be made with the theodolite in the reverse position. This adjustment also can be made with the telescope in the direct position by using the corrected direct reading to adjust the instrument; that is, 1595.293 (1595.1 93 + 0.100).

CAUTION

It may be difficult for you to remember where the various adjusting screws are located when you need to make adjustments on the theodolite. You should always refer to the technical manual published for each type of theodolite. Always perform the tests and adjustments in the sequence in which they are listed. After you make an adjustment, perform the test again to check for accuracy before you go to the next test and adjustment When making adjustments, do not force the movement of the adjusting screws or exert too much pressure. The screws could be damaged and make your instrument unserviceable. A correctly adjusted theodolite is essential in obtaining accurate survey results.

✻ CHAPTER 4
FIELD NOTES

The field notes of any survey are the only original record of the survey that the survey party has once it leaves the field. Therefore, the field notebook must contain a complete record of all measurements made or determined during the progress of the survey. It should include complete sketches, descriptions, and remarks, when necessary, to clarify the notes. The best survey fieldwork is of no value to the using unit if the notes are not accurate, legible, and complete in every detail.

Note. The acronyms and abbreviations in Figure 4-1 are used In the example field notes shown in Figures 4-2 through 4-21.

4-1. FIELD NOTEBOOK

The field notebook (DA Form 4446 [Level, Transit, and General Survey Record Book]) is a hardback, permanently bound book for recording all survey data determined in the field. On the flyleaf inside the front of the book are instructions to the finder for the return of the book if it is lost. Also on the flyleaf are spaces for the identification of the notebook. (See Figure 4-2.) Each set of two facing pages constitutes one numbered page. The page number appears in the upper right comer. The first two facing pages are reserved for the index of the contents of the notebook. (See Figure 4-3.) The index should be kept current at all times.

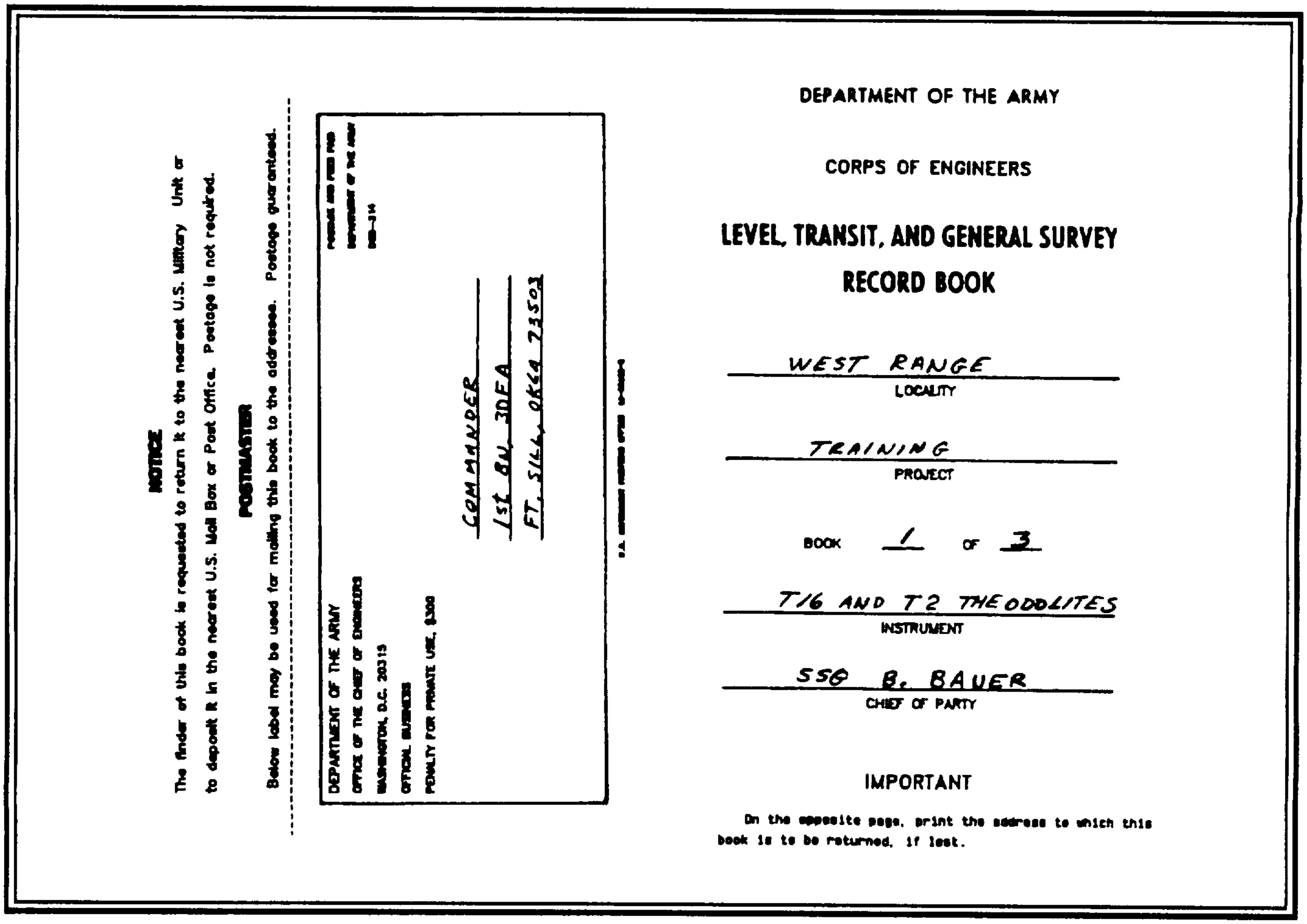
Figure 4-1. **Field notes acronyms and abbreviations**

<	angle	H	height
appmx	approximately	HI	height of instrument
asst	assistant	horiz	horizontal
astro alt	astronomic observation (attitude method)	HT	height of target
arty	artillery	hwy	highway
az	azimuth	ID	identification
az mk	azimuth mark	inst	instrument
BC	battery center	IO	instrument operator
bldg	building	lat	latitude
blvd	boulevard	long	longitude
bn	battalion	mal	malfunction
bn SCP	battalion survey control point	mt	mountain
BRP	boresight reference point	N	north
cal	caliber	no	number
ck	check	1	theodolite marks (PADS)
cont	continue	01	observation post (or observer 1)
COP	chief of party	02	observation post (or observer 2)
EOL	end of orienting line	obsr	observer
E	east	oper	operator
el	elevation	OP	observation post
FSTK	far stake (radar OS)	0S	orienting station
GAZ	grid azimuth	PAE	position, azimuth, elevation (PADS)

Figure 4-1. **Field notes acronyms and abbreviations (continued)**

pos	position	temp	temperature
R	reverse	tgt	target
rcdr	recorder	theod	theodolite
rd	road	TS	traverse station
recip	reciprocal	2	plumb bob marks (PADS)
RP	registration point	2E2	azimuth error (PADS)
S	south	updt	update(d)
SIMO	simultaneous observation	U/A	unadjusted/adjusted data (PADS)
sph	spheroid	vert	vertical
sta	station	w/	with
SW	southwest	W	west
T	telescope	WT	water tower
TAZ	true azimuth	Z-VEL	zero velocity (PADS)

Figure 4-2. **Example of data on flyleaf of a field notebook**



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4-2. DATA RECORDED

a. Recorded field notes consist of a combination of tabulated data, sketches, and descriptions. The total record of any survey in the field notebook should provide a clear and concise picture of the survey performed. This information will include descriptions of the starting and closing stations, a description of any principal station established, the area or locality in which the work is performed, the purpose of the survey, and general remarks on weather, terrain, or other conditions that may be factors in evacuating the results. The information in the field notes must be complete enough that anyone not familiar with that particular survey operation can take the notebook, return to the locality, and recover or reconstruct any portion of the survey. Figures 4-3 through 4-21 are examples of common types of field notes kept by the recorder.

b. Data are recorded in the field notebook in tabulated columns according to a prescribed plan. Enough spaces are provided to permit entry of mean values as they are determined by the recorder.

c. Sketches must be made when needed. For example, if the description of an SCP in the trig list is vague, incorrect, or missing or if maps of the area contain errors, a sketch is required. Each sketch should be drawn to an approximate scale and include a grid north line. Important details of the sketch may be exaggerated for clarity. Sketches should show distances to at least two reference marks from any principal station that might be buried underground. Reference marks should be permanent in nature. If permanent reference marks are not available, the survey party should emplace semipermanent marks. Sketches also are used when necessary to indicate heights of survey signals and other points when vertical angles are observed to other than instrument height. A small protractor, which can also be used as a straightedge, should be used as an aid in making sketches. Each sketch should be legible and should be drawn large enough to ensure that it can be understood. Each station shown on the sketch should be identified.

d. Description should be used to supplement the information shown in the sketch. Remarks may be made to clarify measurements, weather, terrain, and observing conditions. The remarks should include any other factors that might be of any value in the evaluation of the survey. Approved abbreviations and conventional symbols will be used on sketches and in descriptions.

Figure 4-3. **Example index of a field notebook**

DESIGNATION INDEX DATE ______ 19__

PAGE	DATE	TITLE
1	—	INDEX
2	10 SEP 90	TRAVERSE
3	10 SEP 90	TRAVERSE CONT
4	5 OCT 90	TRIANGULATION
5	10 OCT 90	TRIANGULATION
6	10 OCT 90	TRIANGULATION CONT
7	19 OCT 90	3 POINT RESECTION
8	10 NOV 90	TRIG TRAVERSE
9	4 DEC 90	ARTILLERY ASTRO
10	4 DEC 90	HASTY ASTRO
11	7 DEC 90	ASTRO ALTITUDE METHOD
12	8 DEC 90	POLARIS TABULAR
13	9 DEC 90	SIAGL
14	12 DEC 90	SIMO MASTER STATION
15	14 DEC 90	SIMO FLANK STATION
16	16 DEC 90	PADS SURVEY
17	16 DEC 90	PADS SURVEY CONT
18	18 DEC 90	SAMPLE VOIDED ANGLE
19	2 JAN 91	SAMPLE VOIDED PAGE

PAGE	DATE	TITLE

4-3. RECORDING

a. Each numbered page of the field notebook provides space for recording information pertinent to the survey. The type of survey (traverse, resection, and so forth) and the date are entered at the top of the left side of the page. Weather conditions (two variables that identify visibility and temperature), the type and serial number of the instrument, and the names of the party personnel are entered across the top of the right side of the first page of each survey. The rest of the pages are used for recording survey data (instrument readings, mean angles, and distances); for designating the survey stations; for recording telescope positions or number of repetitions measured; and for recording remarks, sketches, and descriptions. The chief of party will check data entered on each page and initial each numbered page before leaving the field. (If an incorrect angle or distance is discovered, it can be remeasured before the party leaves the area.) The instrument operator also should check recorded values for each occupied station before taking down the instrument.

b. All entries in the field notebook will be printed in capital block letters and in a neat and legible manner. Always use a sharpened pencil with lead soft enough to be readily seen but hard enough to be smear proof (3H or harder). Entries will never be made in ink. The recorder goes with the instrument operator and records the data in the field notebook as they are announced to him. He then reads data back to the instrument operator to ensure his entry is correct. Field data entries are recorded directly in the field notebook and not on scraps of paper for later transfer. As the entries are made, the recorder computes and records mean values and, for ease of identification, encircles the data that will be used to compute the survey. The recorder will immediately notify the instrument operator of any incorrect angle before the instrument is moved from the station. Station descriptions, sketches, and remarks are entered in the notebook before the survey party moves to the next station and must be complete enough to permit reestablishment. Only the data for that specific survey will be recorded on the page. Data pertaining to surveys other than the one in progress will be recorded on other pages.

c. Erasures are not permitted in the field notebook. If an incorrect entry is made, it is corrected by drawing a single line through the incorrect data and entering the correct data directly above the incorrect data. When a page is filled with data, sketches, or remarks that will not be used because of a change in plans, the page is crossed out by drawing diagonal lines between opposite comers of each side of the page and printing the word *VOID* in large letters across each side of the page. (See Figure 4-20.) Figure 4-19 is an example of a partially voided page on which all other recorded data are correct.

Figure 4-4. **PADS notes**

DESIGNATION PADS SURVEY DATE 16 DEC 19 90

PADS SERIAL NO: 023 PADS OPER: SGT CHAPIT
TOTAL MILES: 12.7 SPH 1 ASST OPER: PFC SMITH
TOTAL MISSION TIME: 1:07:22 Z-VEL TIME: 10 MIN

STA	ID NO	PAE	U / A	EASTING		NORTHING		EL	TAZ/GAZ AZIMUTH	DISTANCE	MAL-FUNCTION
INITIAL POINT				14: 551	240.0	3 839	350.0	+350.0			
SCP INDIAN	1	U-U		14: 551	203.6	3 839	042.8	+398.8			
OP1	2	2-2	U	553	001.4	3 839	767.9	+379.6			2MAL 0004 00
			A	553	001.3	3 839	767.8	+379.8			
EOL A	3	2-2	U	553	880.2	3 839	971.7	+380.5			
			A	553	880.4	3 839	971.6	+380.7			
OS A	4	222	U	553	076.1	3 839	843.8	+383.4	1576.87	113.6	
			A	553	076.4	3 839	844.0	+383.5	1576.87	113.6	
RADAR	5	111	U	552	225.3	3 841	111.1	+384.1	2697.53	6.9	
			A	552	225.5	3 841	111.4	+384.3	2697.53	6.9	
SCP MISSION	6	U-U		14: 554	301.3	3 839	205.8	+379.2			

4-4. TYPES OF FIELD NOTES

Procedures covering all situations cannot be prescribed; therefore, the examples in Figures 4-2 through 4-21 should be used as a guide in developing suitable techniques, PADS data will also be recorded in DA Form 4446. In the heading, enter the designation of the type of survey performed (PADS survey). The date will be the actual date of the PADS survey. In the heading of the adjoining page, show the PADS serial number (electrical mounting base), the spheroid number, and the total mission time. Across from these three items, enter the names of the PADS operator, assistant operator, and the Z-VEL time used to conduct the mission. Label the columns below the heading, from left to right, as follows:

- Ž STA—to identify the updated or marked stations.
- Ž ID NO—to identify the storage position in the PADS computer corresponding to the update or marked stations. The PADS can store up to 30 positions.
- Ž PAE–to identify the function performed at each position.
- Ž U/A—to identify unadjusted or adjusted data.
- Ž EASTING–to identify the universal transverse mercator (UTM) grid zone and casting grid of the position.

Figure 4-5. **PADS notes (continued)**

DESIGNATION PADS SURVEY CONT. DATE 16 DEC 19 90

STA	T	HORIZ ∡	MN	VERT READING	VERT ∡
PADS	D	0001.0			
	R	3201.0	0001.0		
RADAR	MN ∡	1585.1			+15.2
BRP	D	1586.1		1584.8	+15.2
	R	4786.1	1586.1	4815.1	+15.1

INST: T16 THEOD NO: 1881

REMARKS

THE AZIMUTH FROM RADAR TO BORESIGHT REFERANCE POINT IS 2697.53

NOTES:

1. VERT ∡ REQUIRED FOR RADAR OPERATIONS ONLY.

2. WHEN NECESSARY, THIS PAGE IS USED TO PROVIDE A BRIEF DESCRIPTION AND SKETCH OF CRITICAL POINTS ESTABLISHED DURING THE SURVEY MISSION.

3. MALFUNCTIONS THAT OCCUR DURING THE MISSION WILL BE RECORDED.

JC

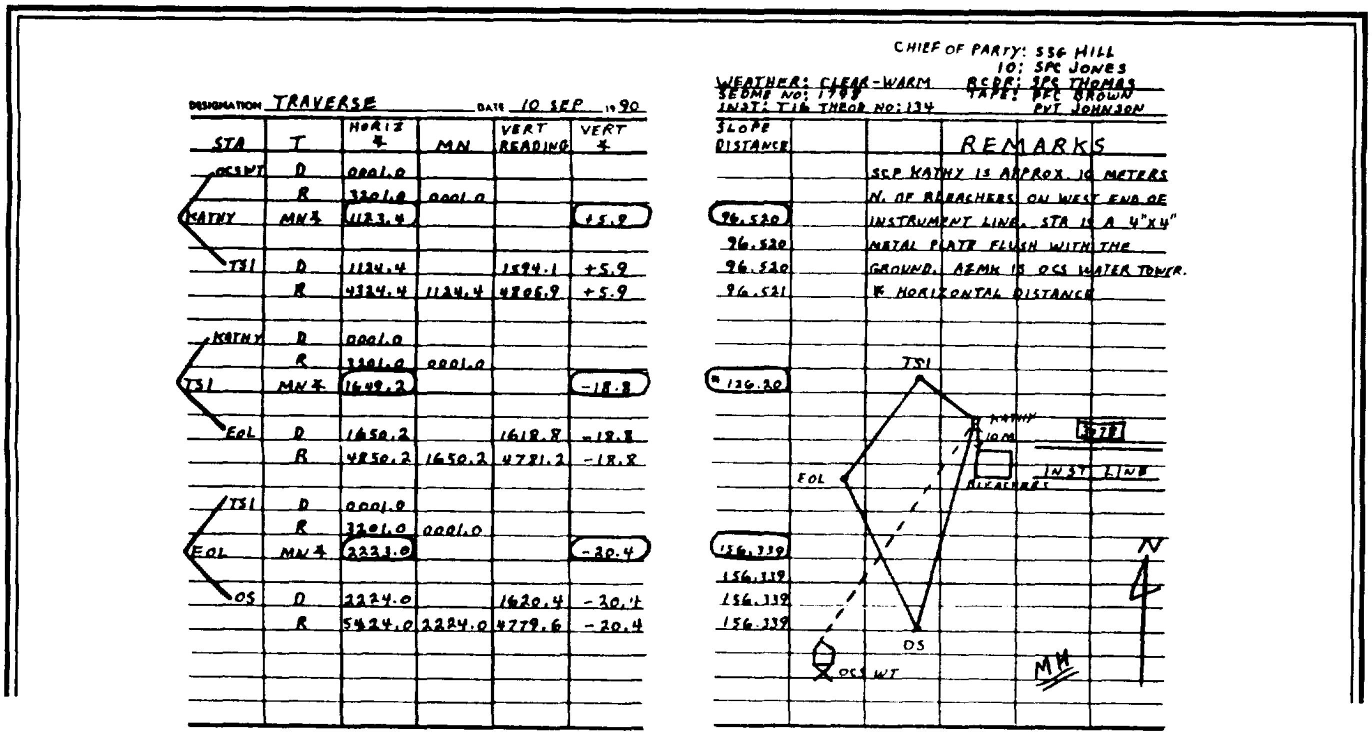
- Ž NORTHING—to identify the northing grid of the position.
- Ž EL-to identify the elevation of the position.
- Ž TAZ-GAZ–to identify the true azimuth and grid azimuth of a plumb bob two-position azimuth mark.
- Ž DISTANCE-to identify the distance (in meters) from the last marked position, when required, or the distance measured in an optical measurement.
- Ž MALFUNCTION–to identify any malfunctions during the survey mission.

> **Note.** Use the next recording page for recording horizontal an angles, grid azimuth, and offset distances for all optics measurements performed during the survey. The rest of the page will be used for remarks.

4-5. SECURITY OF FIELD NOTES

A field survey notebook is as valuable 10 the enemy as a captured map. The notebook would enable the enemy to locate battery centers, OPs, and other military assets (radars, mortars, and such). For this reason, every effort must be made to safeguard the notebook.

Figure 4-6. **Traverse (1:1,000) notes**


DESIGNATION TRAVERSE DATE 10 SEP 19 90

STA	T	HORIZ ∢	MN	VERT READING	VERT ∢
OCS WT	D	0001.0			
	R	3201.0	0001.0		
KATHY	MN ∢	1123.4			+5.9
TS1	D	1124.4		1594.1	+5.9
	R	4324.4	1124.4	4806.9	+5.9
KATHY	D	0001.0			
	R	3201.0	0001.0		
TS1	MN ∢	1649.2			-18.8
EOL	D	1650.2		1618.8	-18.8
	R	4850.2	1650.2	4781.2	-18.8
TS1	D	0001.0			
	R	3201.0	0001.0		
EOL	MN ∢	2223.0			-20.4
OS	D	2224.0		1620.4	-20.4
	R	5424.0	2224.0	4779.6	-20.4

CHIEF OF PARTY: SSG HILL
IO: SPC JONES
WEATHER: CLEAR-WARM RCDR: SPC THOMAS
SEDME NO: 1798 TAPE: PFC BROWN
INST: T16 THEOD NO: 134 PVT JOHNSON

SLOPE DISTANCE	REMARKS
	SCP KATHY IS APPROX. 10 METERS
	N. OF BLEACHERS ON WEST END OF
96.520	INSTRUMENT LINE. STA IS A 4"X4"
96.520	METAL PLATE FLUSH WITH THE
96.520	GROUND. AZMK IS OCS WATER TOWER.
96.521	* HORIZONTAL DISTANCE
* 126.20	
156.339	
156.339	
156.339	
156.339	

Figure 4-7. **Traverse (1:1,000) notes (continued)**

DESIGNATION TRAVERSE (CONT) DATE 10 SEP 19 90

STA	T	HORIZ ∡	MN	VERT READING	VERT ∡	SLOPE DISTANCE	REMARKS
EOL	D	0001.0					
	R	3201.0	0001.0				
OS	MN ∡	(0832.2)			(+25.4)	(222.698)	
						222.698	
KATHY	D	0833.2		1574.6	+25.4	222.698	
	R	4033.2	0833.2	4825.4	+25.4	222.698	
OS	D	0001.0					
	R	3201.0	0001.0				
KATHY	MN ∡	(0572.4)					
OCSWT	D	0573.4					
	R	3773.4	0573.4				

Figure 4-8. **Triangulation (1:1,000) notes**

CHIEF OF PARTY: SSG COX
IO: SPC BARTIN
RCDR: SPC MARTIN
TAPE: PFC GORDON
PVT LONG

WEATHER: CLEAR-HOT

INST: T16 THEOD NO: 173

DESIGNATION TRIANGULATION DATE 5 OCT 19 90

STA	T	HORIZ ∡	MN	VERT READING	VERT ∡	MN OF HRIP VERT ∡	REMARKS
					(+3.6)	(+3.5)	STA BUCK IS 5.5 MILES N OF COURT-
COX	D	0001.0		1596.4	+3.6	+3.6	HOUSE IN LAWTON ON HWY 277, 1,175
	R	3201.2	0001.1	4803.5	+3.5	-3.4	METERS WEST OF HWY, 190 METERS
BUCK	MN ∡	(1762.4)					S OF WHITE FARMHOUSE. STA IS A
							1/4" STEEL ROD SET IN A 6" x 6" CONCRETE
OP1	D	1763.4					BLOCK 4" ABOVE GROUND. BASE OF
	R	4963.6	1763.5				TRIANGLE IS "BUCK-COX". TAPED
					(+29.0)	(+28.9)	DISTANCE OF BASE = 1,261.41 M.
OP1	D	0001.0		1571.1	+28.9	+29.0	AZ COX TO BUCK = 1701.7 MILS.
	R	3201.0	0001.0	4829.0	+29.0	-28.8	VERT ∡ MEASURED TO HI
COX	MN ∡	(0964.9)			(-3.4)		
BUCK	D	0965.8		1603.4	-3.4		
	R	4166.0	0965.9	4796.5	-3.5		
BUCK	D	0001.0					
	R	3201.1	0001.0				
OP1	MN ∡	(0472.5)			(-28.8)		
COX	D	0473.4		1628.8	-28.8		
	R	3673.6	0473.5	4771.1	-28.9		

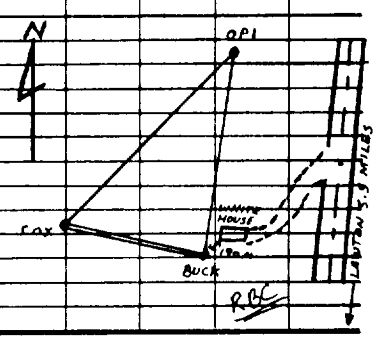


Figure 4-9. **Triangulation (1:3,000) first position notes (two-position angle measurement)**

DESIGNATION TRIANGULATION DATE 10 OCT 19 90

CHIEF OF PARTY: SSG OWENS
IO: SPC WILLIAMS
RCDR: SPC REYNOLDS
TAPE: PFC JERRY
PVT MARTIN

WEATHER: CLOUDY-COLD

INST: T2 THEOD NO: 174

STA	T	HORIZ ∠	MN	VERT READING	VERT ∠	MN OF VERT ∠	REMARKS
					+16.888	+16.814	FIRST POSITION
RED	D	0000.104		1583.116	+16.884	+16.882	DATA FOR STATIONS BLUE, ROSSI, AND JOE
	R	3200.120	0000.112	4816.879	+16.879	-16.746	IN BOOK 2 OF 2, PAGES 7, 8, AND 9.
DICK	MN ∠	0485.318			-20.522	-20.574	5 MAR 90. BASE OF SCHEME IS "DICK-RED".
							TAPED DISTANCE OF BASE: 2,489.78 METERS.
BLUE	D	0485.484		1630.515	-20.515	-20.515	AZ DICK TO RED: 1801.14 MILS (ESTABLISHED
	R	3685.471	0485.478	4779.471	-20.529	+20.633	W/SIAGL). STA DICK IS ON N. APACHE HILL,
DICK	MN ∠	0963.190			+8.390	+8.298	FT. SILL, 14 METERS WEST OF CONCRETE
							BUNKER. STATION IS A 105 MM SHELL
ROSSI	D	1448.645		1591.619	+8.381	+8.390	CASING SET IN CONCRETE FLUSH WITH
	R	4648.630	1448.638	4808.400	+8.400	-8.206	GROUND. A QUAD MARKER IS OVER THE
DICK	MN ∠	0621.100			-3.189	-3.212	STATION.
							SIAGL DATA IS RECORDED IN PAGE
JOE	D	2069.757		1603.177	-3.177	-3.189	4 OF BOOK 3.
	R	5269.720	2069.738	4796.799	-3.201	+3.246	

RNO

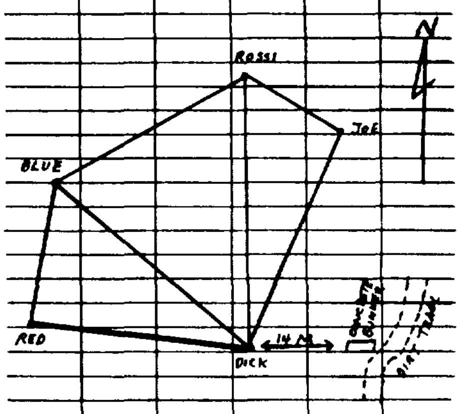
Figure 4-10. **Triangulation (1:3,000) second position notes (two-position angle measurement) (continued)**

DESIGNATION TRIANGULATION (CONT) DATE 10 OCT 19 90

STA	T	HORIZ ∠	MN		MN OF TWO POSITIONS
RED	R	4800.173			
	D	1600.151	4800.162		
DICK	MN ∠	0485.313			0485.314
BLUE	R	5285.484		1ST POS	0485.336
	D	2085.506	5285.495	2D POS	0485.333
DICK	MN ∠	0963.170			0963.180
ROSSI	R	6248.652		1ST POS	0963.190
	D	3048.678	6248.665	2D POS	0963.170
DICK	MN ∠	0621.137			0621.118
JOE	R	0469.741		1ST POS	0621.100
	D	3669.863	0469.802	2D POS	0621.137

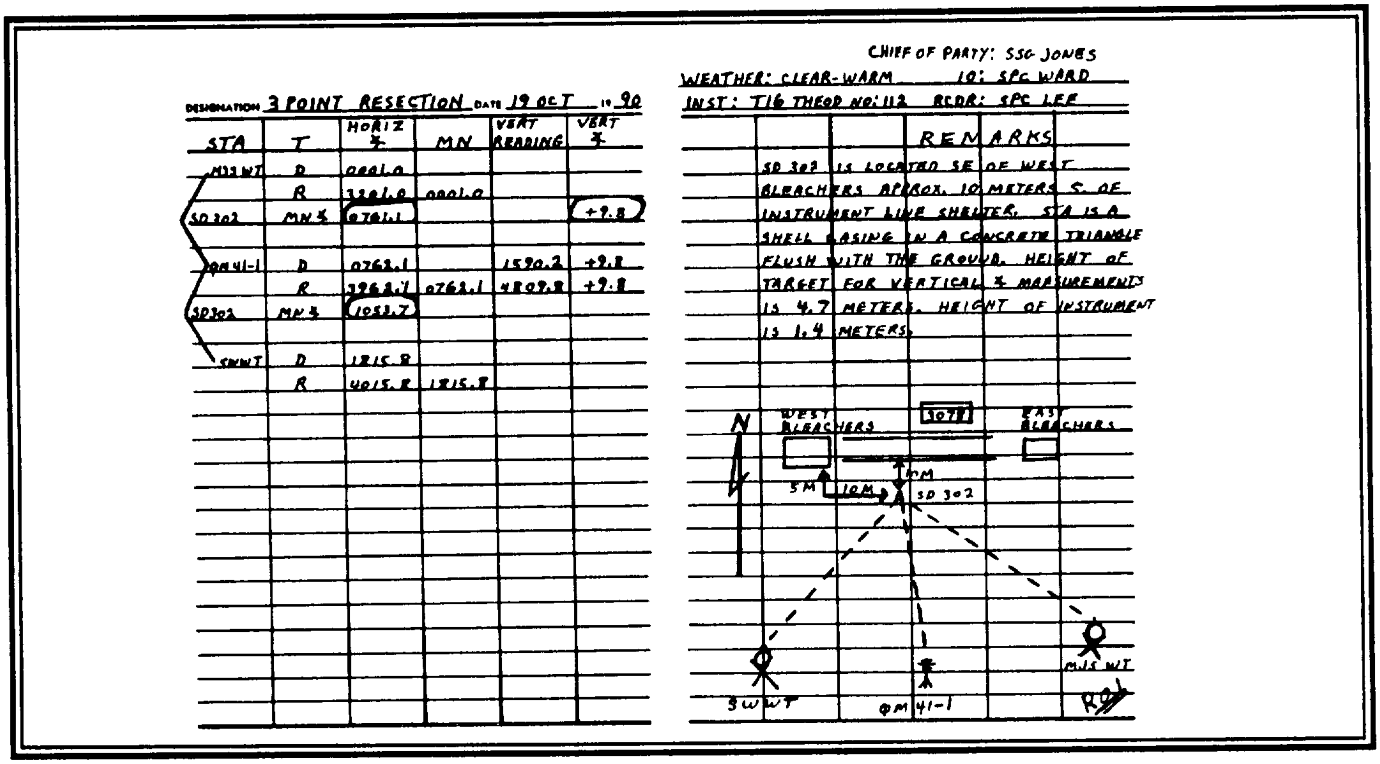
REMARKS

SECOND POSITION



RNO

Figure 4-11. **Three-point resection notes**



DESIGNATION 3 POINT RESECTION DATE 19 OCT 19 90

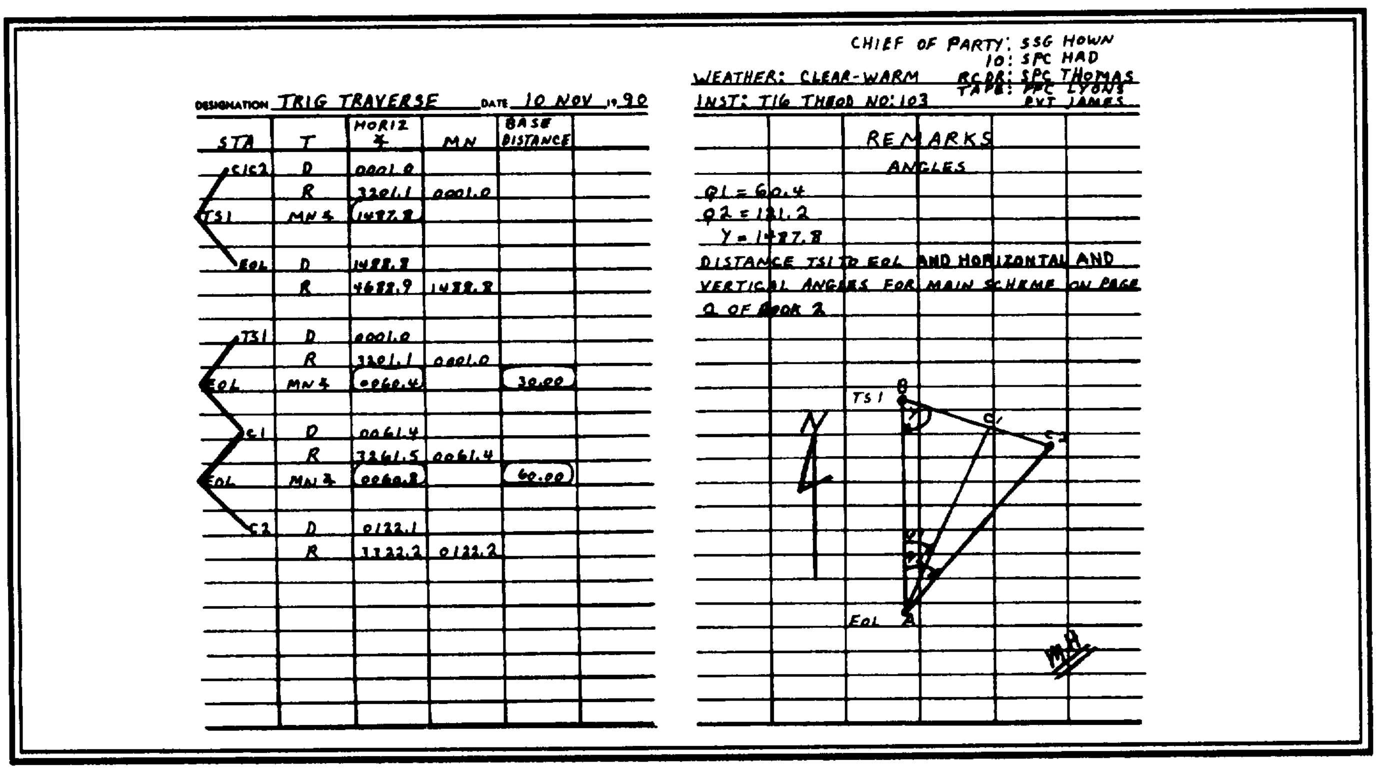
STA	T	HORIZ ∡	MN	VERT READING	VERT ∡
M13 WT	D	0001.0			
	R	3201.0	0001.0		
SD 302	MN ∡	0781.1			+9.8
ΦM 41-1	D	0762.1		1590.2	+9.8
	R	3962.1	0762.1	4809.8	+9.8
SD 302	MN ∡	1053.7			
SWWT	D	1815.8			
	R	4015.8	1815.8		

CHIEF OF PARTY: SSG JONES
WEATHER: CLEAR-WARM IO: SPC WARD
INST: T16 THEOD NO: 112 RCDR: SPC LEE

REMARKS

SD 302 IS LOCATED SE OF WEST BLEACHERS APPROX. 10 METERS S. OF INSTRUMENT LINE SHELTER. STA IS A SHELL CASING IN A CONCRETE TRIANGLE FLUSH WITH THE GROUND. HEIGHT OF TARGET FOR VERTICAL ∡ MEASUREMENTS IS 4.7 METERS. HEIGHT OF INSTRUMENT IS 1.4 METERS.

Figure 4-12. **Trig-traverse notes**



DESIGNATION TRIG TRAVERSE DATE 10 NOV 19 90

STA	T	HORIZ ∡	MN	BASE DISTANCE
C1C2	D	0001.0		
	R	3201.1	0001.0	
TS1	MN ∡	1487.8		
EOL	D	1488.8		
	R	4688.9	1488.8	
TS1	D	0001.0		
	R	3201.1	0001.0	
EOL	MN ∡	0060.4		30.00
C1	D	0061.4		
	R	3261.5	0061.4	
EOL	MN ∡	0060.8		60.00
C2	D	0122.1		
	R	3322.2	0122.2	

CHIEF OF PARTY: SSG HOWN
IO: SPC HAD
WEATHER: CLEAR-WARM RCDR: SPC THOMAS
INST: T16 THEOD NO: 103 TAPE: PFC LYONS
PVT JAMES

REMARKS

ANGLES

Φ1 = 60.4
Φ2 = 121.2
Y = 1487.8

DISTANCE TS1 TO EOL AND HORIZONTAL AND VERTICAL ANGLES FOR MAIN SCHEME ON PAGE 2 OF BOOK 2

Figure 4-13. **Astro altitude method notes (sun or star)**

DESIGNATION ASTRO ALTITUDE METHOD DATE 7 DEC 19 90

STA	T	TIME h	m	s	HORIZ ∡	MN
SEWT	D				0001.0	
	R				3200.9	0001.0
SD12	MN∡	09	13	50	0443.7	
SUN	D	09	13	47	0446.2	
	R	09	14	52	3653.2	0449.7
SEWT	D				0001.0	
	R				3200.9	0001.0
SD12	MN∡	09	19	25	0468.7	
SUN	D	09	18	35	0466.4	
	R	09	20	25	3673.0	0469.7
SEWT	D				0001.0	
	R				3200.9	0001.0
SD12	MN∡	09	24	57	0486.2	
SUN	D	09	24	04	0484.1	
	R	09	25	54	3690.2	0487.2

CHIEF OF PARTY: SSG HAROLD
WEATHER: COLD-CLEAR IO: PFC WRUBEL
INST: T16 THEOD NO: 1195 RCDR: PVT STEINER

VERT READING	VERT ∡	REMARKS
		LATITUDE: 34° 39' 46" N
		LONGITUDE: 98° 24' 04" W
	+301.7	WATCH: 00'
		TEMP: 50° F
1301.0	+299.0	SD 12 IS A SHELL CASING IN A
5104.4	+304.4	CONCRETE CIRCLE FLUSH WITH
		THE GROUND. STA IS APPROX
		8 METERS E. OF BLDG 5613.
	+317.2	
1285.3	+314.7	
5119.8	+319.8	
	+330.2	
1272.0	+328.0	
5132.5	+332.5	

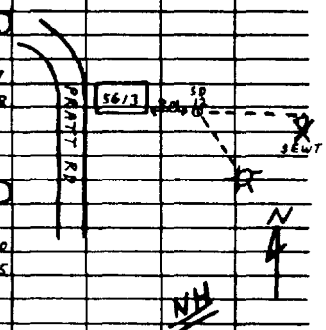


Figure 4-14. **Artillery astro notes (sun or star)**

DESIGNATION ARTILLERY ASTRO DATE 4 DEC 19 90

STA	T	TIME h	m	s	HORIZ READING
OCS WT	D				0001.0
	* R				3201.0
ABLE 2					
SUN	D	14	50	48	5970.2
	D	14	51	49	5974.0
	D	14	52	39	5977.2
OCS WT	R				3201.0
	* D				0001.0
ABLE 2					
SUN	R	14	55	32	2787.9
	R	14	56	16	2790.7
	R	14	57	01	2793.4

CHIEF OF PARTY: SSG PAIN
WEATHER: CLEAR-WARM IO: SPC HURT
INST: T16 THEOD NO: 1231 RCDR: SPC HARM

REMARKS

STA ABLE 2 IS LOCATED APPROX. 5 METERS WEST OF BLEACHERS AT THE END OF THE INSTRUMENT LINE. STA IS A SHELL CASING IN A CONCRETE TRIANGLE FLUSH WITH THE GROUND. KNOWN DATA IS AS FOLLOWS:

EASTING: 554414.7

NORTHING: 3835596.8

ALL READINGS WERE MADE TO THE CENTER OF THE CELESTIAL BODY.

* INSTRUMENT CHECK.

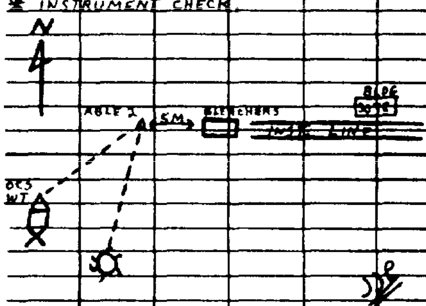
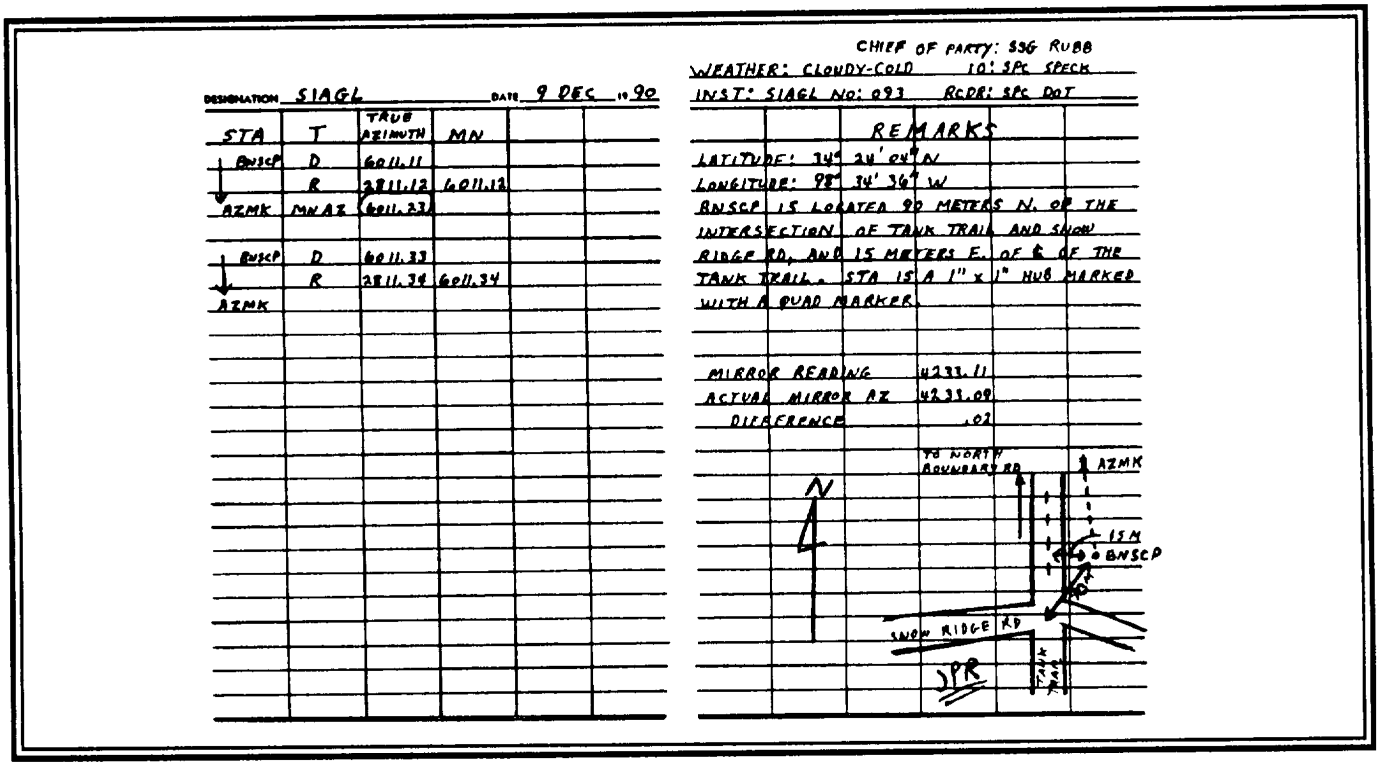


Figure 4-15. **Azimuth determination with SIAGL**



CHIEF OF PARTY: SSG RUBB
WEATHER: CLOUDY-COLD IO: SPC SPECK
INST: SIAGL NO: 093 RCDR: SPC DOT

DESIGNATION SIAGL DATE 9 DEC 1990

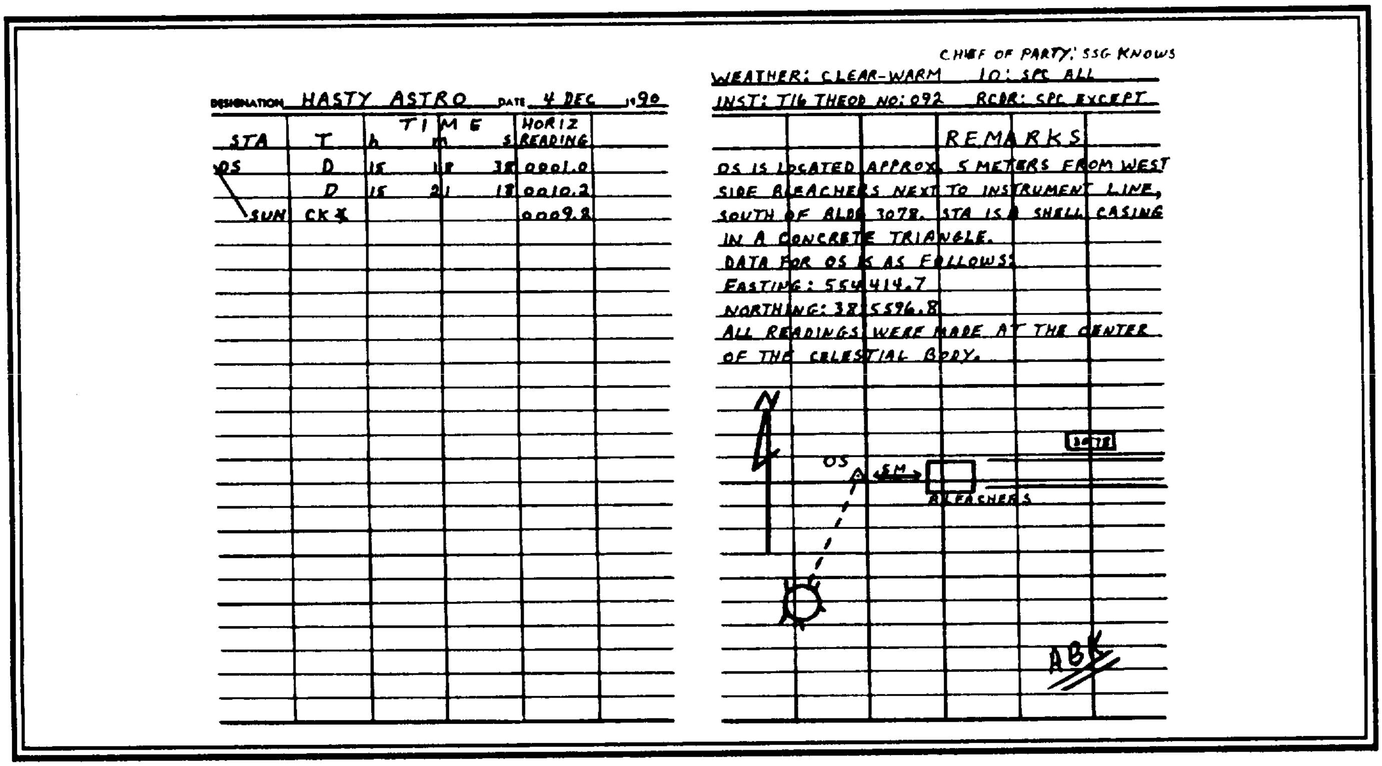
STA	T	TRUE AZIMUTH	MN		
BNSCP	D	6011.11			
	R	2811.12	6011.12		
AZMK	MN AZ	(6011.23)			
BNSCP	D	6011.33			
	R	2811.34	6011.34		
AZMK					

REMARKS

LATITUDE: 34° 24' 04" N
LONGITUDE: 98° 34' 36" W
BNSCP IS LOCATED 90 METERS N. OF THE INTERSECTION OF TANK TRAIL AND SNOW RIDGE RD, AND 15 METERS E. OF ℄ OF THE TANK TRAIL. STA IS A 1" x 1" HUB MARKED WITH A QUAD MARKER.

MIRROR READING	4233.11
ACTUAL MIRROR AZ	4233.09
DIFFERENCE	.02

Figure 4-16. **Hasty astro observation notes (sun or star)**



CHIEF OF PARTY: SSG KNOWS
WEATHER: CLEAR-WARM IO: SPC ALL
INST: T16 THEOD NO: 092 RCDR: SPC EXCEPT

DESIGNATION HASTY ASTRO DATE 4 DEC 1990

STA	T	TIME h	TIME m	TIME s	HORIZ READING
OS	D	15	18	38	0001.0
	D	15	21	18	0010.2
SUN	CK ∑				0009.2

REMARKS

OS IS LOCATED APPROX. 5 METERS FROM WEST SIDE BLEACHERS NEXT TO INSTRUMENT LINE, SOUTH OF BLDG 3078. STA IS A SHELL CASING IN A CONCRETE TRIANGLE.
DATA FOR OS IS AS FOLLOWS:
EASTING: 554414.7
NORTHING: 3815596.8
ALL READINGS WERE MADE AT THE CENTER OF THE CELESTIAL BODY.

Figure 4-17. **Simultaneous observation, master station notes**

DESIGNATION SIMO (MASTER STATION) DATE 12 DEC 19 90

STA	T	HORIZ ∡	MN	VERT READING	VERT ∡
OCSWT	D	0000.143			
	R	3200.148	0000.146		
ADAMS	MN ∡	6049.038			+393.674
SUN	D	6048.172		1197.023	+402.977
	R	2850.197	6049.184	5184.370	+384.370
OCSWT	D	0000.191			
	R	3200.197	0000.194		
ADAMS	MN ∡	6058.272			+348.689
SUN	D	6056.617		1248.334	+351.666
	R	2860.316	6058.466	5145.712	+345.712
OCSWT	D	0000.174			
	R	3200.182	0000.178		
ADAMS	MN ∡	6069.361			+310.140
SUN	D	6066.111		1287.160	+312.840
	R	2872.967	6069.539	5107.441	+307.441

CHIEF OF PARTY: SSG HOFF
WEATHER: COLD-CLEAR   IO: SPC MARTIN
INST: T2 THEOD NO: 619   RCDR: SPC HAYES

AZ TO SUN	REMARKS
3955.665	STA ADAMS IS 15 METERS SW OF JUNCTION OF DUMP RD AND EL RD. STA IS A 1" PIPE SET IN 6"x6" CONCRETE BLOCK FLUSH WITH THE GROUND. AZMK IS THE LIGHTING ROD ON TOP OF THE WATER TOWER 1,000 METERS SW OF STA ADAMS. AZ TO WT = 4306.627
3964.899	
3975.988	

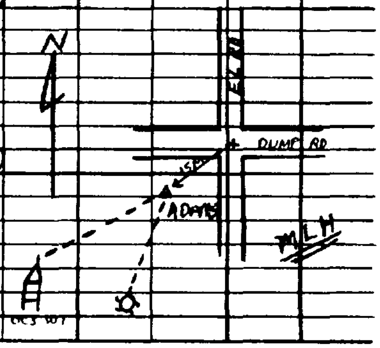


Figure 4-18. **Simultaneous observation, flank station notes**

DESIGNATION SIMO (FLANK STA) DATE 14 DEC 19 90

STA	T	HORIZ ∡	MN	MASTER STA DATA AZ TO SUN	MASTER STA DATA VERT ∡
AZMK	D	0001.0			
	R	3201.0	0001.0		
BNSCP	MN ∡	1193.5		3919.036	+401.619
SUN	D	1191.1			
	R	4397.9	1194.5		
AZMK	D	0001.0			
	R	3200.9	0001.0		
BNSCP	MN ∡	1209.6		3935.201	+351.712
SUN	D	1208.4			
	R	4412.9	1210.6		
AZMK	D	0001.0			
	R	3200.9	0001.0		
BNSCP	MN ∡	1222.7		3948.400	+304.111
SUN	D	1221.1			
	R	4426.3	1223.7		

CHIEF OF PARTY: SSG JAY
WEATHER: COLD-WINDY   IO: SPC FROST
INST: T16 THEOD NO: 161   RCDR: SPC BANK

REMARKS

STA BNSCP IS APPROX. 130 M SW OF FORD ON DUMP RD. 5 METERS S. OF LARGE BOULDER. AZMK IS 240 METERS S. OF BNSCP AND 143 METERS WEST OF LONE TREE. BOTH STATIONS ARE MARKED BY A SHELL CASING IN CONCRETE BLOCKS 2" ABOVE GROUND. PERPENDICULAR DISTANCE FROM FLANK STA TO AZ LINE IS 6,000 M. FLANK STA IS LEFT OF THE MASTER STATION. MEAN AZ BNSCP TO AZMK: 2725.988. MASTER STATION IS LOCATED AT SCP SAM (6234).

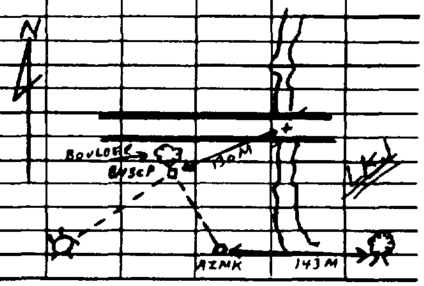


Figure 4-19. **Example of partially voided page notes**

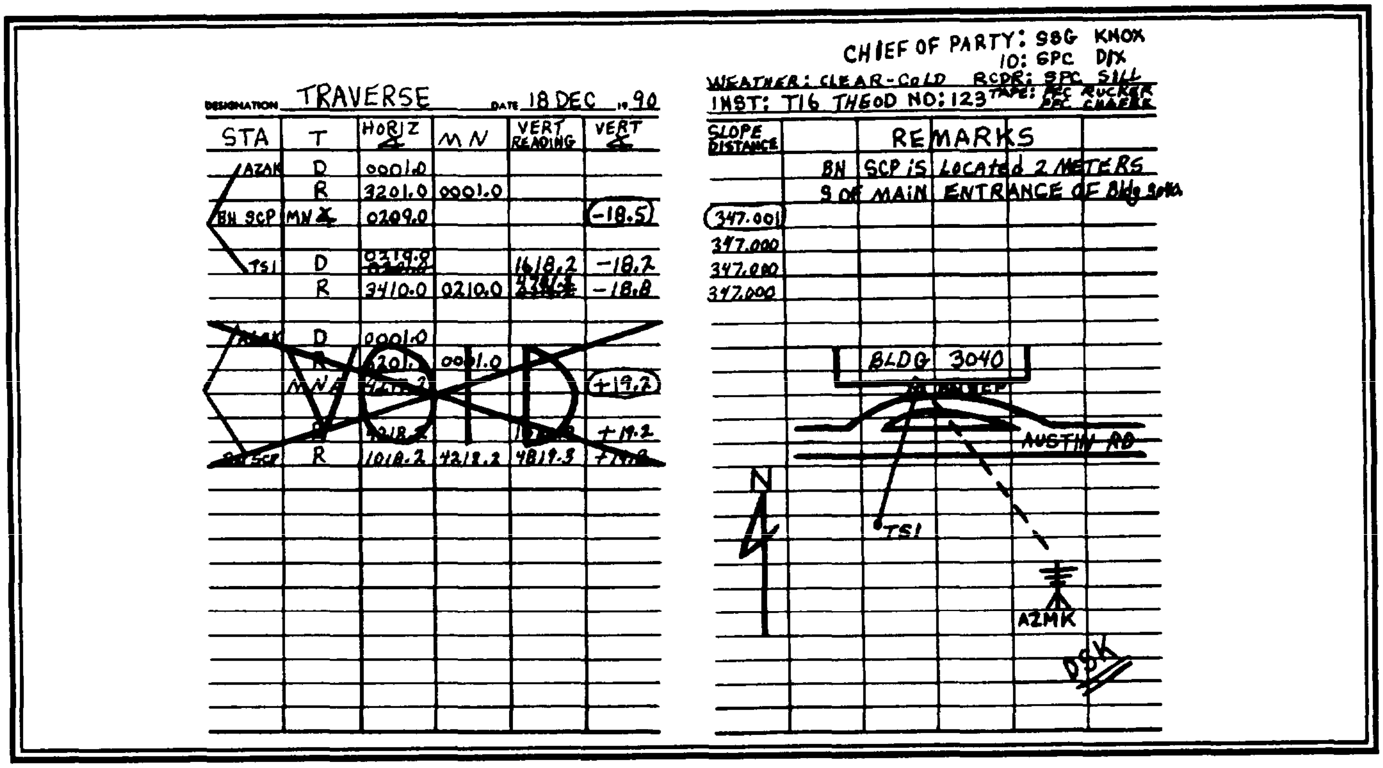


Figure 4-20. **Example of a voided page**

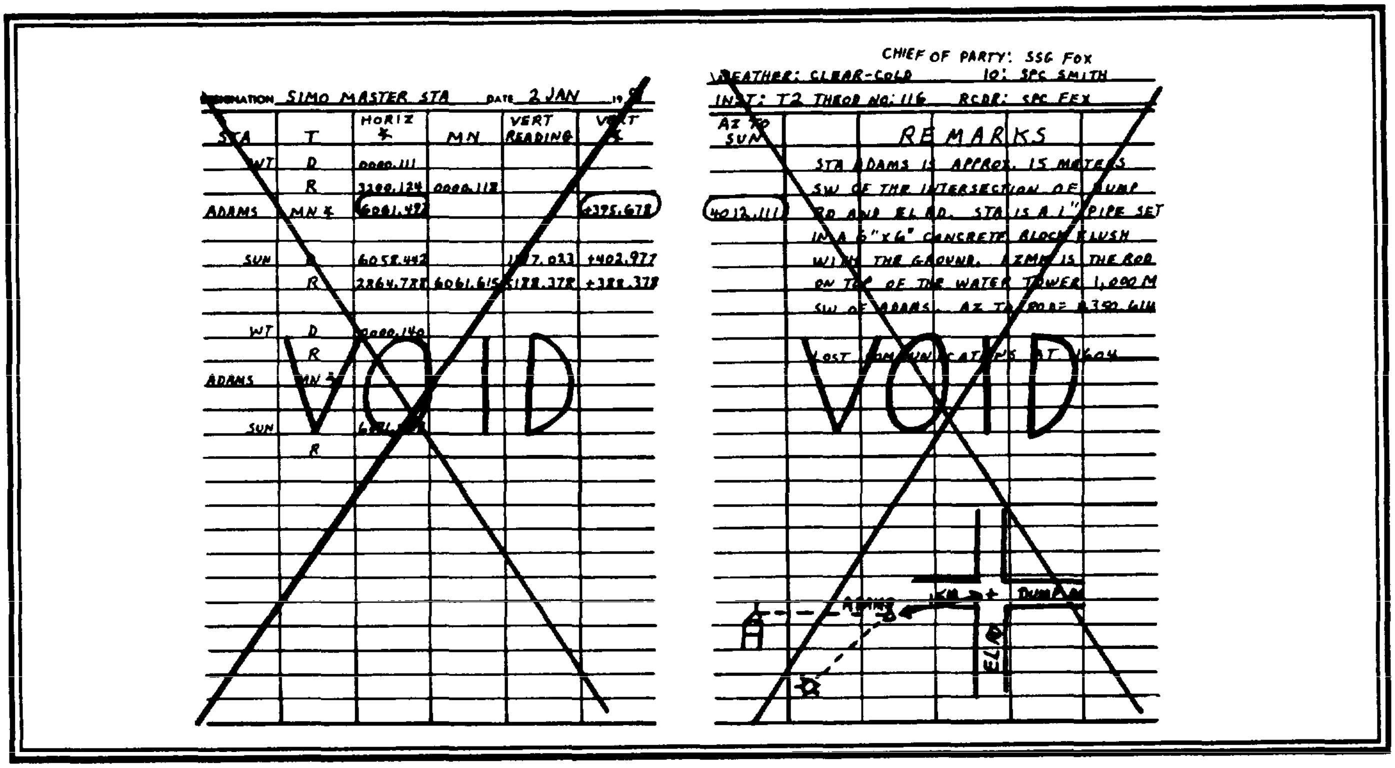
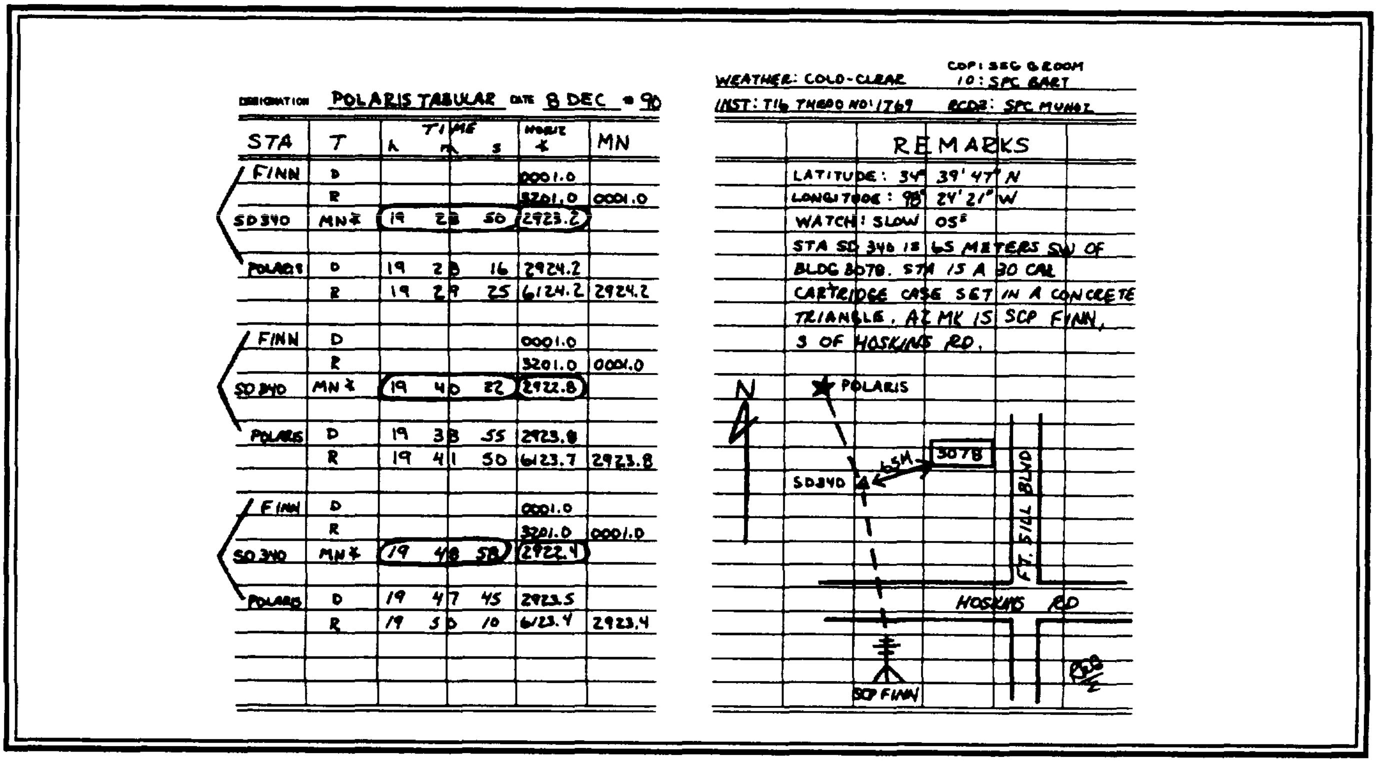


Figure 4-21. **Polaris tabular method notes**



DESIGNATION POLARIS TABULAR DATE 8 DEC 90

STA	T	TIME h	m	s	HORIZ ∠	MN
FINN	D				0001.0	
	R				3201.0	0001.0
SD340	MN ∠	19	23	50	2923.2	
POLARIS	D	19	28	16	2924.2	
	R	19	29	25	6124.2	2924.2
FINN	D				0001.0	
	R				3201.0	0001.0
SD340	MN ∠	19	40	22	2922.8	
POLARIS	D	19	38	55	2923.8	
	R	19	41	50	6123.7	2923.8
FINN	D				0001.0	
	R				3201.0	0001.0
SD340	MN ∠	19	48	58	2922.4	
POLARIS	D	19	47	45	2923.5	
	R	19	50	10	6123.4	2923.4

WEATHER: COLD-CLEAR   CDR: SSG GROOM

10: SPC BART

INST: T16 THEOD NO 1769   RCDR: SPC MUNOZ

REMARKS

LATITUDE: 34° 39' 47" N

LONGITUDE: 98° 24' 21" W

WATCH: SLOW 05s

STA SD 340 IS 65 METERS SW OF BLDG 3078. STA IS A 30 CAL CARTRIDGE CASE SET IN A CONCRETE TRIANGLE. AZ MK IS SCP FINN, S OF HOSKINS RD.

CHAPTER 5
TRAVERSE

In survey, traverse is defined as the field operation of measuring the lengths and directions of a series of straight lines connecting a series of points on the earth. Each of these straight lines is called a traverse leg, and each point is called a traverse station.

Section I

METHODS AND PROCEDURES

Traverse legs are measured by using electronic devices, a 30-meter steel tape, or trig-traverse procedures. At each traverse station, a horizontal angle is measured and used to determine the azimuth of the next traverse leg. These measurements are used to compute the relative horizontal position of each unknown traverse station on some system of coordinates, such as the UTM grid system. A vertical angle is also measured at each station and is used to determine the height above or below vertical datum of each of the unknown traverse stations. In FA surveys, the angular measurements may be made with one of two instruments, depending on the accuracy required and the echelon at which the traverse is conducted. These instruments are the T16 and T2 theodolites.

5-1. FIELDWORK

In a traverse, three stations are considered to be of immediate significance. (See Figure 5-l.) These stations are referred to as the rear station, the occupied station, and the forward station. The rear station is that station from which the persons performing the traverse have just moved or a point to which the azimuth is known. The occupied station is the station at which the angle-measuring instrument is set up. The forward station is the next station in succession and is the immediate destination of the party. During the traverse (Figure 5-2), the horizontal angles, vertical angles, and distances are measured.

a. Horizontal Angles. Horizontal angles are determined from instrument readings made at the occupied station by sighting the instrument on the rear station and turning the instrument clockwise to the forward station. When measuring horizontal angles, the instrument is always sighted at the lowest visible point of the station markers designated the rear and forward stations. Horizontal angles are used in determining azimuths.

b. Vertical Angles. Vertical angles are determined from instrument readings made at the occupied station to the height of instrument on the station marker (usually a range pole) at the forward station. When the distance between two successive stations in a traverse exceeds 1,000 meters, the vertical angle must be measured reciprocally (measured from each end of that particular traverse leg). This reciprocal measurement procedure is used to eliminate errors caused by curvature and reflection. Vertical angles are used in determining the difference in height between stations.

Figure 5-1. **Stations of immediate significance**

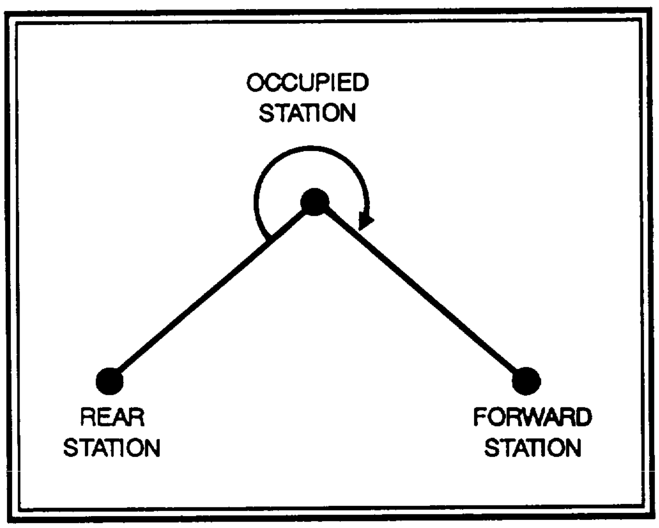
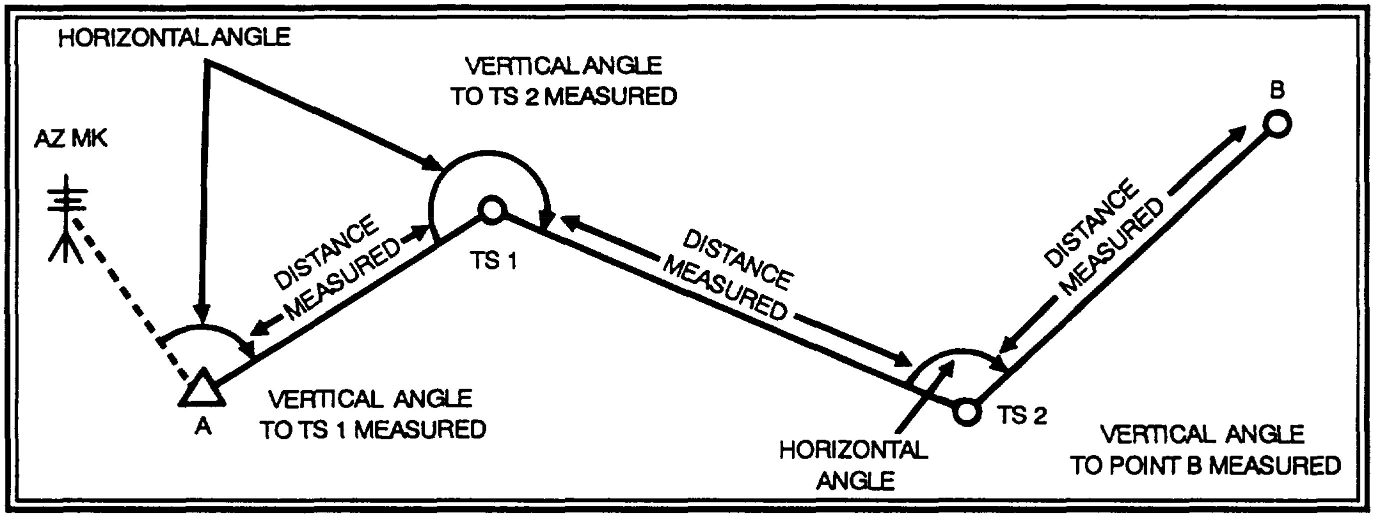


Figure 5-2. **Diagram of a traverse**



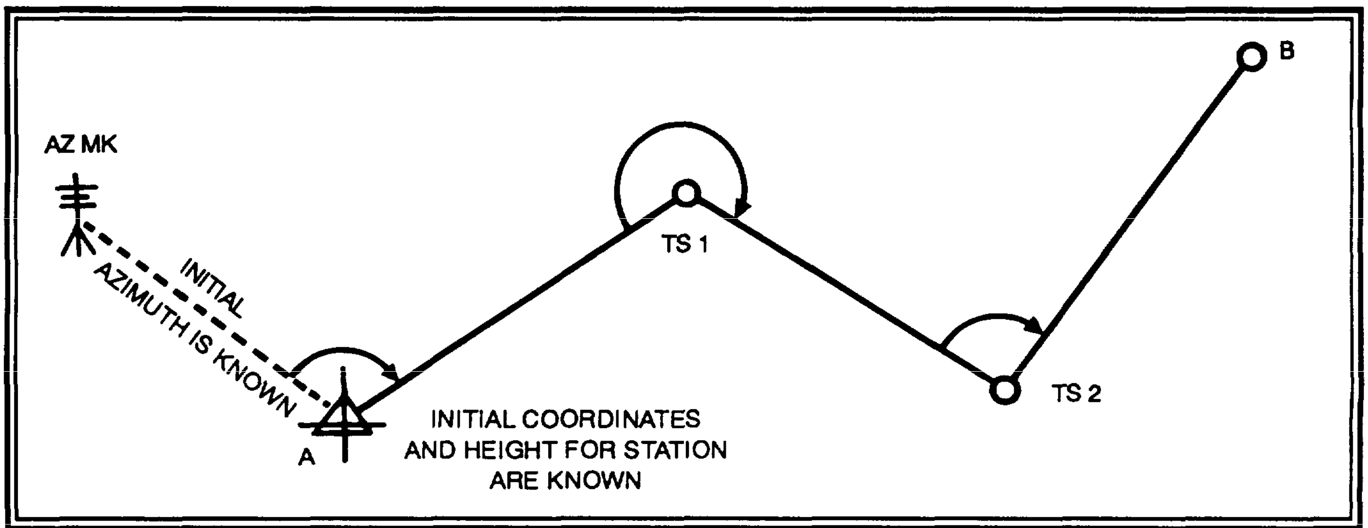
c. Distance. The distance between the occupied station and the forward station is measured by using electronic devices, horizontal taping, or trig-traverse procedures (see Section IV). The distance is used in conjunction with the horizontal and vertical angles to determine coordinates and height.

5-2. STARTING CONTROL (TRAVERSE REQUIREMENTS)

The purpose of traverse is to locate the unknown points relative to each other and to locate all points within the traverse relative to a common grid. Three elements of starting data are needed. They are the coordinates and height of a starting point and an azimuth to a visible azimuth mark. (See Figure 5-3.) Starting data may be obtained from existing control data or maps or may be assumed.

a. Known Control. Known survey control data may be acquired from trig lists, local or national survey agencies, or supporting survey elements of a higher HQ. An azimuth to an azimuth mark (starting direction) may be obtained by use of a SIAGL by astronomic observation, by computation from known coordinates, by reference to an existing trig list, and by PADS.

Figure 5-3. **Diagram of a traverse with starting data**



b. Maps. If no known control is available, a careful map inspection may be used to determine starting coordinates and height. For survey purposes, data scaled from a map are considered to be assumed data. If possible, a starting azimuth should be determined by using a SIAGL astronomic observation, simultaneous observation or PADS. If the situation is such that none of these methods can be used, then a starting azimuth maybe obtained by carefully scaling from a large-scale map or by using a declinated compass.

c. Assumed. When neither known control nor maps are available, the coordinates and height for the starting station may be assumed. Starting direction will be determined by the most accurate means available. Assumed data must be converted as soon as more accurate starting control becomes available.

5-3. TYPES OF TRAVERSE

There are three types of traverse used in FA survey. These are open traverse, closed traverse, and directional traverse.

a. Open Traverse. An open traverse begins at a point of known control and ends at a station whose relative position is known only by computations. The open traverse is considered to be the least desirable type of traverse, because it provides no check on the accuracy of the starting control or the accuracy of the fieldwork. For this reason, traverse is never deliberately left open. Open traverse is used only when time or enemy situation does not permit closure on a known point.

b. Closed Traverse. This traverse starts and ends at stations of known control. There are two types of closed traverse–closed on the starting point and closed on a second known point.

(1) Closed on the starting point. This type of closed traverse begins at a point of known control, moves through the various required unknown points, and returns to the same point. This type of closed traverse is considered to be the second best and is used when both time for survey and limited survey control are considerations. It provides checks on fieldwork and computations and provides a basis for comparison to determine the accuracy of the work performed. This type of traverse does not provide a check on the accuracy of the starting data or ensure detection of any systematic errors. If a conventional survey team uses a PADS SCP, they must close on the same point because of the PADS circular error probable (CEP) and errors in determining assumed data.

(2) Closed on a second known point. This type of closed traverse begins from a point of known control, moves through the various required unknown points, and then ends at a second point of known control. The point on which the

survey is closed must be a point established to an equal or higher order of accuracy than that of the starting point. This is the preferred type of traverse. It provides checks on fieldwork, computations, and starting control. It also provides a basis for comparison to determine the accuracy of the work performed.

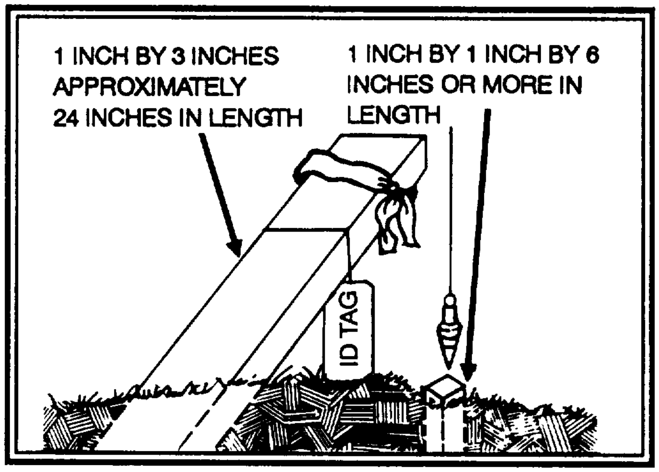
c. Directional Traverse. Directional traverse is a type of traverse that extends directional control (azimuth) only. This type of traverse can be either open or closed. If open, the traverse should be closed at the earliest opportunity. It can be closed on either the starting azimuth or another known azimuth of equal or higher order of accuracy. It also can be closed by comparison to an astronomic azimuth, gyroscopic azimuth, or a PADS azimuth. Since direction is the most critical element of FA survey and time is frequently an important consideration it is sometimes necessary at lower echelons to map-spot battery locations and extend direction only.

5-4. TRAVERSE STATIONS

a. Selection of Stations. In FA survey, sites for traverse stations normally are selected as the traverse progresses. Stations must be located so that at any one station both the rear and forward stations are visible. Some brush cutting may be required to clear lines of sight between stations. If the distance is to be measured with a tape, the line between stations must be free of obstacles for the taping team. Electronic lines of sight must also be free of obstructions if electronic equipment is to be used. The number of stations in a traverse should be kept to a minimum to reduce the accumulation of instrumental errors and the amount of computation required. Short traverse legs require the establishment and use of more stations and may cause excessive errors in azimuth because small errors in instrument centering and pointings will be magnified and reflected in the azimuth closure.

✻**b. Station Markers.** Traverse station markers are usually l-inch by l-inch wooden stakes, 6 inches or more in length. These stakes, called hubs, are driven flush with the ground. The center of the top of the hub is marked with a surveyor's tack or with an X to designate the exact point of reference for angular and linear measurements. To help in recovering **principal stations** such as the OS, EOL, and north reference point and its azimuth mark (patriot unit), a reference (witness) stake is driven into the ground so that it slopes toward the station. (See Figure 5-4.) The identification of the station is written on the reference stake with a lumber crayon or china-marking pencil or on a tag attached to the stake. Signal cloth may also be tied to the reference stake to further help in identifying or recovering the station (unit standing operating procedure [SOP]). During phases of survey expansion, more permanent types of markers may be used, such as shell casings or concrete monuments.

Figure 5-4. **Survey station marked with a reference stake**

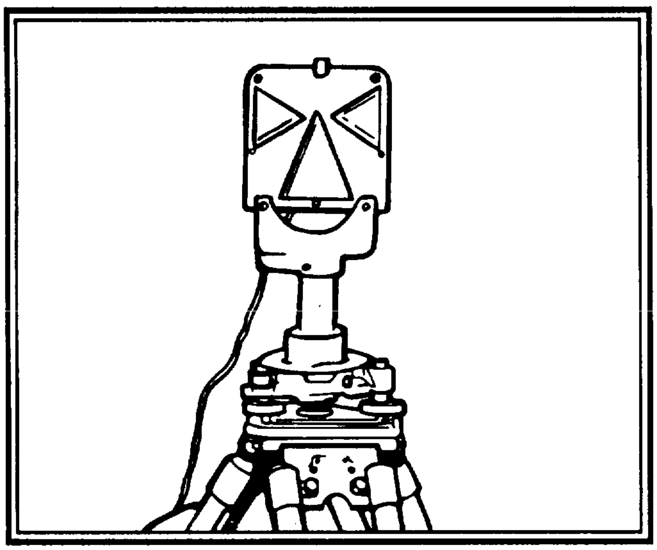


c. Station Signals. Signals must be erected over survey stations to provide sighting points for the instrument operator and to serve as a reference for tape alignment by the taping team. Permanent tripods or similar signals have been erected over some primary survey control stations so that the stations can be occupied without disturbing the signal. In artillery survey, most of the station sites are selected and marked as the fieldwork progresses. Temporary signals must be erected at the stations as they are needed. The equipment used for station signals is discussed below.

(1) Range poles. Range poles are made of tubular steel, and each consists of two interlocking sections. The assembled pole is 6.5 feet long, and one end is tapered to a point. The pole is painted in l-foot sections with alternate colors of red and white. For storage, the pole is disassembled and placed in a canvas case. To use the range pole, place the tapered point on the station mark and use a rod level to make the pole vertical for observations. Place the angular portion of the level against the pole, with the circular level vial facing upward. Then move the top of the pole until the bubble in the vial is centered. Check the verticality of the range pole by verifying that the bubble remains centered at other points on the range pole. Maintain the range pole in a vertical position throughout the observing period, normally by using a range pole tripod. To prevent the measurement of angles to the wrong point, place the range pole in a vertical position only when it is being used to mark a survey station. Cloth flags of various colors may be attached to the top of the range pole to help identify the station.

(2) Target set, surveying. To mark survey stations, artillery missile batteries that have special accuracy requirements for the azimuth of the orienting line use the target set. (See Figure 5-5.) The target set may also be issued to FA survey elements that are required to perform survey to fourth-order accuracy. The target is mounted on the same tripod that is used with the T2 and T16 theodolites. The tripod is set up, leveled, and plumbed in the same manner as the theodolite tripod. After setup, the target is oriented so that it can be seen directly by the instrument that is sighting on it. The target can be illuminated for night use. Greater accuracy is obtained on short traverse legs by using the target rather than range poles. When the telescope is sighted on the target, the telescope cross hairs should bisect the triangles of the target. Flexibility can be obtained by interchanging and leapfrogging theodolites and targets. This reduces setup time by leaving tripods and tribrachs in place. The target level and optical plumb on the target must be adjusted in the same manner as for the T2 theodolite.

Figure 5-5. **Tripod-mounted target**



5-5. ORGANIZATION OF CONVENTIONAL TRAVERSE PARTIES

The number of personnel authorized to perform survey will depend on the unit TOE. The organization of these persons into a traverse party and the duties assigned to each member will depend on the unit SOP. The organization and duties of traverse party members and modifications proposed for reduced-strength parties (a through d below) are based on the functional requirements of a traverse. See Chapter 1 for a detailed description of individual duties.

a. Fifth-Order Traverse Party.

(1) Chief of party. The chief of party plans the traverse, selects and marks the locations of the traverse stations, and supervises the work of the other members of the party. When directed, he helps the survey officer or chief surveyor in the reconnaissance and planning of the survey.

(2) Instrument operator. The instrument operator measures the horizontal and vertical angles at each traverse station. He measures distances with the SEDME-MR. He also operates the azimuth gyro and is responsible for the care and cleaning of those instruments.

(3) Computer-recorder. The computer-recorder keeps the field note-s for the party in a field notebook. He records the angles measured by the instrument operator, the distances measured with the SEDME or measured by the tapemen, and all other data pertaining to the survey. He also checks the length of each taped traverse leg by pacing (fifth order). Also, he computes the grid coordinates and height of each traverse station as the traverse progresses and checks his results with the computer.

(4) Computer. The computer computes the grid coordinates, height, and azimuth of each traverse station as the survey progresses. The computer and the computer-recorder work independently and check their results with each other.

(5) Rodman-tapeman. The rodman-tapeman helps in setting up and marking stations. He erects the SEDME reflector and helps the instrument operator care for the instruments. When the 30-meter steel tape is used, the rodman-tapeman and an individual designated by the chief of party measure the distance from one traverse station to the next. Each keeps a record of the distance taped. They compare their recorded distances before reporting the measured distance to the recorder. The rodman-tapeman maintains all taping equipment.

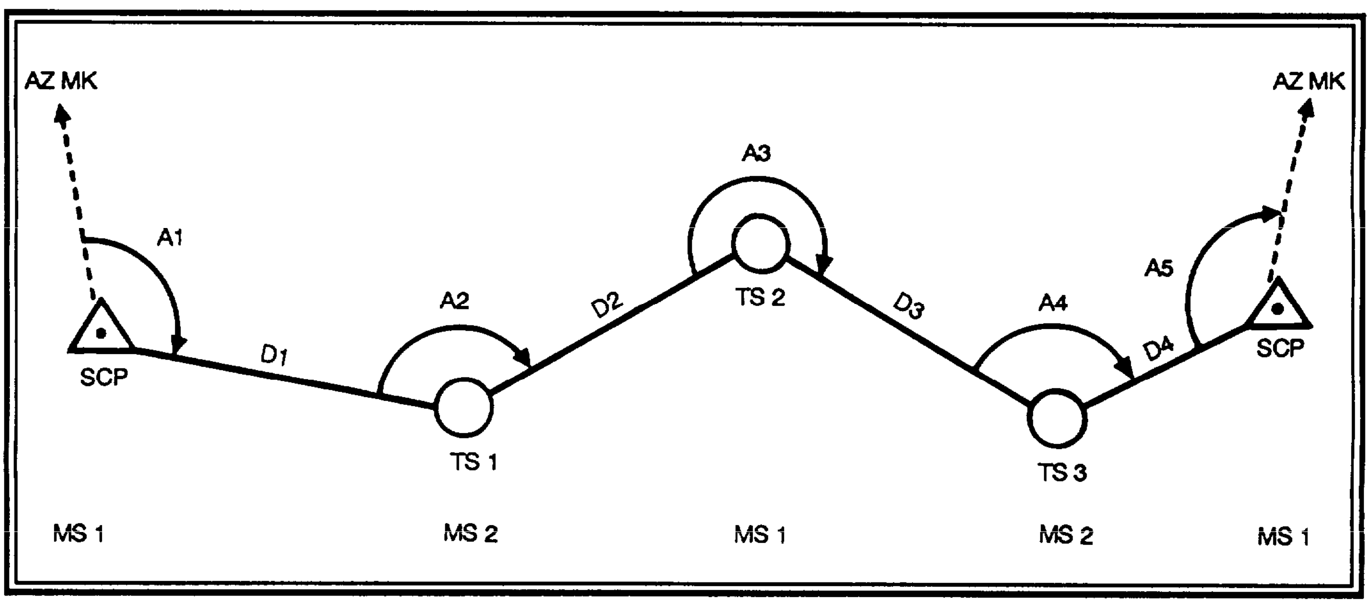
b. Fourth-Order SEDME Traverse Party. The fourth-order SEDME traverse party is equipped with two T2 theodolites and one SEDME-MR. The personnel are one chief of party, two instrument operators, two computer-recorders, and one rodman. Party deployment and measuring operations are shown in Figure 5-6. Measuring Section (MS) 1 occupies the survey control point, measures Angle 1 (A1), and sets up a set of infrared reflectors (IRRs) before moving to TS 2. Measuring Section 2 occupies TS 1, measures A2 and distances 1 and 2 (D1 and D2), and moves to TS 3 to repeat the cycle. The recon section plans the survey, establishes forward stations, and recovers the IRRs and range poles, as required.

c. Fourth-Order Taped Traverse Party. Duties for a fourth-order taped traverse are the same as in a above with the exceptions discussed below.

(1) The computer-recorder is not required to check the length of a taped traverse leg by pacing.

(2) In artillery fourth-order taped traverse, all distances are double taped to a comparative accuracy of 1:5,000. The recorder helps the rodman-tapeman with the taping operation.

Figure 5-6. **Operational concept for div arty or TAB survey party**



(3) There are two instrument operators and two T2 theodolites in each fourth-order party.

d. Reduced-Strength Party. Often, enough personnel are not available for a full traverse party. In such circumstances, members of the survey party may be required to do more than one job. Shortages in personnel will never affect the jobs of the instrument operator or tapemen, since these two jobs must be done if a traverse is to be conducted. Shortages will, therefore, be apparent in the duties of rodman, computer, and computer-recorder. If the party is short one rodman, the chief of party will perform, in addition to his own duties, the duties of the rodman. If three or more members are absent from the party, the fieldwork is completed and the computations are performed later by designated personnel. The organization of a reduced-strength party is not bound by strict rules. However, for a party to function when personel shortages exist, each party member must be trained to perform all duties.

5-6. NIGHT TRAVERSE

At times, the FA surveyor will be required to survey at night to accomplish his mission. Night traverse can be done by modifying daylight techniques and organization. However, night traverses require more work, more training, more personnel, and more coordination.

a. Equipment. The same equipment used for performing daylight traverse is also used to perform night traverse with the addition of night-lighting equipment. This lighting equipment includes flashlights for all personnel and two signal lights for each range pole. If signal lights are not available, two flashlights for each range pole will suffice. All lighting devices should be equipped with filters of some type to ensure greater light security and to prevent undue glare in the telescope of the observing instrument when it is pointed at a station. The observing instrument should be equipped with its integral lighting equipment.

b. Personnel. The standard traverse party must be supplemented with additional personnel to enable it to function properly at night. Three additional men who are light holders go with and help the tapemen.

c. Station Marking. At night, the traverse stations are marked the same as in daylight except for the lighting devices required at the rear and forward stations. Two signal lights should be placed on each range pole that will be observed from a traverse station. Usually, this will include two range poles-both the rear and the forward stations. One of these lights should be placed on the pole at the height of the instrument and the other at the lowest point visible from the instrument. Both lights should be pointed directly at the observing instrument. If signal lights are not available, flashlights may be taped or securely strapped to the pole in the same manner prescribed for the target lights. To ensure that the lights are placed and pointed properly, the chief of party will designate one man to remain with the range poles and coordinate the placement and pointing of the lights with the instrument operator.

d. Angle Measuring and Recording.

(1) Angle measuring. There is no different between measuring angles at night and measuring angles during daylight, except at night the instrument must be equipped with a night-lighting device. The chief of party should coordinate with the instrument operator to ensure that the lights at the rear and forward stations are placed and pointed properly and are moved to the next station when the observation is completed.

(2) *Recording.* The same recording procedures used for recording during daylight hours are used for night recording except that the recorder must have a flashlight so he can see to record. He should record in the remarks section of the field notes anything that may affect the survey, such as burnt-out lights or only one light on the forward station.

e. Distance Measurement at Night.

(1) Taping. For information on taping at night see paragraph 2-18.

(2) SEDME. Use the same procedures at night as for daylight measurements. Lighting devices are required to orient the SEDME and reflector assembly. After the SEDME is oriented and before measurements are taken, lights at or behind the reflector assembly must be turned off. Communication between stations must be maintained.

f. Communication. Communication during a night traverse should be by radio. However, radio is not always convenient or available, and at times, the survey party must resort to light signals. These light signals should be prearranged and simple. For example, the instrument operator may have to signal the rodman to raise or lower the bottom light on a range pole or inform him to move to the next station. In arranging signals, the survey party should avoid waving lights, since a waving light may easily attract the enemy's attention. Every precaution should be taken in sending light signals to avoid detection by the enemy.

5-7. TRAVERSE FIELD NOTES

For correct procedures and examples of field notes on traverse, see paragraphs 4-1 through 4-5 and Figures 4-6 and 4-7.

Section II

TRIGONOMETRY OF TRAVERSE

The distance and azimuth between points can be used to form and compute a right triangle. The distance between points serves as the hypotenuse, and the azimuth can be used to determine an angle. Three right triangles must be solved for each leg. Three trigonometric functions are used to compute a traverse. These functions are the sine, cosine, and tangent. The sine and cosine functions are used to compute the differences in casting and northing coordinates. The tangent is used to compute the difference in height.

5-8. AZIMUTH DETERMINATION

An azimuth to an azimuth mark (starting direction) may be obtained by use of the following:

- Ž SIAGL.
- Ž Astronomic observation.
- Ž Amputation from known coordinates.
- Ž Reference to an existing trig list.
- Ž PADS.

As the last effort, the azimuth maybe scaled from a map, but an accurate azimuth must be obtained as soon as possible.

5-9. EXTENDING AZIMUTH

In artillery survey, direction may be defined as the angular measurement between a specific reference line and a given line. Azimuth is the term used in artillery survey to describe direction and is the horizontal clockwise angle from a reference line (grid north [GN]) to a given line. Every line has two azimuths (a forward azimuth and a back-azimuth), depending on the observer's position on the line. In Figure 5-7, a survey is progressing from Station A toward Station B. Angle a is the forward azimuth for the line from A to B. To designate the azimuth from B to A, the Angle b is used. This is known as the back-azimuth of the line. For artillery survey purposes, the forward azimuth and the back-azimuth of a line differ by 3,200 mils (forward azimuth ±3,2000 mils = back-azimuth). To compute a traverse, an azimuth to the forward station must be determined for each leg of the traverse. This is done by adding the value of the station angle to the azimuth to the rear station. Figure 5-8 and the example on page 5-9 illustrate this procedure. It should be noted that on occupation of each successive station, the first step is to compute the back-azimuth of the preceding traverse leg.

5-10. AZIMUTH AND DISTANCE COMPUTATIONS

In survey operations, the azimuth and distance between two stations of known coordinates must be determined. Some examples of such a requirement are the computation of the following:

- Ž Azimuth and length of a target area base.
- Ž Base of a triangulation scheme.
- Ž Azimuth and distance between critical points inconverting an assumed grid to a common grid.
- Ž Astarting azimuth for a control point when the coordinates of the two intervisible points are known.

5-11. DA FORM 5590-R

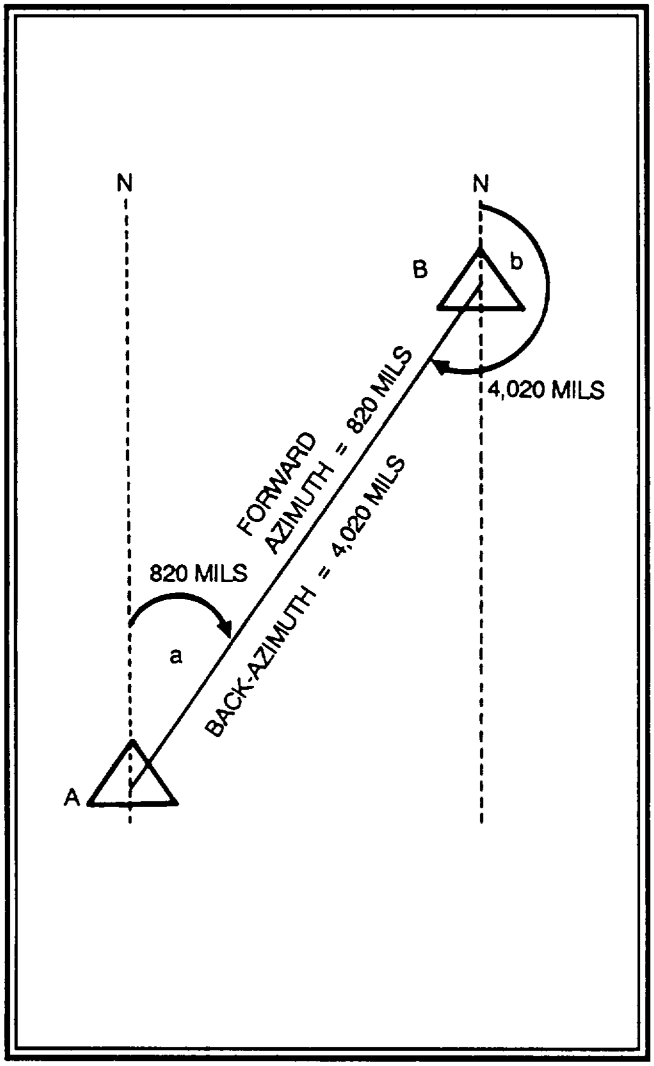
DA Form 5590-R (Computation of Azimuth and/or Distance From Coordinates (BUCS)) (Figure 5-9) is used to record the computation of the grid azimuth and distance between two points of known coordinates. (A reproducible copy of this form is at the back of this book.) The form is designed to help the operator perform the computations. The form has five sections as discussed below.

a. At the top of the form, right below the form title, you will notice six blocks. These blocks are for recording administrative information. Each block is labeled for the information required for each block. When conducting field survey operations, all required information must be entered.

b. On the left side of the form under the six administrative blocks, are the instructions for using the BUCS. These instructions consist of three columns–STEP, PROMPT, and PROCEDURE. These columns are used to compute the azimuth and distance.

(1) The STEP column specifies the sequence in which the computations must be performed.

Figure 5-7. **Azimuth and back-azimuth**



EXAMPLE

Given

Azimuth from Station A to az mk	5,592.6 mils
Angle az mk-Station A-TS 1	2,134.0 mils
Angle Station A-TS 1-TS 2	3,820.5 mils
Angle TS 1-TS 2-Station B	1,756.5 mils

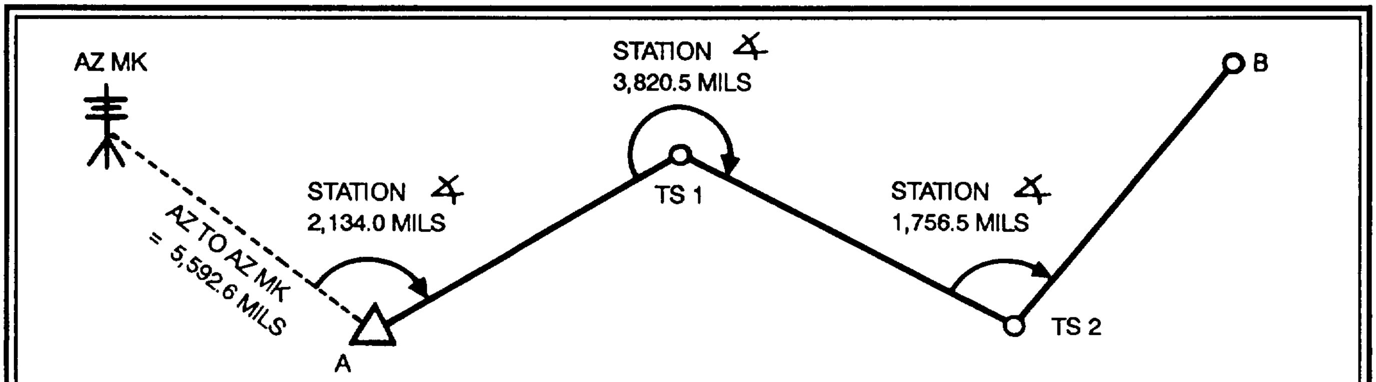
Required

Azimuth from TS 2 to Station B

Solution

(1) At Station A—	
Azimuth to az mk	5,592.6 mils
Angle az mk-Station A-TS 1	+ 2,134.0 mils
Sum	7,726.6 mils
Minus a full circle	- 6,400.0 mils
Azimuth Station A to TS 1 (forward azimuth)	1,326.6 mils
(2) At TS 1—	
Azimuth Station A to TS 1	1,326.6 mils
Plus a half circle	+ 3,200.0 mils
Azimuth TS 1 to Station A (back-azimuth)	4,526.6 mils
Angle Station A-TS 1-TS 2	+ 3,820.5 mils
Sum	8,347.1 mils
Minus a full circle	-6,400.0 mils
Azimuth TS 1 to TS 2 (forward azimuth)	1,947.1 mils
(3) At TS 2—Azimuth TS 1 to TS 2	1,947.1 mils
Plus a half circle	+ 3,200.0 mils
Azimuth TS 2 to TS 1 (back-azimuth)	5,147.1 mils
Angle TS 1-TS 2-Station B	+ 1,756.5 mils
Sum	6,903.6 mils
Minus a full circle	- 6,400.0 mils
Azimuth TS 2 to Station B (forward azimuth)	0503.6 mils

Figure 5-8. **Diagram of determination of azimuths**



Note. Azimuth from Station A to azimuth mark is known.

(2) The PROMPT column indicates the display that should appear on the BUCS at each step.

(3) The PROCEDURE column lists the actions that the operator must take at each step.

c. Immediately below the INSTRUCTION section is the REMARKS: section. The REMARKS: section is used for recording any information that will help clarify the computations or survey.

d. On the right side of the form under the administrative section, is a block containing notes. The purpose of these notes is to help the operator use the form and the BUCS to compute the survey.

e. On the right side of the form under the notes is the DATA RECORD section. The blocks in the DATA RECORD section are used for recording the field data, known data and station names. This is where the known coordinates of the occupied station and the azimuth mark, the name of the occupied station and the azimuth mark, and the results of the BUCS computations are recorded. (See Table 5-1 for instructions on computing DA Form 5590-R.)

(1) The blocks marked with a filled-in arrow are for recording the known coordinates. Blocks that are not marked with the filled-in arrow are for recording the computed azimuth and distance. The remaining blocks are for recording the station names.

(2) There are spaces on the form to record the results of four individual sets of azimuth and distance computations.

Table 5-1. **Instructions on computing DA Form 5590-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 1. Enter the number 1, and press the END LINE key.
2	The prompt AZIMUTH/DISTANCE appears. There is no procedure. Press the END LINE key.
3	The prompt E OCC STA: 0.00 appears. Enter the easting coordinates of the occupied station. Record the easting coordinates in the EASTING: block in the DATA RECORD section. Press the END LINE key.
4	The prompt N OCC STA: 0.00 appears. Enter the northing coordinates of the occupied station. Record the northing coordinates in the NORTHING: block in the DATA RECORD section. Press the END LINE key.
5	The prompt E OF AZMK: 0.00 appears. Enter the easting coordinates of the azimuth mark. Record the easting cordinates in the EASTING: block in the DATA RECORD section, Press the END LINE key.
6	The prompt N OF AZMK: 0.00 appears. Enter the northing coordinates of the azimuth mark. Record the northing coordinates in the NORTHING: block in the DATA RECORD section. Press the END LINE key. You have now completed entering the data that BUCS needs to compute the azimuth and distance.
7	The next prompt is ^AZ TO AZMK: 0.000. This is the azimuth from the occupied station to the azimuth mark. Record the azimuth in the AZIMUTH (MILS): block in the DATA RECORD section. Press the END LINE key.
8	The prompt DIST AZMK: 0.00 appears. This is the distance between the occupied station and the azimuth mark. Record the distance in the DISTANCE (METERS): block in the DATA RECORD section. Press the END LINE key.
9	The prompt MORE POINTS (Y/N): appears. The BUCS is inquiring if the computer desires to compute more azimuths and distances. If the computer desires to compute additional sets, he will press the Y key and then the END LINE key. The BUCS program will return to step 2, and the prompt AZIMUTH/DISTANCE appears. To compute the additional sets, repeat steps 2 through 8 with new data. If the computer answers N to step 9, the BUCS will proceed to step 10.
10	The prompt END OF MSN (Y/N): appears. At this point in the program, the computer may return to the previous prompt of MORE POINTS (Y/N): by pressing the N key and then the END LINE key. This gives him a last chance to recall the data just computed, to compute additional sets, or to exit Program 1 by pressing the Y key and then the END LINE key.

Figure 5-9. **Sample DA Form 5590-R**

COMPUTATION OF AZIMUTH AND/OR DISTANCE FROM COORDINATES (BUCS)

For use of this form see FM 6 2 the proponent agency is TRADOC

COMPUTER SSG PENA	NOTEBOOK REFERENCE FM 6-2	DATE 21 MAR 91
CHECKER SFC KING	AREA FT. SILL	SHEET 1 OF 1 SHEETS

INSTRUCTIONS

NOTES 1 PRESS [illegible] AFTER COMPLETION OF EACH STEP
2 RECORD ADDITIONAL SETS OF DATA IN DATA RECORD COLUMN
3 FOUR AZIMUTH DISTANCE SETS CAN BE RECORDED
4 ENTER FIELD DATA IN BLOCKS MARKED ▶

STEP	PROMPT	PROCEDURE	DATA RECORD	
1		CALL PROGRAM 1	OCCUPIED STATION NAME: BILL	OCCUPIED STATION NAME:
2	AZIMUTH DISTANCE			
3	E OCC STA: 0 00	ENTER EASTING OF OCCUPIED STATION	▶ EASTING: 550678.34	▶ EASTING:
4	N OCC STA: 0 00	ENTER NORTHING OF OCCUPIED STATION	▶ NORTHING: 3894439.45	▶ NORTHING:
			AZIMUTH MARK NAME: DAVE	AZIMUTH MARK NAME:
5	E OF AZMK: 0 00	ENTER EASTING OF AZIMUTH MARK	▶ EASTING: 553421.87	▶ EASTING:
6	N OF AZMK: 0 00	ENTER NORTHING OF AZIMUTH MARK	▶ NORTHING: 3894749.43	▶ NORTHING:
7	AZ TO AZMK: 0 000	RECORD AZIMUTH	AZIMUTH (MILS): 1485.400	AZIMUTH (MILS):
8	DIST AZMK: 0 000	RECORD DISTANCE	DISTANCE (METERS): 2760.986	DISTANCE (METERS):
9	MORE POINTS (Y N):	ENTER Y OR N		
10	END OF MSN (Y N):	ENTER Y OR N		

SAMPLE

REMARKS:

DATA RECORD

OCCUPIED STATION NAME:	OCCUPIED STATION NAME:
▶ EASTING:	▶ EASTING:
▶ NORTHING:	▶ NORTHING:
AZIMUTH MARK NAME:	AZIMUTH MARK NAME:
▶ EASTING:	▶ EASTING:
▶ NORTHING:	▶ NORTHING:
AZIMUTH (MILS):	AZIMUTH (MILS):
DISTANCE (METERS):	DISTANCE (METERS):

DA FORM 5590-R, DEC 86

5-12. AZIMUTH AND BEARING ANGLE RELATIONSHIP

a. An azimuth is required in traverse to permit determination of a bearing angle. The bearing angle of a traverse leg and not the azimuth is used in traverse computations to determine differences in coordinates. The bearing angle of a line is the acute angle formed by the intersection of that line with a grid north-south line. Figure 5-10 illustrates the relationship between the azimuth of a line and its bearing angle.

b. In artillery survey, the horizontal plane (or circle) is divided into four quartets. Each quarter circle contains 1,600 mils and is called a quadrant. The four quadrants are numbered in a clockwise direction, since azimuths are measured in a clockwise direction. Numbering begins at grid north and proceeds around the circle, using reman numerals I through IV. (See Figure 5-10.)

5-13. DETERMINATION OF BEARING ANGLE

The manner in which the bearing angle is computed from a given azimuth depends on the quadrant in which that azimuth lies. (See Figure 5-11.)

a. When the azimuth is in the first quadrant (0 to 1,600 mils), the bearing angle equals the azimuth.

b. When the azimuth is in the second quadrant (1,600 to 3,200 mils), the bearing angle equals 3,200 mils minus the azimuth.

c. When the azimuth is in the third quadrant (3,200 to 4,600 mils), the bearing angle equals the azimuth minus 3,200 mils.

d. When the azimuth is in the fourth quadrant (4,600 to 6,400 mils), the bearing angle equals 6,400 mils minus the azimuth.

Figure 5-10. **Azimuth-bearing relationship**

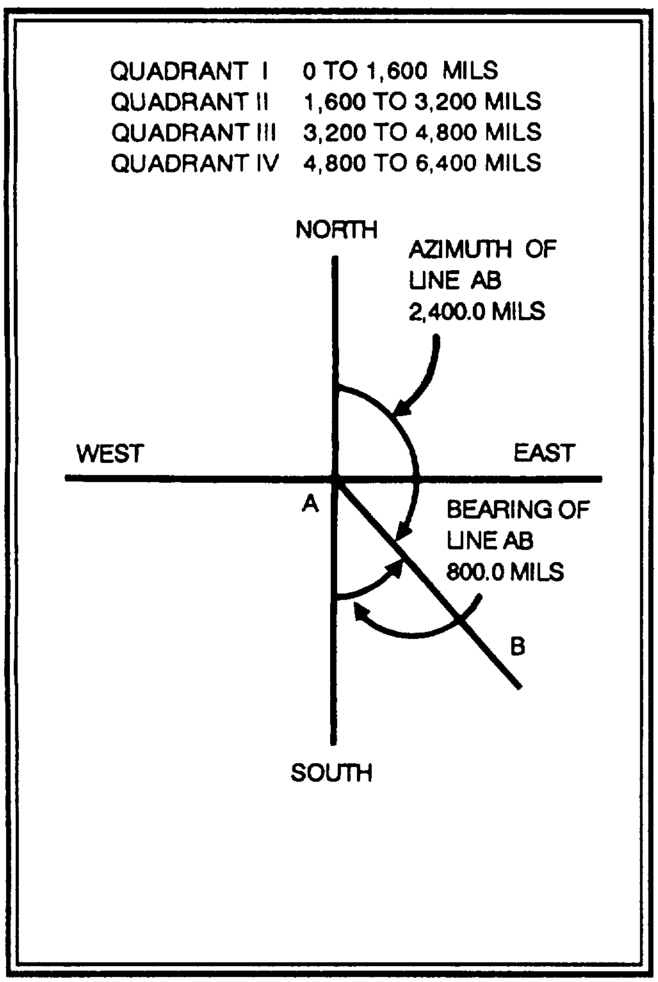
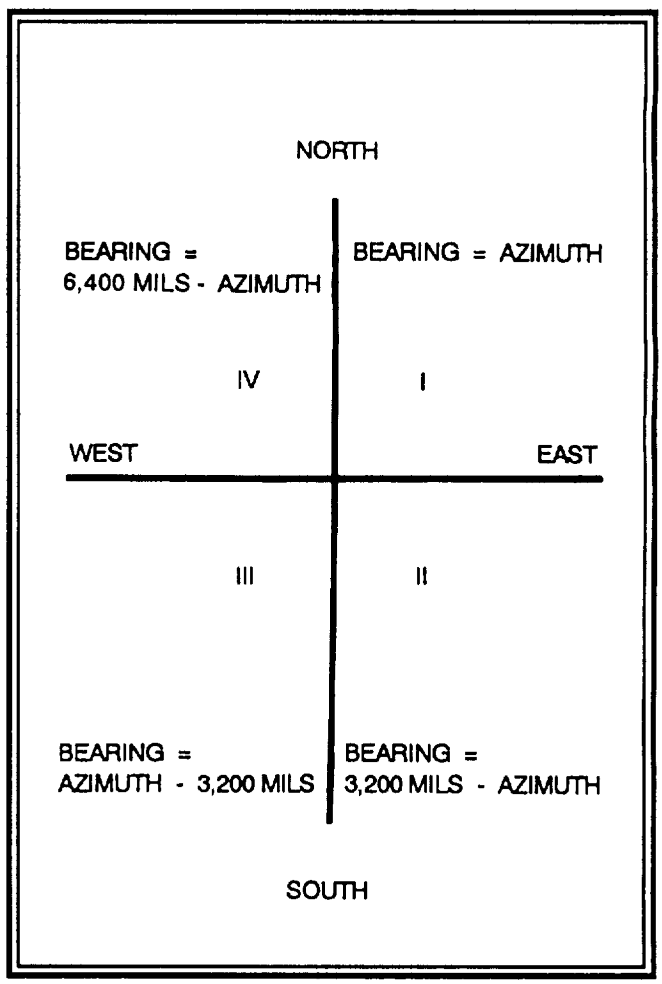


Figure 5-11. **Determination of bearing angles**



5-14. TRIGONOMETRY AND THE TRAVERSE LEG

a. If the coordinates of a point are known and the azimuth and distance from that point to a second point are known, the coordinates of the second point can be determined. In Figure 5-12, the coordinates of Station A are known and the coordinate of TS 1 are to be determined. The azimuth and distance from Station A to TS 1 have been determined by turning the horizontal angle at Station A from the azimuth mark to TS 1 and by measuring the horizontal distance from Station A to TS 1.

b. Determining the coordinates of TS 1 requires the solution of a right triangle. The intersection of the north-south line through Station A and the east-west line through TS 1 forms a right angle (1,600 mils or 900). The known side (A to TS 1) (measured distance) becomes the hypotenuse, and the bearing angle at Station A is determined from the azimuth of Station A to TS 1. Thus, a right triangle is formed.

5-15. COORDINATE COMPUTATIONS

The two unknown sides of this right triangle are designated as the difference in casting (dE) and the difference in northing (dN). To compute the length of sides dE and dN, use two of the trigonometric functions of a right triangle. To determine dE, use the following formula:

Sine of bearing angle =

$$\frac{\text{opposite side}}{\text{hypotenuse}} = \frac{\text{dE}}{\text{distance}}$$

dE = sine of bearing angle x distance

> **Note.** When using a BUCS or a calculator capable of performing logarithms, enter the formula as follows:
>
> Distance (Hypotenuse) x SIN (bearing angle x .05625) END LINE = dE

To determine dN, use the following formula:

Cosine of bearing angle =

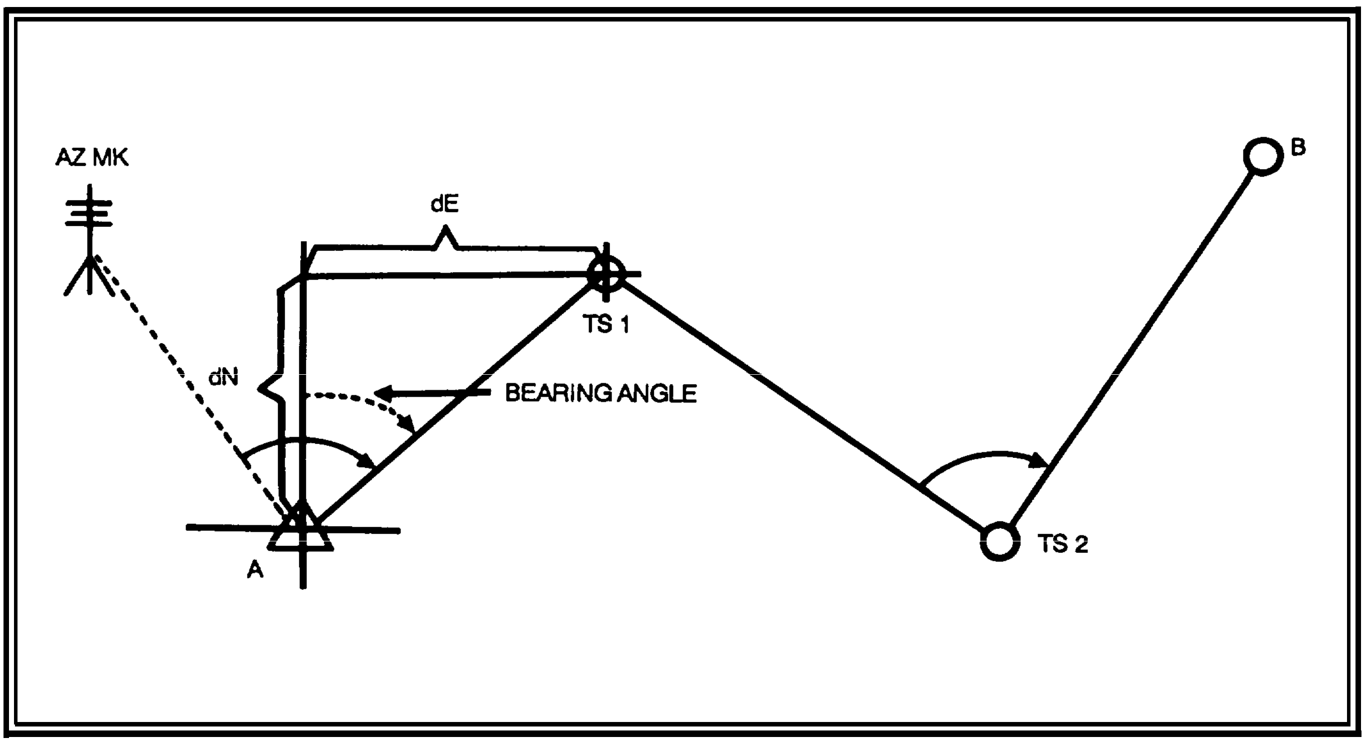
$$\frac{\text{Adjacent side}}{\text{hypotenuse}} = \frac{\text{dN}}{\text{distance}}$$

or

dN = cosine of bearing angle x distance

> **Note.** When using a BUCS or a calculator capable of performing logarithms, enter the formula as follows:
>
> Distance (Hypotenuse) x COS (bearing angle x .05625) END LINE = dN

Figure 5-12. **Schematic diagram illustrating dE and dN requirements**



To determine the coodinates of the unknown point (TS 1), algebraically add the difference in casting to the casting coordinate of the known point (Station A) and the difference in northing to the northing coordinate of the known point (Station A). In Figure 5-13, for the traverse leg appearing in the first quadrant, the dE and dN must be added to the casting and northing coordinates of Station A. For the traverse legs in the other quadrants, the signs of the dE and dN change. In all instances, the quadrant in which the traverse leg lies determines if dE and dN are added to or subtracted from coordinates of Station A. (See Figure 5-13.)

5-16. DETERMINATION OF dH

a. In a traverse, the FA surveyor must determine the height of each of the unknown stations in relation to the height of the starting (known) station. He does this by computing the difference in height (dH) between the occupied station and the forward station. Through the solution of a right triangle, the vertical angle at the occupied station and the measured horizontal distance to the forward station are used to determine the difference in height between the two stations. This difference is then added to or subtracted from the known height at the occupied station.

b. In Figure 5-14, the measure distance is the horizontal distance from Station A to Station B. The vertical angle at Station A is measured to the height of instrument at Station B (AA is the height of instrument at Station A, and BB is the height of instrument at Station B). Both of the heights are the distance from the known ground elevation at Station A to the horizontal axis of the telescope of the instrument being used. AA' is equal to BB'. The height of instrument must be determined and marked on the range pole at the forward station. The difference in height between the two stations is side CB of the right triangle. Determine dH as follows :

$$\text{Tangent of vertical angle} = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{dH}{\text{distance}}$$

or

$$dH = \text{tangent of vertical angle} \times \text{distance}$$

> **Note.** When using a BUCS or a calculator capable of performing logarithms, enter the formula as follows:
>
> Distance (Hypotenuse) x TAN (vertical angle x .05625) END LINE = dH

The dH computed is actually the difference in height at ground level between the two stations. The computed dH is added to or subtracted from the height of the known station according to the sign of the measured vertical angle.

Figure 5-13. **Quadrant-sign relationship for dE and dN**

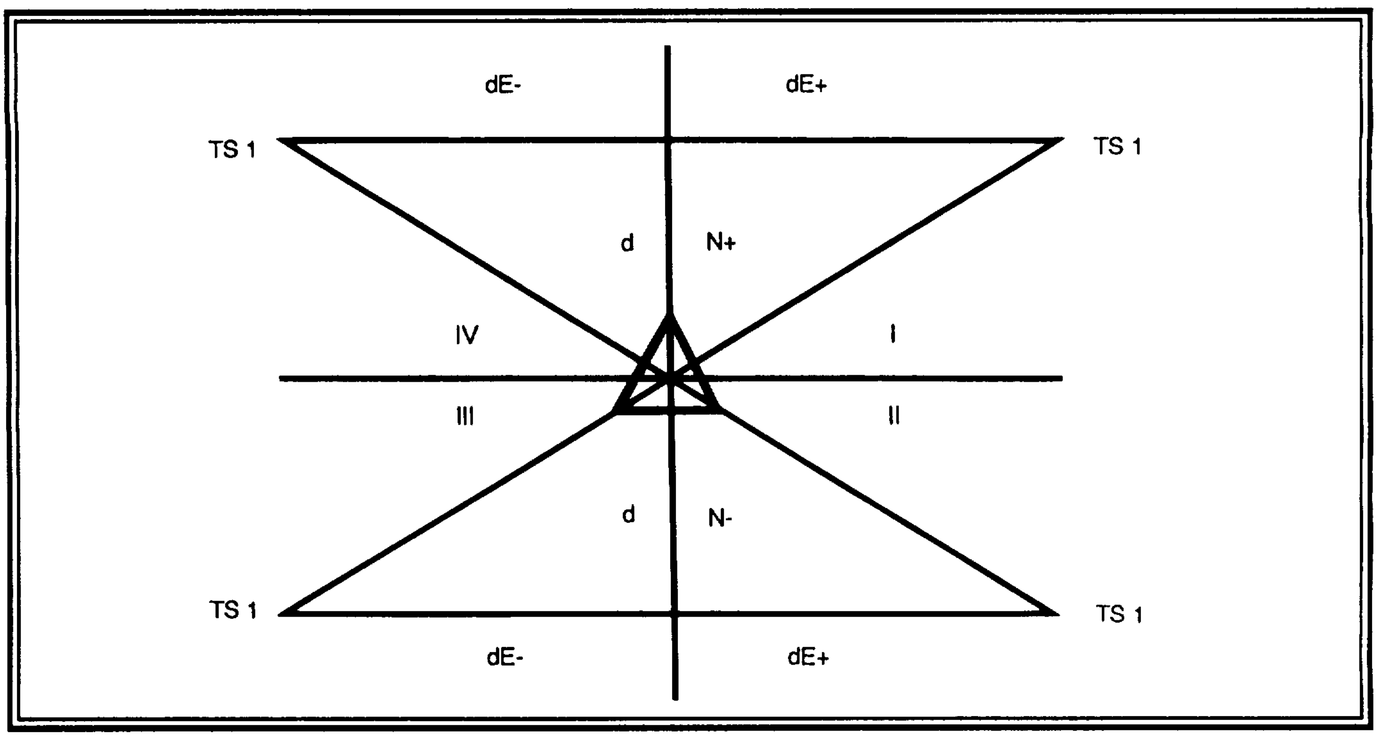
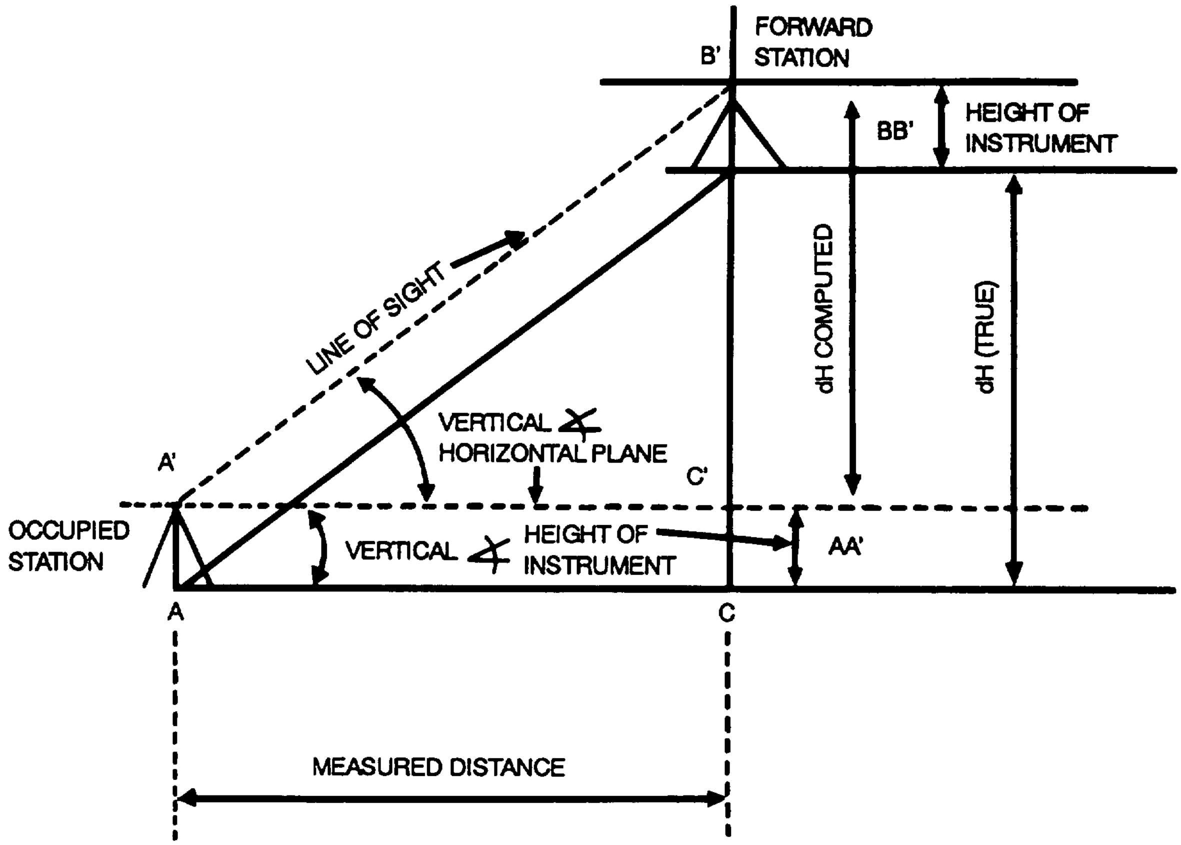


Figure 5-14. **Right triangle for determination of dH**



5-17. UNIVERSAL TRANSVERSE MERCATOR GRID

The grid coordinates used most often in survey computations are coordinates based on the UTM grid system. These coordinates differ from the military grid reference system in that the grid reference of a point has a grid zone designator and a 100,000-meter square identification. The grid zone designator and 100,000-meter identification replace the false casting and northing digits of UTM grid coordinates. In the lower margin of military maps, the grid reference box shows the grid zone designator and 100,000-meter identification for that map sheet. For a detailed discussion of map reading, see FM 21-26, Chapter 4, page 4-17, Figure 4-14, and paragraph 4-4c(1).

Section III

TRAVERSE COMPUTATIONS

Survey computations can be performed in any mathematical sequence that will produce the correct solution. However, for the purpose of simplicity and uniformity, Department of the Army has devised standardized forms for use in performing survey computations. Accurate and timely computations are the key to a successful survey. Computations performed on a standard form are easily checked, adjusted, and filed when necessary.

5-18. COMPUTING THE TRAVERSE LEG

a. To determine the coordinates of the unknown point, the azimuth and distance from the known point to the first unknown station are used.

b. Determining the coordinates of the first unknown point requires the use of DA Form 5591-R. (See Figures 5-15 and 5-16.)

5-19. DETERMINATION OF HEIGHT

In a traverse, the FA surveyor must determine the height of each of the unknown stations in relation to the height of the starting (known) station. The vertical angle at the occupied station and the measured horizontal distance to the forward station are used to determine the height of the unknown station.

5-20. DA FORM 5591 -R

a. DA Form 5591-R is the form on which traverse computations are recorded. It is used in conjunction with Program 2 (BUCS, SURVEY REV1) to determine coordinates and height from azimuth, distance, and vertical angle of main scheme traverse stations. The program also converts slope distance to horizontal distance and computes the total traverse length, total azimuth and height corrections, radial error of closure, accuracy ratio, and traverse adjustment.

b. Entries on the form are discussed below. (Instructions for completing the front and reverse sides of DA Form 5591-R are in Tables 5-2 and 5-3.)

(1) The known data of the starting and closing stations and the traverse field data are required by the BUCS. The known starting and closing data consist of the coordinates and height of the starting and closing stations and a line of known azimuth at each of the stations. The traverse field data consist of horizontal and vertical angles measured at each station and the distance between the traverse stations.

(2) The user must enter the known starting station data and then the traverse field data. The traverse field data must be entered in the same sequence that the traverse stations were encountered in the field operations.

Table 5-2. **Instructions for computing DA Form 5591-R (front)**

STEP	INSTRUCTION
1	The prompt MODULE DESIRED appears. The procedure in the PROCEDURE column is CALL PROGRAM 2. Call Program 2 by entering the number 2 and then pressing the END LINE key.
2	The prompt TRAVERSE appears. Press the END LINE key.
3	The prompt E OCC STA: 0.00 appears. Enter the easting of the starting station. Press the END LINE key. Record the easting in the block so labeled in the DATA RECORD section.
4	The prompt N OCC STA: 0.00 appears. Enter the northing of the starting station. Press the END LINE key. Record the northing in the block so labeled in the DATA RECORD section.
5	The prompt HT OCC STA: 0.00 appears. Enter the height of the starting station. Press the END LINE key. Record the height in the HEIGHT (METERS): block of the DATA RECORD section.

Table 5-2. **Instructions for computing DA Form 5591-R (front) (continued)**

STEP	INSTRUCTION
6	The prompt AZ TO REAR: 0.00 appears. Enter the azimuth to the rear station. Press the END LINE key. This completes the entering of the known starting data. The azimuth is recorded in the AZIMUTH TO REAR (MILS): block of the DATA RECORD section.
7	The prompt MN SCH LEG (Y/N): appears. If the computer's response is Y (yes), the leg is classified as a main scheme station. Main scheme station data can be recalled for collection, review, or adjustment. If the computer's response is N (no), the leg is classified as an offset station. The offset data can be recalled only for correction or review during calculation and must be recorded as the results are displayed. Once the prompt AZ TO REAR: 0.000 is displayed and the END LINE key is pressed, data for the offset leg cannot be recalled.
8	The prompt HZ<FWD: 0.000 appears. The next step in the computations is to enter the measured field data. BUCS is requesting input of the first measured horizontal angle (HORIZONTAL ANGLE (MILS): block). Enter the angle, and press the END LINE key.
9	The prompts VA (+/-): 0.000 appears. BUCS is requesting input of the first measured vertical angle (VERTICAL ANGLE (MILS): block) along with the sign. If the sign of the vertical angle is minus, you must enter a minus sign before entering the vertical angle. If no sign is entered, the computer will consider the sign to be plus. Enter the vertical angle, and press the END LINE key.
10	The prompt RECIP VA (Y/N): appears. Enter Y or N by pressing the Y or N key, and press the END LINE key.
11	The prompt ^DIST FWD (-:SL/+:HZ) 0.000 appears. The ^ indicates the display window is full and a second prompt will follow. Do not try to enter the distance at this prompt. The plus and minus signs are used to inform the BUCS of the type of distance. The minus sign indicates a slope distance. The plus sign indicates a horizontal distance. If no sign is entered, the computer considers the distance to be horizontal (plus sign). Press the END LINE key. The second prompt will be : 0.000. Enter the distance, and press the END LINE key. Pressing the END LINE key at this point activates the computing mode of the BUCS.
12	The prompt HZ DIST: 0.000 appears. If the operator had indicated that the distance was a slope distance, the BUCS would convert the slope distance to a horizontal distance and the displayed distance would be slightly different from the slope distance. If a slope distance had been entered, you would record the computed horizontal sea level distance in the HORIZONTAL DISTANCE (METERS): block in the DATA RECORD section. Press the END LINE key.
13	The display shows E FWD STA: 0.00. This is the easting coordinates of the first computed station. Record the coordinates in the EASTING block. Press the END LINE key. Record the coordinates in the EASTING: block in the DATA RECORD section. Press the END LINE key.
14	The display shows N FWD STA: 0.000. This is the northing coordinates of the first computed station. Record the coordinates in the NORTHING: block in the DATA RECORD section.. Press the END LINE key.
15	The display shows HT FWD STA: 0.00. Record this height for the computed station in the HEIGHT (METERS): block in the DATA RECORD section.. Press the END LINE key.
16	The display shows AZ TO REAR: 0.0. Record this azimuth in the AZIMUTH TO REAR (MILS): block in the DATA RECORD section. This is the azimuth from the computed station back to the known station. If the azimuth from the known station to the computed station is needed, add or subtract 3200 from the azimuth. This completes computations of data for the first station. Be sure to number the station 2. Press the END LINE key.
17	The prompt CLOSURE (Y/N): appears. The BUCS is inquiring if the computer wishes to compute data for additional stations or closure data. If the response is N, press the END LINE key. The BUCS will go to step 7. Steps 7 through 17 are repeated for each station in the survey.

Figure 5-15. **Sample DA Form 5591-R (fifth-order traverse) (front)**

COMPUTATION OF COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE, AND VERTICAL ANGLE (BUCS)

For use of this form, see FM 6-2, the proponent agency is TRADOC

COMPUTER SSG PENA	NOTEBOOK REFERENCE FM 6-2	DATE 22 MAR 91
CHECKER SGT FRALIX	AREA FT. SILL	SHEET 1 OF 1 SHEETS

NOTES: 1 OFFSET LEGS ARE NOT GIVEN STATION NUMBERS
2 STEP 17, FOR ADDITIONAL LEGS, ENTER N AND PROGRAM GOES TO STEP 7
3 STEP 17 FOR CLOSURE ENTER Y AND PROGRAM GOES TO STEP 1 BACK OF FORM
4 FOUR TRAVERSE LEGS CAN BE RECORDED PER FORM
5 SEE BACK OF FORM FOR CLOSURE AND ADJUSTMENT
6 ENTER FIELD DATA IN BLOCKS MARKED ▶

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	REAR STATION: OCS WT	REAR STATION: OSA
1		CALL PROGRAM 2	STATION NAME: QM FINN, NUMBER: 1	STATION NAME: A EOL, NUMBER: 3
2	TRAVERSE			
3	E OCC STA 0.00	ENTER EASTING OF OCCUPIED STATION	EASTING: 554732.9	EASTING: 555000.11
4	N OCC STA 0.00	ENTER NORTHING OF OCCUPIED STATION	NORTHING: 3840371.7	NORTHING: 3840113.84
5	HT OCC STA 0.0	ENTER HEIGHT OF OCCUPIED STATION	HEIGHT (METERS): 337.8	HEIGHT (METERS): 341.6
6	AZ TO REAR 0.000	ENTER AZIMUTH TO REAR STATION	AZIMUTH TO REAR (MILS): 4433.4	AZIMUTH TO REAR (MILS): 5114.4
7	MN SCH LEG (Y/N)	ENTER Y OR N		
8	HZ < FWD 0.000	HORIZONTAL ANGLE TO FORWARD STATION	HORIZONTAL ANGLE (MILS): ▶ 4409.3	HORIZONTAL ANGLE (MILS): ▶ 1183.2
9	VA (+ -) 0.000	VERTICAL ANGLE TO FORWARD STATION	VERTICAL ANGLE (MILS): ▶ ⊙ 10.9	VERTICAL ANGLE (MILS): ▶ ⊙ 34.2
10	RECIP VA (Y/N)	ENTER Y OR N	~~(RECIPROCAL)~~ (NONRECIPROCAL)	~~(RECIPROCAL)~~ (NONRECIPROCAL)
11	*DIST FWD (-SL +HZ) 0.000	ENTER HORIZONTAL OR SLOPE DISTANCE	SLOPE DISTANCE (METERS): ▶ ( )	SLOPE DISTANCE (METERS): ▶ ( )
12	HZ DIST 0.000	RECORD HORIZONTAL DISTANCE	HORIZONTAL DISTANCE (METERS): ▶ · 331.96	HORIZONTAL DISTANCE (METERS): ▶ · 225.36
			STATION NAME: OSA, NUMBER: 2	STATION NAME: BN SCP, NUMBER: 4
13	E FWD STA 0.00	RECORD EASTING	EASTING: 554957.51	EASTING: 554977.50
14	N FWD STA 0.00	RECORD NORTHING	NORTHING: 3840127.43	NORTHING: 3840337.98
15	HT FWD STA 0.0	RECORD HEIGHT	HEIGHT (METERS): 341.4	HEIGHT (METERS): 349.2
16	AZ TO REAR 0.000	RECORD AZIMUTH TO REAR	AZIMUTH TO REAR (MILS): 5642.7	AZIMUTH TO REAR (MILS): 3097.6
17	CLOSURE (Y/N)	ENTER Y OR N		
REMARKS			HORIZONTAL ANGLE (MILS): ▶ 2671.7	HORIZONTAL ANGLE (MILS): ▶
			VERTICAL ANGLE (MILS): ▶ ⊙ 6.3	VERTICAL ANGLE (MILS): ▶ ·
			~~(RECIPROCAL)~~ (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
			SLOPE DISTANCE (METERS): ▶ ( )	SLOPE DISTANCE (METERS): ▶ ( )
			HORIZONTAL DISTANCE (METERS): ▶ · 44.73	HORIZONTAL DISTANCE (METERS): ▶ ·

SAMPLE

DA FORM 5591-R, DEC 86

Table 5-3. **Instructions for computing DA Form 5591-R (reverse)**

STEP	INSTRUCTION
1	The display prompts CLOSING: 0.000. The procedure in the PROCEDURE column is ENTER CLOSING ANGLE. Enter the closing horizontal angle in the CLOSING ANGLE (MILS): block. Press the END LINE key.
2	The display prompts CMPTD AZ: 0.000. The procedure is RECORD AZIMUTH FORWARD. Record the azimuth in the COMPUTED AZIMUTH FORWARD (MILS): block. This is the azimuth to the closing azimuth mark computed by BUCS from the entered starting azimuth and the measured horizontal angles. Press the END LINE key.
3	The display prompts KN AZ FWD: 0.000 appears. The procedure is ENTER KNOWN AZIMUTH. Enter the known azimuth to the closing azimuth mark. Record it in the KNOWN AZIMUTH FORWARD (MILS): block in the DATA RECORD section. Press the END LINE key.
4	The display prompts AZ CORR: 0.000. The procedure is RECORD TOTAL AZIMUTH CORRECTION. Record the azimuth correction in the TOTAL AZIMUTH CORRECTION (MILS): block in the DATA RECORD section. This is the difference between the known azimuth and the azimuth established by the survey. The operator must ensure the azimuth meets closure specifications. Check survey specification for traverse (Appendix B). Press the END LINE key.
5	The display prompts KN HT: 0.0. The procedure is ENTER THE KNOWN HEIGHT. Enter the known height. Record it in the KNOWN HEIGHT (METERS): block in the DATA RECORD section. Press the END LINE key.
6	The display prompts HT CORR: 0.0. The procedure is RECORD TOTAL HEIGHT CORRECTION. Record the height correction in the TOTAL HEIGHT CORRECTION (METERS): block in the DATA RECORD section. This is the difference between the known height of the closing station and the surveyed height of the point. Check survey specifications for traverse (Appendix B). Press the END LINE key.
7	The display prompts KN EAST: 00.0. The procedure is ENTER THE KNOWN EASTING. Enter the known easting coordinates of the closing station. Record them in the KNOWN EASTING: block in the DATA RECORD section. Press the END LINE key.
8	The display prompts KN NORTH: 0.00. The procedure is ENTER THE KNOWN NORTHING. Enter the known northing coordinates of the closing station. Record them in the KNOWN NORTHING: block in the DATA RECORD section. Press the END LINE key.
9	The display prompts TTL: 0.000. The procedure is RECORD TOTAL TRAVERSE LENGTH. Record the traverse length in the TOTAL TRAVERSE LENGTH (METERS): block in the DATA RECORD section. This is the sum of the main scheme horizontal distances. Press the END LINE key.
10	The display prompts RE: 0.00. The procedure is RECORD RADIAL ERROR. Record the radial error in the RADIAL ERROR (METERS): block in the DATA RECORD section. This is the straight line distance between the known coordinates of the closing survey control point and the coordinates of the point established by the survey. Press the END LINE key.
11	The display prompts AR: 1/. The procedure is RECORD ACCURACY RATIO. Record the accuracy ratio in the ACCURACY RATIO: block in the DATA RECORD section. The computed accuracy ratio is always reduced to the next lower hundred and recorded on the right side of the accuracy ratio block. Press the END LINE key.
12	The display prompts ^ADJUST (Y/N): The procedure is ENTER Y OR N. BUCS is inquiring if the computer wants to adjust the traverse survey. Fifth-order traverse surveys are not adjusted; therefore, the response will be N (the program will skip to step 19). When fourth-order traverse operations are being performed, the correct response is Y because fourth-order traverse surveys are adjusted for coordinates, height, and azimuth.
13	The display prompts STA__ The procedure is RECORD STATION NUMBER. Enter the number of the station to be adjusted. Press the END LINE key.
14	The display prompts EAST: 0.00. The procedure is RECORD ADJUSTED EASTING. Record the adjusted easting coordinates of the station in the EASTING: block in the DATA RECORD section. Press the END LINE key.
15	The display prompts NORTH: 0.00. The procedure is RECORD ADJUSTED NORTHING. Record the adjusted northing coordinates of the station in the NORTHING: block in the DATA RECORD section. Press the END LINE key.

Table 5-3. **Instructions for computing DA Form 5591-R (reverse) (continued)**

STEP	INSTRUCTION
16	The display prompts HT: 0.0. The procedure is RECORD ADJUSTED HEIGHT. Record the adjusted height of the station in the HEIGHT (METERS): block in the DATA RECORD section. Press the END LINE key.
17	The display prompts AZ TO REAR: 0.000. The procedure is RECORD ADJUSTED AZIMUTH TO REAR. Record the adjusted azimuth to the rear station in the ADJUSTED AZIMUTH TO REAR (MILS): block. Press the END LINE key.
18	The display prompts AZ FWD AZMK: 0.000. The procedure is RECORD ADJUSTED AZIMUTH FORWARD. Record the adjusted azimuth in the ADJUSTED AZIMUTH FORWARD (MILS): block in the DATA RECORD section. Press the END LINE key.
19	The display prompts END OF MSN (Y/N): This is the last point in the program at which data can be retrieved. A response of Y will cause the BUCS to clear its memory of the traverse data and return to the display prompt of SURVEY PGM MENU REV1. A response of N will cause the BUCS to return to the previous display prompt, and data can be recalled.

(3) The operator must enter the known closing station data to allow computation of the following:

- Total traverse distance.
- Total azimuth and height corrections.
- Radial error of closure.
- Traverse accuracy ratio.
- Adjusted traverse station data.

(See Figure 5-16.)

(4) The basic design of DA Form 5591-R is the same as DA Form 5590-R. In the DATA RECORD section, there are spaces for recording the starting data, the field data for four traverse stations, and the computed data for three traverse stations. The computed data for the fourth station must be recorded on another form. Additional forms are used as required. Closure and adjustment data are recorded on the reverse side of the form.

(5) The administrative information is entered in the six spaces provided on the top of each form. When a survey operation is conducted, all information must be recorded.

(6) The names of the stations are entered in the blocks on the left side of the DATA RECORD section. Start with the REAR STATION: block, and then complete the STATION NAME: blocks for the forward and known stations. Number the known station 1. Each station name in a traverse must be written and numbered.

(7) The coordinates of the known point are recorded in the EASTING: and NORTHING: blocks of the DATA RECORD section.

(8) The height of the known point is recorded in the HEIGHT (METERS): block, The height is obtained from a trig list of local survey control.

(9) The azimuth from the known point to an azimuth mark is recorded in the AZIMUTH TO REAR (MILS): block.

(10) The next information recorded on the form is the measured field data- horizontal angles, vertical angles (with sign and whether reciprocal or nonreciprocal noted), and the distances (whether horizontal or slope noted). The field data must be obtained from the recorder. The recorder also provides the station names. Enter the data in the blocks with the black triangle.

c. The computer is now ready to compute the first leg of the traverse.

d. The reverse side of DA Form 5591-R is used to record the closing data for the survey just computed. The format of the front and reverse sides of the form is similar. The DATA RECORD section has spaces for recording the known closing data, the measured closing horizontal angle, the computed closing data, and the adjusted data for four stations. Fifth-order surveys are not adjusted.

Note. If the response in step 17 is Y; END LINE, the steps in e and f below are followed.

e. If the computer wishes to compute closure date, he must record the known data of the closing station on the reverse side of the form. He records these data as discussed below.

(1) Record the closing horizontal angle in the CLOSING ANGLE (MILS): block. The angle is obtained from the recorder.

(2) Record the known closing azimuth in the KNOWN AZIMUTH FORWARD (MILS): block. This azimuth may be determined from a trig list, by using an azimuth gym, by astronomic observation, by computation, or by PADS.

Figure 5-16. **Sample DA Form 5591-R (fifth-order traverse) (reverse)**

CLOSURE ADJUSTMENT

NOTES: 1. STEP 11 CHECK SPECIFICATIONS ON CLOSURE.
2. IF STEP 12 IS N, PROGRAM GOES TO STEP 19.
3. IF STEP 12 IS Y, PROGRAM PERFORMS ADJUSTMENT ON EACH MAIN SCHEME STATION OF THE TRAVERSE.
4. FOUR ADJUSTED STATIONS CAN BE RECORDED PER FORM.

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	CLOSURE DATA	ADJUSTED DATA
1	CLOSING <: 0.000	ENTER CLOSING ANGLE	CLOSING ANGLE (MILS): 4211.1	STATION NAME:
2	CMPTD AZ: 0.000	RECORD AZIMUTH FORWARD	COMPUTED AZIMUTH FORWARD (MILS): 0908.7	STATION NUMBER:
3	KN AZ FWD: 0.000	ENTER KNOWN AZIMUTH	KNOWN AZIMUTH FORWARD (MILS): 0908.9	EASTING:
4	AZ CORR: 0.000	RECORD TOTAL AZIMUTH CORRECTION	TOTAL AZIMUTH CORRECTION (MILS): +.2	NORTHING:
5	KN HT: 0.0	ENTER KNOWN HEIGHT	KNOWN HEIGHT (METERS): 349.5	HEIGHT (METERS):
6	HT CORR: 0.0	RECORD TOTAL HEIGHT CORRECTION	TOTAL HEIGHT CORRECTION (METERS): +.3	ADJUSTED AZIMUTH TO REAR (MILS):
7	KN EAST: 000.0	ENTER KNOWN EASTING	KNOWN EASTING: 554977.4	STATION NAME:
8	KN NORTH: 0.00	ENTER KNOWN NORTHING	KNOWN NORTHING: 3840337.7	STATION NUMBER:
9	TTL: 0.000	RECORD TOTAL TRAVERSE LENGTH	TOTAL TRAVERSE LENGTH (METERS): 602.05	EASTING:
10	RE: 0.00	RECORD RADIAL ERROR	RADIAL ERROR (METERS): .30	NORTHING:
11	AR: 1:	RECORD ACCURACY RATIO	ACCURACY RATIO: 1/2004 = 1/2000	HEIGHT (METERS):
			ADJUSTED DATA	ADJUSTED AZIMUTH TO REAR (MILS):
12	ADJUST (Y/N):	ENTER Y OR N	STATION NAME:	STATION NAME:
13	STA: —	RECORD STATION NUMBER	STATION NUMBER:	STATION NUMBER:
14	EAST: 0.00	RECORD ADJUSTED EASTING	EASTING:	EASTING:
15	NORTH: 0.00	RECORD ADJUSTED NORTHING	NORTHING:	NORTHING:
16	HT: 0.0	RECORD ADJUSTED HEIGHT	HEIGHT (METERS):	HEIGHT (METERS):
17	AZ TO REAR: 0.000	RECORD ADJUSTED AZIMUTH TO REAR	ADJUSTED AZIMUTH TO REAR (MILS):	ADJUSTED AZIMUTH TO REAR (MILS):
18	AZ FWD AZMK: 0.000	RECORD ADJUSTED AZIMUTH FORWARD		ADJUSTED AZIMUTH FORWARD (MILS):
19	END OF MSN (Y/N):	ENTER Y OR N		

REMARKS:

SAMPLE

REVERSE OF DA FORM 5591-R, DEC 86

(3) Record the known height in the KNOWN HEIGHT (METERS): block the known casting in the KNOWN EASTING: block, and the known northing in the KNOWN NORTHING: block. These data may be obtained from a trig list, or they could be provided by the supporting survey element.

f. The computer ensures the BUCS is still displaying the prompt CLOSURE (Y/N): The actions required to compute the closing data are to press the Y key and then the END LINE key. The BUCS now starts computing the closing data for the survey.

5-21. RECIPROCAL MEASUREMENT OF VERTICAL ANGLES

The effects of the curvature of the earth and atmospheric refraction must be considered for traverse legs in excess of 1,000 meters. Vertical angles at each end of such a leg are measured to compensate for these effects. When vertical angles are measured reciprocally, the vertical angle at each end of the leg should be measured to the same height above the station (normally the HI).

5-22. ACCURACY RATIO

a. Certain minimum accuracy requirements are prescribed for survey fieldwork and computations. These accuracies are based on the requirements of installations to be surveyed (howitzer position or molar position). To determine whether this accuracy requirement has been met for a closed traverse, an accuracy ratio is computed. If the accuracy requirement is not met and the errors cannot be determined, the traverse must be performed again.

b. An accuracy ratio is expressed as a ratio between the radial error of closure and the total length of the traverse (for example, 1:3,000, 1:1,000). It may also be expressed as a fraction with a numerator of 1 (for example, 1/3000, 1/1000). The radial error of closure is the linear distance between the known coordinates of the closing point and the computed coordinates of the closing point as determined from the survey. The total length of the traverse is the sum of the lengths of all traverse legs (excluding distances to offset stations). The numerator of the accuracy ratio is 1; the denominator is equal to the total length of the traverse divided by the radial error of closure. The equation for the accuracy ratio is as follows:

$$\text{Accuracy ratio} = \frac{1/\text{ total length of traverse}}{\text{radial error of closure}}$$

c. After the accuracy ratio has been computed, the denominator of the fraction is always reduced to the next lower hundred (for example, 1/3879 becomes 1/3800).

5-23. RADIAL ERROR OF CLOSURE

a. The radial error of closure is determined by comparing the correct coordinates of the closing point with the computed coordinates of that point and determining the differences. The difference between the two castings of the closing point, or error in casting (eE), forms one side of a right triangle. The difference between the two northings of the closing point, or error in northing (eN), forms the second side of the triangle. The hypotenuse of this right triangle is the radial error of closure. (See Figure 5-17.) It is computed by using DA Form 5590-R or the Pythagorean theorem. From the Pythagorean theorem, it is derived that the radial error of closure is equal to the square root of the sum of the square of the error in casting and the square of the error in northing. The equation for computing the radial error is as follows:

$$\text{Radial error of closure} = \sqrt{(eE)^2 + (eN)^2}$$

EXAMPLE

Known coordinates of closing point	555131.89	3839365.46
Computed coordinates of closing point	555131.33	3839364.74
Error of closure	0.56	0.72
Radial error	$\sqrt{(0.56)^2 + (0.72)^2} = \sqrt{0.83} = 0.91$	

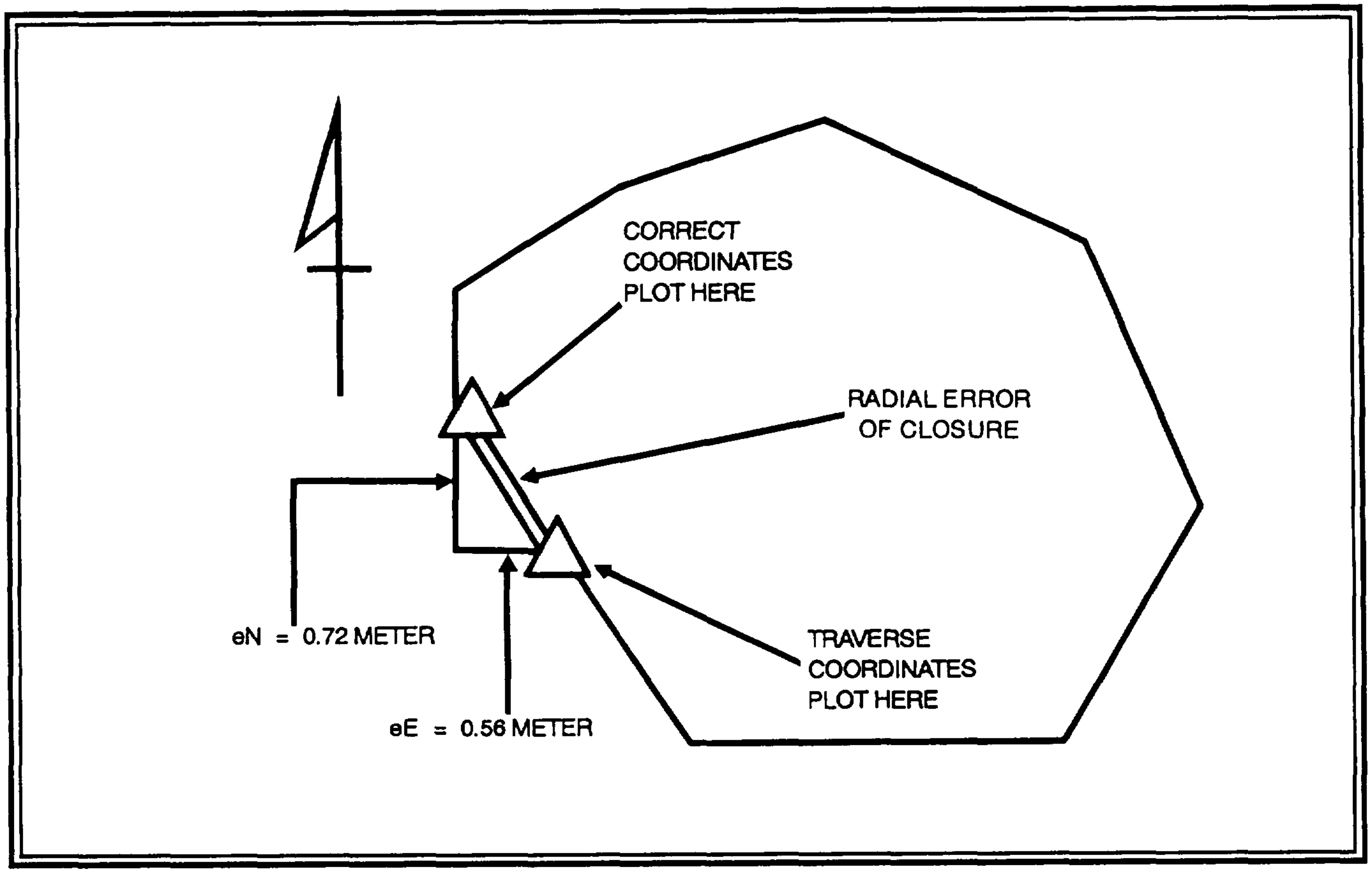
If computed by using the BUCS, the equation is computed as follows:

SQR(.56^2 + .72^2) END LINE = .91

b. The maximum allowable error in position closure for a fourth-order traverse generally is expressed as 1:3,000, or 1 unit of radial error for each 3,000 similar units of traverse. A maximum allowable radial error for a fourth-order survey is determined in one of two ways. If the traverse is less than 9,000 meters in length, the maximum allowable radial error is determined by dividing the total length of the traverse by 3,000. For example, in a 3,469.91-meter fourth-order traverse, the maximum allowable radial error by the 1:3,000 evaluation is 1.15 meters (3,469.91 + 3,000). When the traverse length exceeds 9,000 meters (9 km), the accuracy achieved may be within 1:3,000 yet the radial error will be excessive. Therefore, the maximum allowable radial error (AE) is determined by the following formula:

$AE = \sqrt{K}$ in which AE = allowable radial error and K = total (main scheme) length of the traverse to the nearest 0.1 km.

Figure 5-17. **Radial error of closure**



For example, using the 1:3,000 evaluation in a traverse 37.3 km in length would allow a maximum radial error of 12.4 meters (37,300 + 3,000). Whereas $\sqrt{K}$ would allow a maximum radial error of 6.1 meters ($\sqrt{37.30} = 6.1$). The result of the method used will then be compared with the radial error computed for the traverse to determine if the traverse radial error meets the requirement. The traverse must be rerun when the radial error exceeds the computed maximum allowable radial error and no error can be determined.

EXAMPLE

Compute the accuracy ratio for a fourth-order traverse of less than 9,000 meters in length as follows:

Radial error	0.91 meter
Total length of traverse	3,469.91 meters
Accuracy ratio	$\frac{1}{3469.91 \div 0.91}$ $\frac{1}{3813}$ or $\frac{1}{3800}$

5-24. CLOSING AZIMUTH ERROR

The closing azimuth error is determined by comparing the known closing azimuth with the closing azimuth determined by the traverse. The difference between the two is the closing azimuth error. The error is considered to be within tolerance if it does not exceed 0.1 mil per main scheme angle for fifth-order traverse. Fourth-order traverses are evaluated for azimuth closure in two ways. If the number of main scheme angles is six or less, multiply the number of main scheme angles by 0.04. For traverses of seven or more main scheme angles, multiply the square root of the number of main scheme angles by 0.1 (Appendix B).

5-25. ACCURACIES, SPECIFICATIONS, AND TECHNIQUES

The overall accuracy of a traverse depends on the equipment and methods used in the measurements, the accuracy achieved during the fieldwork, and the accuracy of the starting and closing data.

a. Fourth-Order Accuracy. Normally, fourth-order surveys are performed by the div arty survey platoon and the TAB survey platoon to extend survey control to using units. The maximum allowable error in position closure for an artillery fourth-order traverse generally is expressed as 1:3,000, or 1 unit of radial error for each 3,000 similar units of traverse executed. A fourth-order traverse starting from existing survey control must start and close on stations established to fourth-order accuracy or higher. If survey control of the required accuracy is not available, the fieldwork and computations can be computed and the traverse evaluated for accuracy (accuracy ratio determined) by using assumed starting data, provided the traverse is ended at the starting station. The T2 theodolite is used to measure the angles. Horizontal angles are measured as one-position angles (1 D/R). Vertical readings are taken once with the telescope in the direct position and once in the reverse position (1 D/R). The vertical angle is then computed. If traverse legs are greater than 1,000 meters in length, vertical readings must be observed reciprocally. Distances are double taped with the 30-meter steel tape to a comparative accuracy of 1:5,000. When the SEDME is used, three readings must be taken to determine the distance.

(1) Position accuracy. The procedure used to evaluate the position accuracy of a fourth-order traverse depends on the length of the main scheme of the traverse. Traverses of less than 9,000 meters in main scheme length are evaluated by determining accuracy ratios as explained in paragraph 5-23b. However, when the traverse length exceeds 9,000 meters, the accuracy achieved may be excessive. Therefore, when the main scheme length of the traverse exceeds 9,030 meters (9 km), the maximum allowable radial error is computed by the formula $AE = \sqrt{K}$, in which K is the total length of the traverse to the nearest 0.1 km.

EXAMPLE

Total length of traverse = 14,823.24

$AE = \sqrt{K}$

$AE = \sqrt{14.8}$

AE = 3.85 meters

Therefore, in this example, 3.85 meters is the maximum allowable radial error for the traverse length. If the radial error of the traverse exceeds 3.85 meters and no errors are determined, the traverse must be rerun.

(2) Azimuth closure. The allowable error in azimuth closure depends on the number of main scheme angles used in carrying the azimuth through the traverse. If the traverse exceeds 25 main scheme angles, then azimuth must be checked by comparing the computed azimuth with an astronomic azimuth, gyroscopic azimuth, a preestablished azimuth or a PADS azimuth. The allowable azimuth error in mils for a traverse having no more than six main scheme angles is computed by the formula AE = 0.04 x N, in which N is the number of main scheme angles used to carry azimuth. If there are more than six main scheme angles in the traverse, the allowable azimuth error is computed by the formula $AE=0.1\sqrt{N}$.

(3) Height accuracy. The allowable error in meters for the height closure of a traverse of any length performed to fourth-order accuracy is also computed by the formula $AE = \sqrt{K}$.

b. Fifth-Order Accuracy. NormalIy, FA battalions perform fifth-order survey to establish survey control for the firing units of the battalion. A fifth-order traverse starting from existing control must start and close on stations established to fifth-order accuracy or greater. When survey control of the required accuracy is not available, the fieldwork and computations can be completed and the traverse evaluated for accuracy (accuracy ratio) by using assumed starting data, provided the traverse is closed on the starting station. The T16 theodolite is used to measure the angles. Horizontal angles are turned one position with the T16 theodolite. Vertical readings arc taken once with the telescope in the direct position and once with the telescope in the reverse position (1 D/R), The vertical angle is then computed. Distances, when measured with the 30-meter steel tape, are single taped and checked for gross errors by pacing. When distances are measured with the SEDME, three readings will be taken.

(1) Position accuracy. The maximum allowable error in position closure is expressed by the accuracy ratio of 1:1,000, or 1 unit of error for each 1,000 similar units of traverse executed.

(2) Azimuth closure. The allowable error in azimuth closure is computed by the formula AE = 0.1 mil x N, in which N is the number of main scheme angles in the traverse After 20 main scheme angles, azimuth must be checked by comparing the computed azimuth with an astronomic azimuth gyroscopic azimuth, a preestablished azimuth, or a PADS azimuth.

(3) Height accuracy. The maximum allowable error in height closure is 2 meters for traverses of less than 4,000 meters. For traverses over 4,000 meters, use the formula $AE = 1.2 \times \sqrt{K}$ to compute allowable error.

Section IV

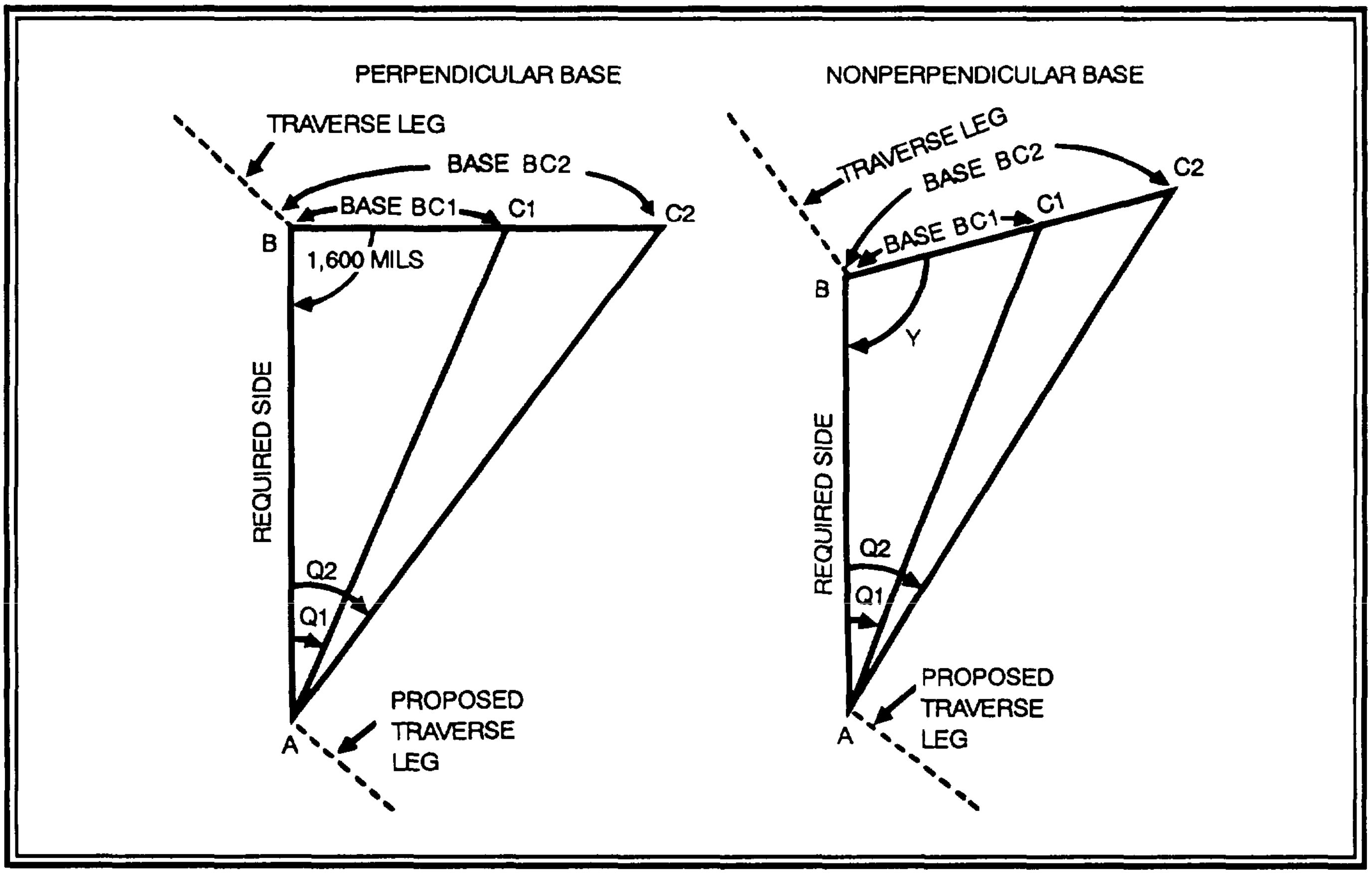
TRIG TRAVERSE

When a traverse is conducted in the field, it may be impossible to tape or electronically measure a traverse leg because of the terrain, electrical interference, or equipment failure. If this occurs, a method known as trig traverse may be used. When properly executed, this method is adequate for accomplishing fourth- and fifth-order traverse requirements. The trig traverse method uses the triangular figure, the base of which is carefully measured.

5-26. METHOD

In the trig traverse method, the base of the triangle need not be established perpendicular to the required side of the triangle but may be established at an angle more convenient for measurement. When possible, however, it should be placed perpendicular to the required side by using the theodolite to place the base ends at right angles to the desired side. If it is not possible to make the base perpendicular, the angle formed by the base and the desired side must be measured. The base must be long enough to minimize the effects of instrumental error on the distance to be measured. To do this, the base must be longer than one-twentieth and preferably about one-tenth of the distance to be determined. In Figure 5-18, the length to be determined is the line AB. Two independent bases are measured to offset the slight inaccuracy that will prevail in the base measurement and to provide a check on the work. The bases are shown by the lines BC1 and BC2. The shortest base should not be less than one-twentieth of the required distance.

Figure 5-18. **Trig traverse method**



5-27. BASE ACCURACY

The accuracy of the base measurement is the key to a succesful trig traverse. When the base length is one-twentieth of the required side and an error of 0.01 meter was made in determining the length of the base, the result is an error of 0.20 meter in determining the computed length of the base. Each base should be double taped separately within a comparative accuracy of 1:7,000 for fourth order and 1:3,000 for fifth order. The distance C1 to C2 is also measured to provide a check. Reasonable control over the accuracy of the distance measurements can be exercised by limiting the ratio of the length of the base to the length to be computed.

5-28. ANGLES

a. In fourth-order survey, the T2 theodolite is used for angle measurement. Two-position horizontal angles are measured. If the two measured values for any angle differ by more than 0.050 mil, these angles will be rejected and remeasured.

b. In fifth-order survey, the T16 theodolite is used for angle measurement. One-position horizontal angles are measured.

5-29. TARGETS

Because of the very short distance to the end of the base, the targets must be designed for accurate pointings. The string of a suspended plumb bob or a sharpened pencil point may be sighted on. On longer bases, a range pole may be used, provided the range pole is very carefully plumbed over the point. If available, a tripod-mounted target may also be used. It also must be carefully leveled and plumbed over the point.

5-30. DISTANCE COMPUTATION

Two independent lengths (AB1 and AB2) are computed, one from each base. The mean of the two computed lengths is the required distance. A comparative accuracy is computed to determine the reliability of the computed distance. For fourth-order survey, the required side accuracy must be at least 1:5,000; and for fifth-order survey, at least 1:1,000. Computations for perpendicular and nonperpendicular bases without the use of DA forms are described below.

a. Perpendicular Base. If the base is perpendicular to the required side, the distance is easily computed by using the following formulas:

$$AB1 = \cot Q1 \times BC1$$

$$AB2 = \cot Q2 \times BC2$$

AB is the required distance (AB1 is the first distance, AB2 is the seared distance), Q1 is the angle from B to Cl, Q2 is the angle from B to C2, BC1 is the distance from B to C1, and BC2 is the distance from B to C2. See the perpendicular base in Figure 5-18.

b. Nonperpendicular Base. When the base is not perpendicular, the distance is computed by using the following formulas:

$$AB1 = \frac{BC1 \times \sin (Q1 + Y)}{\sin Q1}$$

$$AB2 = \frac{BC2 \times \sin (Q2 + Y)}{\sin Q2}$$

Y is the angle formed by the base and the required side. See the nonperpendicular base in Figure 5-18.

5-31. DA FORM 5603-R

Trig traverse is computed with the BUCS and by using DA Form 5603-R (Computation of Trig Traverse/Subtense (BUCS)), (A reproducible copy of this form is included at the back of this book.) This form follows the same basic format of the BUCS forms used in computing the traverse.

a. The top of the form is for recording administrative data. Data in this area include the following:

- Computer.
- Name of the individual who checks the computations (checker).
- Area in which survey was performed.
- Notebook reference.
- Date computations were performed.
- Identification of the sheet number.

b. The next part of the form provides notes for the specific operations of the program and other notes needed to complete the form.

c. The next part of the form is divided into two major sections. The section on the left provides instructions for the operator to complete the program.

(1) The right section is for recording data-both field and computed. Two trig traverses may be computed on each form.

(2) The left section is divided in three columns-STEP, PROMPT, and PROCEDURE. The STEP column is the numerical sequence the operator uses as he proceeds down the form. The PROMPT column tells the operator what will appear on the BUCS display at each particular step. The PROCEDURE column tells the operator what action he should take at each particular step or prompt.

Table 5-4. **Instructions for computing DA Form 5603-R**

STEP	INSTRUCTION
1	There is no prompt. The procecure in the PROCEDURE column is CALL PROGRAM 11. Call Program 11. At this point, the computer enters the survey module and calls up the required program.
2	The prompt TRIG TRAV (Y/N): appears. The procedure is ENTER Y. Enter Y by pressing the Y key and then the END LINE key. This program also computes a subtense.
3	The prompt ANGLE Q1: 0.000 appears. The procedure is ENTER ANGLE Q1. Enter Angle Q1 by entering the value of the angle measured from Point B to Point C1 or from Point C1 to Point B. Record the value in the ANGLE Q1 (MILS): block in the DATA RECORD section. Press the END LINE key.
4	The prompt ANGLE Q2: 0.000 appears. The procedure is ENTER ANGLE Q2. Enter Angle Q2 by entering the value of the angle measured from Point B to Point C2 or from Point C2 to Point B. Record the value in the ANGLE Q2 (MILS): block in the DATA RECORD section. Press the END LINE key.
5	The prompt BASE B/C1: 0.000 appears. The procedure is ENTER BASE B TO C1. Enter base B to C1 by entering the distance measured from Point B to Point C1. Record the value in the BASE B TO C1 (METERS): block in the DATA RECORD section. Press the END LINE key.
6	The prompt BASE B/C2: 0.000 appears. The procedure is ENTER BASE B TO C2. Enter base B to C2 by entering the distance measured from Point B to Point C2. Record the value in the BASE B TO C2 (METERS): block in the DATA RECORD section. Press the END LINE key.
7	The prompt PERPENDICULAR (Y/N): appears.The procedure in ENTER Y OR N. Enter Y or N by using either the Y or N key. Press the END LINE key. At this step, the computer tells the BUCS whether the base was established perpendicular or nonperpendicular to the required side. If the answer to this step is Y, the program will skip step 8 and go to step 9. If the answer to this step is N, the program will go to step 8.
8	The prompt ANGLE Y: 0.000 appears.The procedure is ENTER ANGLE Y. Enter Angle Y by entering the angle measured from Point A to the base or from the base to Point A. Record the value in the ANGLE Y (MILS): block in the DATA RECORD section.
9	The prompt DIST #1: 0.000 appears. The procedure is RECORD DISTANCE #1. Record distance number 1 in the DISTANCE NUMBER 1 (METERS): block in the DATA RECORD section. Press the END LINE key.
10	The prompt DIST #2: 0.000 appears. The procedure is RECORD DISTANCE #2. Record distance number 2 in the DISTANCE NUMBER 2 (METERS): block in the DATA RECORD section. Press the END LINE key.
11	The prompt MN DIST: 0.000 appears. The procedure is RECORD MEAN DISTANCE. At this step, record the mean computed distance in the MEAN DISTANCE (METERS): block. This is the mean of distances 1 and 2. Press the END LINE key
12	The prompt CA:1/ appears. The procedure is RECORD COMPARATIVE ACCURACY. Record the comparative accuracy in the COMPARATIVE ACCURACY: block in the DATA RECORD section. Record the accuracy exactly as displayed on the BUCS, express it to the next lower hundred, and record it in the same block in the DATA RECORD section. Press the END LINE key.
13	The prompt ANOTHER TRIG (Y/N): appears. The procedure is ENTER Y OR N. Enter Y or N by using the Y or N key. Press the END LINE key. If the answer to this step is Y, the program returns to step 2. If the answer to this step is N, the program goes to step 14.
14	The prompt END OF MSN (Y/N): appears. The procedure is ENTER Y OR N. Enter Y or N by using the Y or N key. Press the END LINE key. If the answer to this step is Y, the program returns to SURVEY PGM MENU REV1. If the answer to this step is N, the program returns to step 13.

Figure 5-19. **Sample DA Form 5603-R**

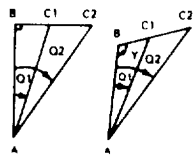
COMPUTATION OF TRIG TRAVERSE/SUBTENSE (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER SSG PENA	NOTEBOOK REFERENCE FM 6-2	DATE 22 MAR 91
CHECKER SGT FRALIX	AREA FT. SILL	SHEET 1 OF 1 SHEETS

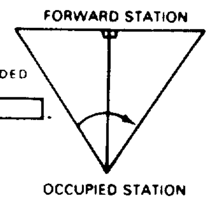
TRIG TRAVERSE

NOTES: 1. IF STEP 7 IS Y PROGRAM GOES TO STEP 8.
2. IF STEP 7 IS N PROGRAM GOES TO STEP 9.
3. STEP 12 CHECK SPECIFICATIONS.
4. IF STEP 13 IS Y PROGRAM GOES TO STEP 2.
5. IF STEP 13 IS N PROGRAM GOES TO STEP 14.
6. TWO TRIG-TRAVERSE PROBLEMS CAN BE RECORDED PER FORM.
7. ENTER FIELD DATA IN BLOCKS MARKED ▶.



SUBTENSE

NOTES: 1. IF STEP 7 IS Y, PROGRAM GOES TO STEP 2
2. IF STEP 7 IS N, PROGRAM GOES TO STEP 8
3. TWO SUBTENSE PROBLEMS CAN BE RECORDED PER FORM
4. ENTER FIELD DATA IN BLOCKS MARKED ▶.



TRIG-TRAVERSE INSTRUCTIONS / TRIG-TRAVERSE DATA RECORD

STEP	PROMPT	PROCEDURE	DATA RECORD (1)	DATA RECORD (2)
1		CALL PROGRAM 11		
2	TRIG TRAV (Y/N):	ENTER Y		
3	ANGLE Q1: 0.000	ENTER ANGLE Q1	▶ ANGLE Q1 (MILS): 36.9	▶ ANGLE Q1 (MILS): 98.717
4	ANGLE Q2: 0.000	ENTER ANGLE Q2	▶ ANGLE Q2 (MILS): 42.6	▶ ANGLE Q2 (MILS): 103.630
5	BASE B/C1: 0.000	ENTER BASE B TO C1	▶ BASE B TO C1 (METERS): 100.00	▶ BASE B TO C1 (METERS): 300.00
6	BASE B/C2: 0.000	ENTER BASE B TO C2	▶ BASE B TO C2 (METERS): 115.71	▶ BASE B TO C2 (METERS): 315.00
7	PERPENDICULAR (Y/N)	ENTER Y OR N	N	Y
8	ANGLE Y: 0.000	ENTER ANGLE Y	▶ ANGLE Y (MILS): 1959.7	▶ ANGLE Y (MILS): ~~~
9	DIST#1: 0.000	RECORD DISTANCE #1	DISTANCE NUMBER 1 (METERS): 2554.358	DISTANCE NUMBER 1 (METERS): 3085.792
10	DIST#2: 0.000	RECORD DISTANCE #2	DISTANCE NUMBER 2 (METERS): 2554.441	DISTANCE NUMBER 2 (METERS): 3085.483
11	MN DIST: 0.000	RECORD MEAN DISTANCE	MEAN DISTANCE (METERS): 2554.399	MEAN DISTANCE (METERS): 3085.638
12	CA:1/	RECORD COMPARATIVE ACCURACY	COMPARATIVE ACCURACY: 1 30,600	COMPARATIVE ACCURACY: 1 9,900
13	ANOTHER TRIG (Y/N):	ENTER Y OR N		
14	END OF MSN (Y/N):	ENTER Y OR N		

SAMPLE

SUBTENSE INSTRUCTIONS / SUBTENSE DATA RECORD

STEP	PROMPT	PROCEDURE	DATA RECORD (1)	DATA RECORD (2)
1		CALL PROGRAM 11		
2	TRIG TRAV (Y/N):	ENTER N		
3	SUBTENSE			
4	SUBTENDED <: 0.000	ENTER SUBTENDED ANGLE	▶ SUBTENDED ANGLE (MILS):	▶ SUBTENDED ANGLE (MILS):
5	SUBT BASE: 0.000	ENTER SUBTENDED BASE	▶ SUBTENDED BASE (METERS):	▶ SUBTENDED BASE (METERS):
6	HZ DIST: 0.000	RECORD HORIZONTAL DISTANCE	HORIZONTAL DISTANCE (METERS):	HORIZONTAL DISTANCE (METERS):
7	ANOTHER SUBT (Y/N):	ENTER Y OR N	REMARKS:	
8	END OF MSN (Y/N):	ENTER Y OR N		

DA FORM 5603-R, DEC 86

Section V

LOCATION OF TRAVERSE ERRORS

A good survey plan executed by a well-trained party provides for numerous checks in both computations and fieldwork. However, these checks do not always eliminate errors. On the contrary, errors made both in fieldwork and in computations often are not discovered until the survey has been completed. The FA surveyor must, therefore, be able to isolate these errors and determine their causes. Often, a critical analysis of both the fieldwork and the computations of a survey in error will save additional hours of repetitious labor and computation.

5-32. ANALYSIS OF TRAVERSE FOR ERRORS

To rapidly analyze a survey, a well-trained chief of survey party will maintain a sketch of the fieldwork, to state, of each survey as it is being conducted. If a reliable map is available, it will allow him to check errors that may occur in either the fieldwork or the computations. If, upon completion of the survey, an error is apparent, then the following assumptions can be made. To isolate an error in a traverse, an assumption must be made that only one error exists. If more than one error exists, isolation of the error may not be possible. Under some conditions, when there is more than one error in a traverse, an apparent solution will exist; however, an investigation of the error isolated may show that both fieldwork and computations are correct for the station in question, When this condition exists, no effort should be made to continue an analysis. Instead, provisions should be made to perform the entire traverse again. Table 5-5 lists the error indicators and the type of error for a traverse closed on the starting point and closed on a second known point. This table assumes that only one error is made.

Table 5-5. **Traverse error indicators**

ERROR INDICATORS		MOST LIKELY CAUSE OF ERROR[1]	
AZIMUTH CLOSED	COORDINATES CLOSED	TRAVERSE CLOSED ON STARTING POINT	TRAVERSE CLOSED ON SECOND KNOWN POINT
Yes	Yes	No error	No error
Yes	No	Distance error	Distance error
No	Yes	Starting or closing angle	Closing angle
No	No	Angle error	Error in starting angle or a station angle, but not in closing angle

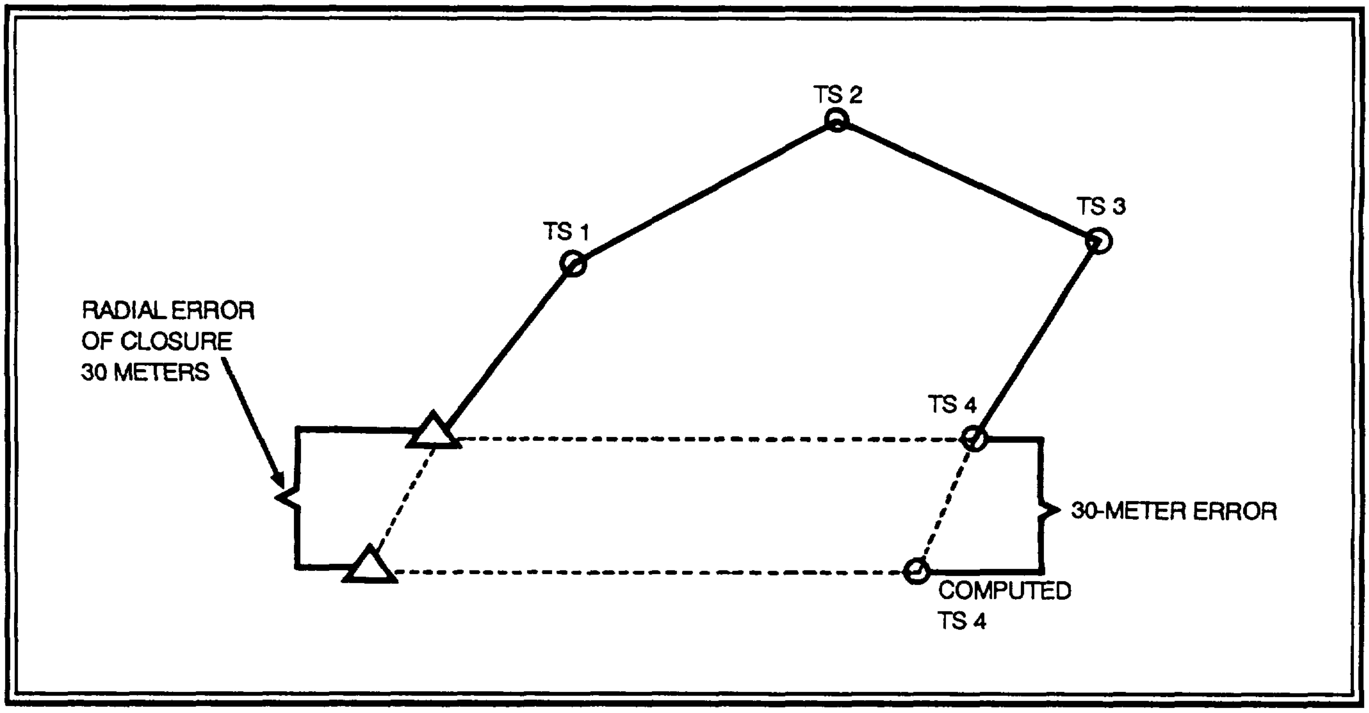
[1]Assuming only one error exists

5-33. ISOLATION OF DISTANCE ERRORS

a. A distance error is indicated when the azimuth for the traverse closes within tolerance but coordinate closure is in error beyond the limits allowed for the prescribed accuracy.

b. Compare the known coordinates of the point on which the survey was closed to the computed coordinates determined by the survey. From this comparison, determine the error in easting and the error in northing. Note the sign of each error, and compute the azimuth from the known coordinates of the closing station to the computed coordinates of the closing station on DA Form 5590-R. The traverse leg containing the distance error will have the same azimuth (or back-azimuth) as the azimuth computed. (See Figure 5-20.) The distance computed will be the radial error. In analyzing an error of this nature, some tolerance and judgement must be used to determine the traverse leg in error, This is because in both angular and distance measurements, minor errors occur that are too small to affect the overall accuracy but are large enough to make error analysis difficult. Under some circumstances, several legs with azimuths approximating the azimuths of the radial error could contain the distance error. Check computations for each suspected leg. If there is no error in computations, then each suspected leg must be remeasured until the leg containing the error is found.

Figure 5-20. **Distance error**



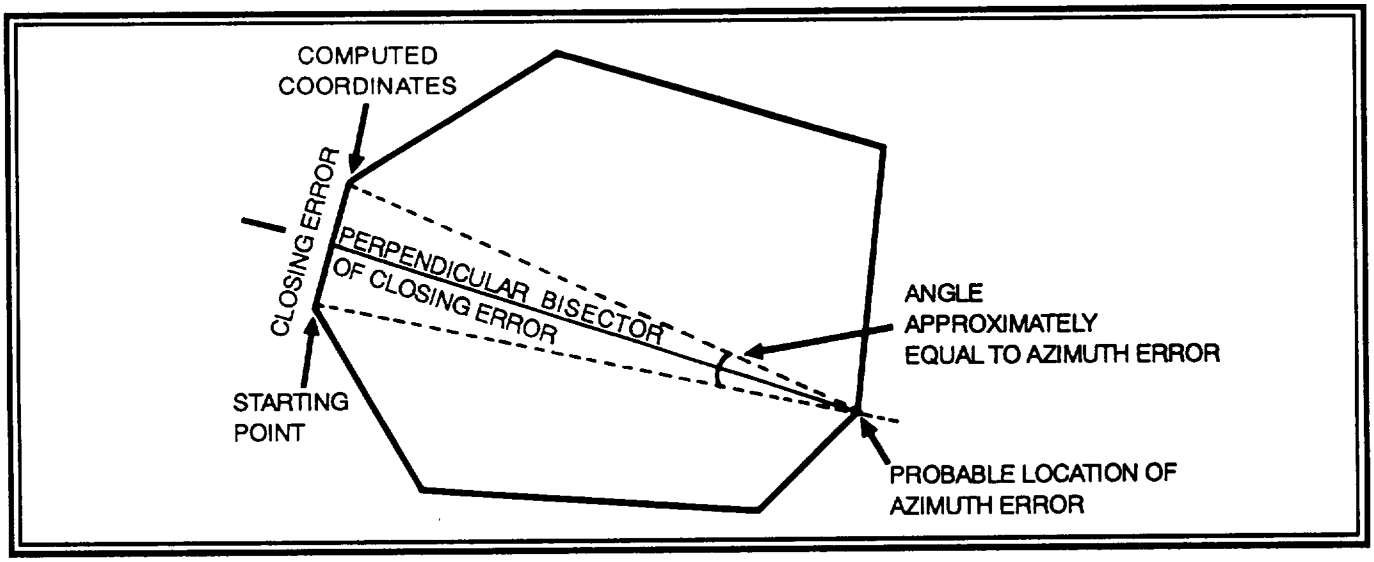
5-34. ISOLATION OF AZIMUTH ERRORS

a. Indication of Azimuth Error. An azimuth error is indicated when the azimuth does not close within required tolerance and coordinate closure is in error beyond the limits allowed for the prescribed accuracy.

b. Isolation Procedure. Compare the computed azimuth to the known azimuth of the closing point, and determine the azimuth error. Compare the computed coordinates of the closing station to the known coordinates, and determine the error in casting and the error in northing. Compute the distance (RE) and azimuth of the radial error by using DA Form 5590-R, the known coordinates of the closing station, and the computed coordinates of the closing station. Using a scaled sketch of the traverse, construct a line perpendicular to, and at the midpoint of, the plotted radial error line. Extend this line in the appropriate direction through the area in which the fieldwork was executed. (See Figure 5-21.) The suspect station at which the angle error was made will be on or very near the extended line.

c. Corrective Procedure. After the suspect station is located, a check should be made of amputations at the station to include the angular values in the field notes recorded for that station. If there was no error in meaning of angles, the angle for the station should be remeasured and compared with the recorded angle measured as a part of the original survey. This procedure will reveal the error, if one exists. If the remeasured angle compares favorably with the recorded angle, a multiple error exists in the survey and a solution is not possible. When this situation occurs, the survey should be rerun to determine the location of the errors.

Figure 5-21. **Method of locating azimuth error in traverse**



d. Alternate Solution. The trial-and-error method is another method that may be used to determine the location of the angular error when a graphical plot of the survey is not available or the perpendicular method does not isolate one station. To determine suspect stations (stations where the error may exist) by this method, first compute the distance between the correct coordinates of the closing station and the computed coordinates of the closing station. Second, determine the amount the azimuth is in error by comparing the closing azimuth with the correct grid azimuth at the closing station. Third, substitute the distance error and the azimuth error into the miI relation formula (w/r = m), and determine the approximate distance (in kilometers) from the closing station to the station in error. By this procedure, one or more suspect stations may be determined. Then use the trial-and-error method and systematic elimination to locate the suspect station in error. Using the coordinates of the suspect station and the known coordinates of the closing station, compute the azimuth and distance between the two. Using the coordinates of the suspect station and the computed coordinate of the closing station, compute an additional azimuth and distance between these two. Compare the results with the azimuth and distance first determined. If the error is at the suspect station, the azimuth should vary by the amount of the azimuth error of closure and distances should agree relatively closely. If the error is not at the suspect station, the azimuth will disagree but not by an amount equivalent to the azimuth closure error. (See Figure 5-22.)

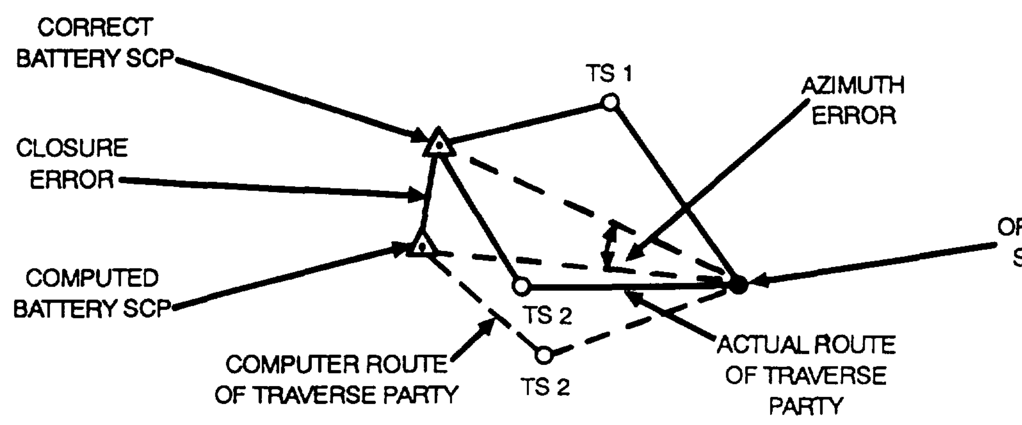
EXAMPLE

Radial error of closure 100 meters
Azimuth error of closure 10 mils
Use the mil relation formula in which
W = radial error
r = range in kilometers
m = azimuth error
100/r = 10 mils
or
$r = \frac{100}{10}$
or
r = 10 (10,000 meters = approximate distance of station in error from closing station)

5-35. ISOLATION OF MULTIPLE ERRORS

Multiple errors are errors in both azimuth and distance or more than one error in either azimuth or distance. When there are multiple errors in a traverse, the indications will be the same as for an azimuth error. It is possible that in the procedure for azimuth error determination, definite suspect stations will be located but an analysis of the fieldwork and computations at these stations will not produce the error. When this occurs, the entire traverse should be performed again to locate the errors that were made.

Figure 5-22. **Azimuth error**



Section VI

TRAVERSE ADJUSTMENT

Establishing a common grid throughout an entire corps or div arty sector is not as simple as it may first appear. When a party is extending survey control over long distances by traverse, the traverse may well be within the prescribed accuracy and still be considerably in error. This problem is magnified when several traverse parties are used to extend control and try to tie their work together. Seldom, if ever, will these parties coincide on their linkage. By adjusting the traverse, throughout, however, some compensation will be made for those errors that have accumulated. A traverse executed to a prescribed accuracy of fourth order must always be closed and adjusted. An adjusted traverse is one in which the errors have been distributed systematically so that the closing data determined by the traverse, coincide with the correct closing data. There is, of course, no possible means of determining the true magnitude of the errors in angle and distance measurement that occur throughout a traverse. Therefore, a traverse adjustment is based on the assumption that the errors have accumulated gradually, and the corrections are made accordingly. Three adjustments must be made when adjusting a traverse. These are azimuth, coordinates, and height, These adjustments eliminate the effects of systematic errors on the assumption that they have been constant and equal in their effect on each traverse leg. Traverse adjustment cannot compensate for blunders such as dropped tape lengths or misread angles. Also, a traverse that does not meet the prescribed standard of accuracy is not adjusted but is checked for error. If the error cannot be found, the entire traverse must be performed again.

Note. *The BUCS will perform these adjustments if required.*

5-36. SOURCES OF ERRORS

The errors for which traverse adjustment compensates are not those errors commonly known as mistakes or blunders but are errors that fall into one of the classes discussed below.

a. Instrumental Errors. These are errors that arise from imperfections in, or faulty adjustment of, the instruments with which the measurements are taken. For example, a tape could be too long or the optical plumb might be out of adjustment.

b. Personnel Errors. These are errors that arise from the limitations of the human senses of sight and touch. For example, an error might be made in estimating the tension applied to a steel tape or in plumbing a plumb bob over a point.

c. Natural Errors. Natural errors arise from variation in the phenomena of nature, such as temperature, humidity, wind, gravity, and refraction. For example, the length of a tape varies directly with the temperature. The tape becomes longer as the temperature increases and shorter as the temperature decreases.

5-37. AZIMUTH ADJUSTMENT

a. Determining Azimuth Correction. Since the computation of position depends partly on azimuth, the first step in adjusting a traverse is to determine the azimuth error and adjust the azimuth. The azimuth error is obtained by determining the difference between the azimuth established by traverse (computed) and the known azimuth at the closing point. The azimuth correction is the azimuth error with the proper sign affixed so that the computed azimuth with the azimuth correction applied will equal the known azimuth.

EXAMPLE

A traverse is performed from Point A to Point B. The azimuth from Point B to an azimuth mark is known to be 4,794.529 mils and was used as the closing azimuth. However, the azimuth to the same point from Point B derived from the traverse (computed azimuth) was 4,794.459 mils. Therefore, the azimuth error for this traverse was 0.070 mil (4,794.529 - 4,794.459).

b. Application of Azimuth Correction. Since traverse adjustment is based on the assumption that errors present have accumulated gradually and systematically throughout the traverse, the azimuth correction is applied accordingly. The correction is distributed equally among the angles of the traverse with any remainder distributed to the larger angles. For example, assume that the traverse for which the azimuth correction was determined consisted of three traverse legs and four angles. The azimuth correction is divided by the total number of angles. In this case, +0.070 mil + 4 = 0.017 mil per angle with a remainder of 0.002 roil. Each of the four angles will be adjusted by 0.017 roil, and the two largest angles will be adjusted by an additional 0.001 mil each to compensate for the remaining 0.002 roil.

EXAMPLE

Station	Measured Angle	Azimuth Correction	Adjusted Angle
Point A	2,410.716	+0.017	2,410.733
TS 1	2,759.630	+0.017	2,759.647
TS2	3,765.876	+0.018	3,765,894
Point B	2,886.617	+0.018	2,886.635

c. Action After Adjustment. After the angles have been adjusted, the adjusted azimuth of each leg of the traverse should be recomputed by using the starting azimuth and adjusted angles at each traverse station. These computations should be performed on clean copies of DA Form 5591-R, not on the forms used for the original computations. The adjusted azimuth should be computed throughout the entire traverse and checked against the correct azimuth to the closing azimuth mark before adjusting the coordinates After the azimuth of each traverse leg has been adjusted, the coordinates of the stations in the traverse must be adjusted. The first step in adjusting the coordinates is to recompute the coordinates of all stations in the traverse, using the adjusted azimuths. It is now assumed that all azimuth error has been eliminated. Any remaining error is assumed to be a distance error.

EXAMPLE

Easting	Northing
550554.50	3835829.35 (known coordinates)
-550550.50	3835835.35 (computed coordinates)
eE = +4.00	eN = -6.00

5-38. COORDINATE ADJUSTMENT

a. Determining Easting and Northing Corrections. The casting and northing corrections for the traverse are determined by algebraically subtracting the coordinates of the closing station (as recomputed with the adjusted azimuth) from the known coordinates of the closing station.

b. Application of Easting and Northing Corrections. The corrections determined in a above are for an entire traverse. It is assumed that these corrections are based on errors proportionate y accumulated throughout the traverse. Therefore, the corrections must be distributed proportionately throughout the traverse. The amount of casting or northing correction to be applied to the coordinates of each station is computed by multiplying the total correction (casting or northing) by the total length of all the traverse legs up to that station and dividing the result by the total length of all of the legs in the traverse For example, using the total casting and northing corrections previously determined, assume the total length of the traverse is 22,216.89 meters and the total length of the traverse legs up to TS 4 is 3,846.35 meters.

EXAMPLE

Easting correction at TS 4 =

$$\frac{\text{Total easting correction x traverse length to TS 4}}{\text{total traverse length}}$$

$$= \frac{4.00 \times 3{,}846.35}{22{,}216.89}$$

$$= \frac{15{,}385.40}{22{,}216.89}$$

= +0.69 meter easting correction for TS 4

Northing correction at TS 4 =

$$\frac{\text{Total northing correction x traverse length to TS 4}}{\text{total traverse length}}$$

$$= \frac{-6.00 \times 3{,}846.35}{22{,}216.89}$$

$$= \frac{-23{,}078.10}{22{,}216.89}$$

= -1.04 meters northing correction for TS 4

5-39. HEIGHT ADJUSTMENT

a. Height adjustment is based on the assumption that the error of closure of height is accumulated throughout the traverse in equal amounts at each traverse station and not proportionately to the length of the traverse legs. Errors caused by this assumption have no effect for FA purposes.

b. The height correction is the error in height with the sign reversed. It is determined by comparing the height of the closing point established by the traverse with the known height of the closing point and applying a sign (±) that will cause the established height, with the algebraic correction applied, to equal the known height. For example, if the known height is 478.3 meters and the computed height (established by traverse) is 477.5 meters, the height correction would be 0.8 meter (478.3 - 477. S). For the height determined by traverse to equal the correct height, 0.8 meter would have to be added to the height of the closing station determined by traverse.

c. The height correction is distributed equally among the stations of the traverse with any remainder distributed to those stations computed from the longest legsi. Assume that the traverse for which the height correction was determined consists of four stations. To distribute the height correction throughout the traverse, divide the height correction by the total number of stations in the traverse excluding the starting station (a known height). In this case, 0.8 meter +3 stations = 0.2 meter with a remainder of 0.2 meter to be divided and applied equally to those stations computed from the longest legs. The adjustment would be as shown in the example below. The adjustment is an accumulation of the correction, since the correction is applied to the differences in height between the stations and not directly to the station heights. The height adjustment can be made on the same form and at the same time that coordinate adjustments are being made.

5-40. DISCRETION ADJUSTMENT

Although traverse adjustment is a systematic operation, there will be times in the field when surveyors may rely on judgment alone. In these case-s, the error maybe distributed arbitrarily in accordance with the surveyor's estimation of the field conditions. It is reasonable to assume that if certain legs of the traverse are over rough terrain, the error in taping these legs will be relatively large compared to taping over ideal terrain and the correction should be correspondingly greater. If lines of sight are steep and visibility is poor, larger angular errors would be expected than when observing conditions are relatively favorable. The artillery surveyor should not resort to this method of adjustment unless he is experienced and has a keen knowledge of where errors are most likely to occur and of their effect on the overall survey. In any event, the field notebook should contain a detailed account of any unfavorable survey conditions so that it may be used to substantiate any arbitrary adjustments.

EXAMPLE

Traverse Station Starter	Height 450.4	Distance	Difference in Height (dH)	Correction	Adjusted Height 450.4
TS 1	471.7	384.5	+21.3	+0.3	472.0
TS 2	482.4	284.3	+10.7	+0.3	483.0
Close	477.5	269.4	-4.9	+0.2	478.3

CHAPTER 6

TRIANGULATION

Triangulation is a method of conventional survey used when the traverse method is impractical or impossible. This method is ideally suited to rough or mountainous terrain. The triangulation method employs oblique triangular figures and enables the surveyor to cross obstacles and long distances. This method is time-consuming and requires careful planning and extensive reconnaissance.

Section I

METHODS AND OPERATIONS

The triangulation method of survey uses triangular figures to determine survey data. If the values of certain elements of a triangle are known, the values of other elements of the triangle can be computed.

6-1. SURVEY METHODS USING TRIANGLES

a. In FA surveys, the term triangulation is restricted to operations that involve the measurement of all angles within a triangle, (See Figure 6-l.) Other methods of survey, however, use the triangular figure, but the procedures used in the fieldwork and in the computations differ somewhat from the methods used in triangulation. Two of these methods used in FA survey are intersection and resection.

(1) In the intersection method, two angles are measured. If the length and azimuth of one side and two angles are known, the intersection can be computed. (See Figure 6-2.)

Figure 6-1. **Triangulation**

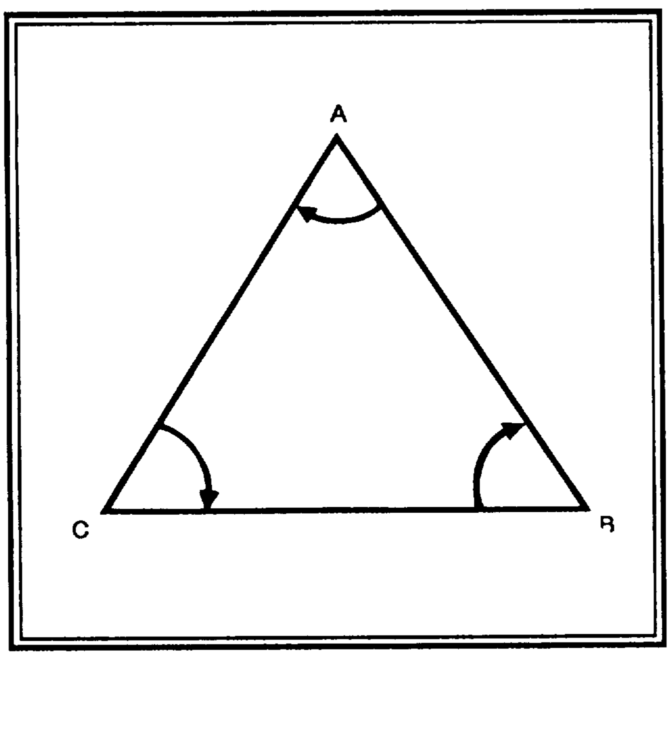
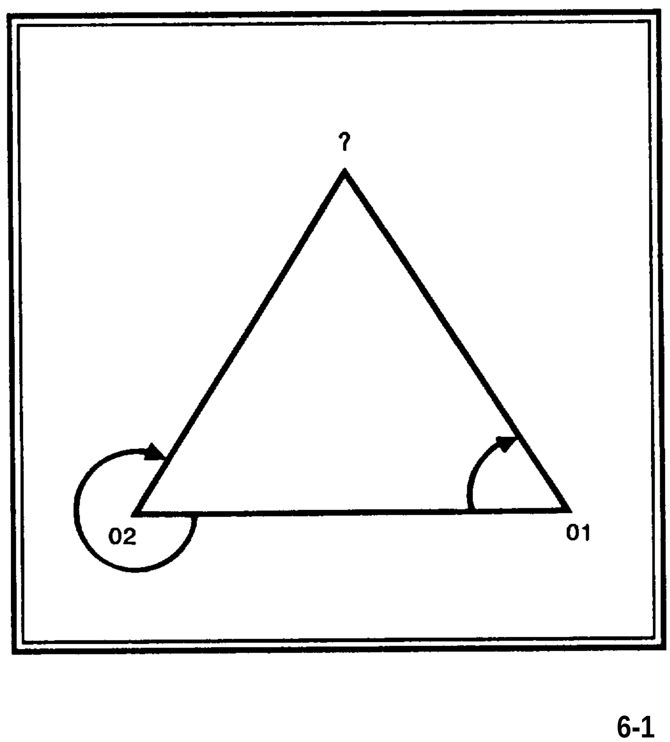


Figure 6-2. **Intersection**



(2) In resection, the coordinates of an unknown point are obtained by determining the horizontal angles at the unknown point between three unoccupied points of known coordinates. (See Figure 6-3.)

Figure 6-3. **Three-point resection**

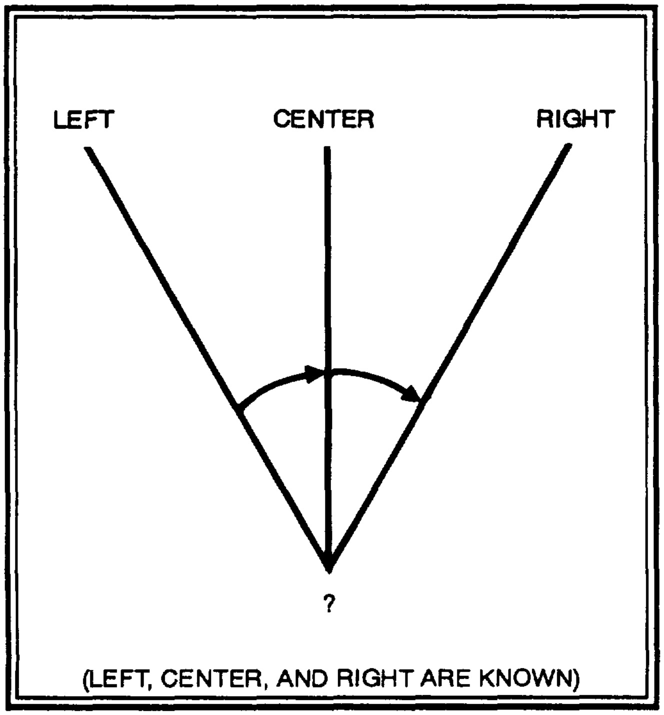
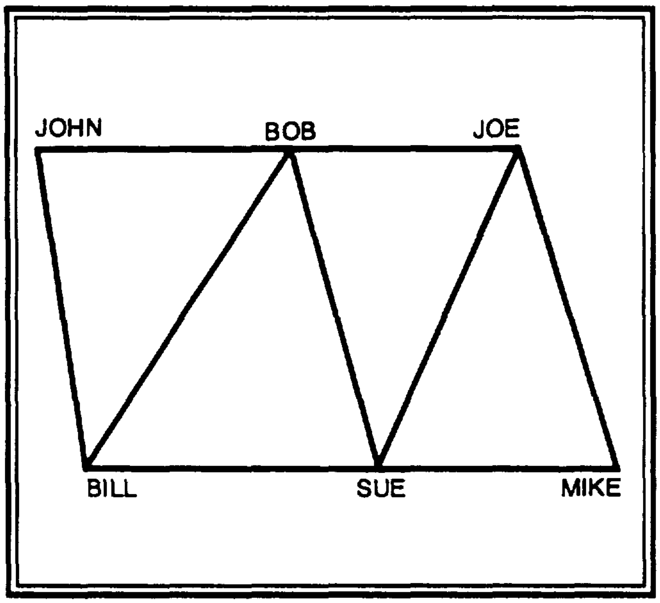


Figure 6-4. **Chain of triangles**



b. Survey methods using the triangular figure may be used at all levels of FA survey to establish the locations of survey control points. Generally, it is better to use some method of survey that employs these procedures if the distance or terrain involved makes traverse difficult or impossible.

c. Triangulation involves single triangles (Figure 6-1) and chains or schemes of triangles (Figure 6-4). Whether a particular triangle is a single triangle or part of a scheme of triangles, the angles in the triangle are determined in the same manner, and the unknown elements of the triangle are computed in the same manner. In a single triangle, the base (known side) is measured with electronic distance-measuring devices or a 30-meter steel tape, or it is computed from known coordinates of the required accuracy. In a chain of triangles, the base of the first triangle is determined in the same manner as a single triangle. The base for the second triangle is the side of the first triangle that is common to both triangles. This side is computed, which establishes a base distance for computation of the second triangle. The same procedure is used to determine the base for each triangle in a triangulation scheme.

6-2. TRIANGULATION PARTIES

a. Triangulation operations are not confined to one area at any one time. Several operations are involved in triangulation. The personnel involved in each phase are usually separated from the personnel performing other phases of the survey. Since different lengths of time are required for the various operations, no standard division of duties can be made. There are general operations that must be performed in triangulation, and each of the survey personnel is assigned to one or more of these functions. The general operations are as follows:

- Reconnaissance and planning.
- Determination of angles.
- Base measurement.
- Computation.

b. The recon party normally consists of the survey officer and/or the chief surveyor and such other personnel as deemed necessary. The recon party selects and marks each station to be used in the triangulation scheme. It also may erect a target over each station. If considerable clearing of trees and underbrush is required near the station, clearing may be performed by either the recon party or the angle-measuring personnel. Additional personnel may be required in the party that does the clearing. (Usually, the time and personnel available to perform artillery surveys preclude extensive clearing of trees and underbrush.)

c. The angle-measuring party consists of the instrument operator, the recorder, and (when necessary) personnel for clearing.

d. When the base is measured with the SEDME-MR a team of two men is required. This team consists of one instrument operator-recorder and one man to set up the reflector prism at the end of the base. If taping teams are used, the base is double taped to the specified comparative accuracy. If only one taping team is available, it must make at least two independent measurements of the base to the specified comparative accuracy. A tension handle with a 25-pound pull should be used, and horizontal alignment must be maintained to ensure the required accuracy of a taped base measurement. If SEDME-MR devices are used to measure the base, the base will be measured three times and the mean reading used to compute the base. After completing all required measurements, these personnel may be used as directed by the chief of party or the survey and recon officer.

e. The computing party consists of two computers (one has a dual role of computer-recorder). The computers make independent computations and compare their results. They make their computations at any convenient location specified by the party chief or the survey officer. Data from the various points in the survey are reported to the computer by some prearranged method (for example, by radiotelephone).

6-3. TRIANGULATION FIELD NOTES

a. As the bases are measured, each tapeman of the two taping teams records all the base measurements in the taping notebook. As soon as practical, these recorded distance-s are transferred to the field notes kept by the recorder. When the base length is measured with the SEDME-MR, the recorder at the end of the base at which the SEDME is located enters the distance in the field notebook.

b. The field notes kept by the recorder in an angle-measuring party are discussed in Chapter 4. Figures 4-7 through 4-9 are examples of notes kept by a recorder for 1 :1,000 (T16 theodolite) and 1:3,000 (T2 theodolite) triangulation.

6-4. STANDARDS AND SPECIFICATIONS

In triangulation, fieldwork and computations adhere to certain standards and specifications to produce surveys of the desired accuracy. These standards and specifications are described in Appendix B.

Section II

TRIANGULATION COMPUTATION

A triangle is defined as a closed the-sided geometric figure containing three interior angles the sum of which is 3,203 mils. Each triangle is solved separately whether it is a single triangle or a triangle in a scheme. The only type of triangulation problem (excluding intersection and resection) involved in artillery surveys is the solution of a triangle in which the values of all three angles and the length and azimuth of one side are known. This type of problem is solved by using DA Form 5592-R (Computation of Plane Triangle Coordinates and Height From One Side, Three Angles, and Vertical Angles (BUCS)). (A reproducible copy of this form is included at the back of this book.)

> **Note.** If the BUCS or form is not available, the triangle can be solved by using the law of sines. For an explanation on the law of sines, see paragraph 6-16.

6-5. SURVEY APPLICATION OF BASIC TRIANGLE

To determine the coordinates and height of a point from another point of known coordinates and height requires three items of information-vertical angle, azimuth, and distance. To associate the basic triangle in Figure 6-5 with these objectives, assume that Point A of this triangle is a point at which the coordinates and height are to be determined by triangulation. To do this, take the steps discussed below.

a. Select two other points, B and C, intervisible to each other and Point A. The coordinates and height of at least one of these two points must be known.

b. Measure the horizontal interior angles and vertical angles at Points A, B, and C with an instrument. With one more item, a known side (the base), the triangle can be solved. The specifications for angle measurement for fourth- and fifth-order accuracies are shown in Appendix B.

c. The length of the base can be obtained in either of two ways-by direct measurement or by computation (see (1) below). As mentioned earlier, the coordinates and height of Point B or C must be known. The specifications for baseline measurement for fourth- and fifth-order accuracies are shown in Appendix B.

(1) If the coordinates and height of both B and C are known, the azimuth and length of the base (the line joining B and C) can be computed on DA Form 5590-R. These known coordinates and heights must be of an equal or higher accuracy than that of the survey being performed. (If a fourth-older survey is being conducted, the coordinates used to compute the azimuth and length of the base should be of third-order accuracy or higher but must be at least fourth-order accuracy.)

(2) If the coordinates of only one of the points are known, the base length must be taped or measured electronically. The azimuth must be obtained by astronomic observation, by gyroscopic means, or by sighting on a point of known azimuth (azimuth mark).

Note. If the distance is determined electronically, it must be converted to horizontal distance before computation. To convert a slope distance to horizontal distance, see paragraph 2-23d.

d. When the three horizontal interior angles, vertical angles, azimuth of the base (thus, the azimuths of all three sides), and length of the base have been determined, the triangle can be solved to determine coordinates and height of A. The decision as to which side to compute will be based on distance angles.

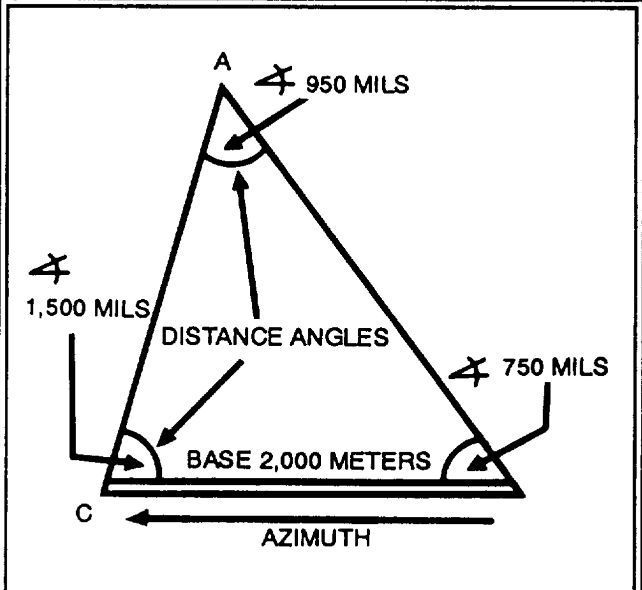
Note. The height of A (unknown point) is determined in a manner similar to that used in traverse. Reciprocal vertical angles (measured from both ends of a line) are measured along the forward, or required, side at the occupied and unknown stations. (Reciprocal vertical angles are not necessary when distances are less than 1,000 meters.) If the instrument operator **does not** know which is the required side, reciprocal vertical angles will be measured along all sides of the triangle.

6-6. DISTANCE ANGLES OF A SINGLE TRIANGLE

a. Only strong figures should be used in triangulation to minimize the effects of small measurement errors. The ideal figure is an equilateral triangle. However, field conditions generally make the use of the ideal figures impractical, and often figures must be selected that only approximate the ideal.

b. Computing the length of a side in a triangle involves two of the three angles in the triangle. The angles involved in the computation of the length of a side are called distance angles. Distance angles are defined as those angles in a triangle opposite the known side (base) and the required side (side common to an adjacent triangle). Since in a single triangle there is no specific required side, the distance angles in a single triangle are the angles opposite the known side and the stronger (closest to 1,600 mils) of the two remaining angles. (See Figure 6-5.)

Figure 6-5. **Distance angles of a single triangle**

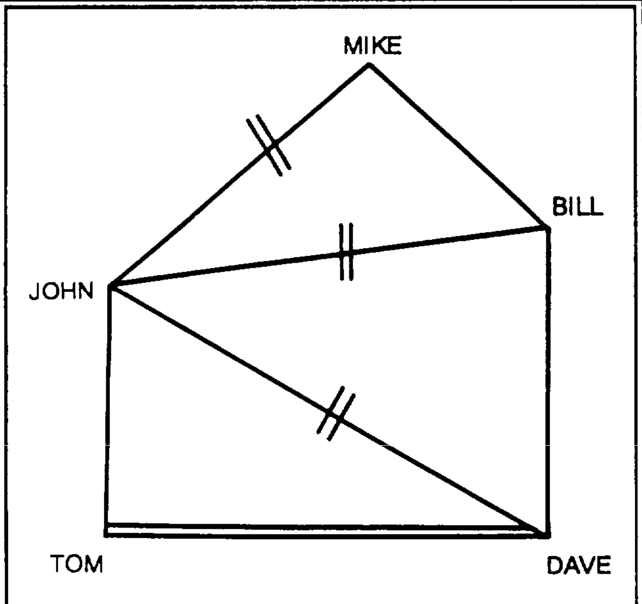


Note. Double line indicates known base.

c. The difference between the sines of angles near 0 mils or 3,200 mils is quite large for very small differences between angles. Because of this, a small error in the value of an angle near O mils or 3,200 mils will cause a relatively large error in the sine of the angle and a corresponding error in the computed length of the side opposite the angle. Therefore, for beat results, distance angles must be at least 400 mils and preferably 533 mils For this reason, in the case of a single triangle, the side opposite the stronger angle is the side computed.

d. Vertical angles at each end of the side of a triangle should be measured reciprocally to the height of instrument. Often, because of distances involved, the instrument operator must measure the vertical angle to a target erected and plumbed over the forward station. When the triangulation stations are greater than 1,000 meters, the vertical angle is measured reciprocally. In any triangulation scheme, the coordinates and height of at least one station must be known. This station is used as the starting point to obtain the height of the next station. The height control is extended along the forward line of each triangle in the scheme. In Figure 6-6, use the height of Point Dave as a starting point, since the height of Point John must be computed along the forward line (Dave-John). Using the height of Point John, compute the height of Point Bill and the height of Point Mike. If side Bill-Mike had been the forward line, then the computation would have been from Point Bill to Point Mike.

Figure 6-6. **Route of trigonometric height computations**



Note. // indicates forward line.

Section III

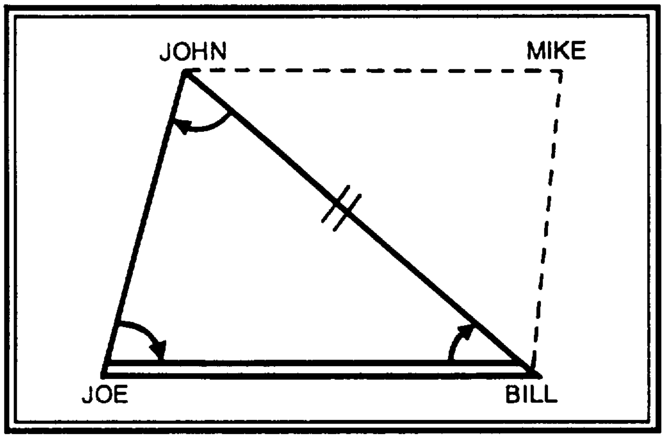
TRIANGULATION SCHEMES

A chain (scheme) of triangles is a series of single triangles connected by common sides. (See Figure 6-4.) In a chain of triangles, only the length of the first, or original, base and the length of each check base are measured. The lengths of all other sides are computed.

6-7. DESCRIPTION, SOLUTION, AND CHECKS OF A CHAIN OF TRIANGLES

a. In Figure 6-7, side John-Bill is common to triangles John-Bill-Joe and Mike-Bill-John. Each of these triangles may be solved individually if one side and the interior angles are known. In Figure 6-7, assume there is a requirement to locate an additional point, Mike, outside the single triangle John-Bill-Joe. While the interior and vertical angles at John and Bill are being measured, the angles for the new triangle would also be measured. Then the horizontal and vertical angles at Point Mike would be determined. Since side Joe-Bill is a known side, all the information needed to compute both triangles would then be available. Side John-Bill would be the required side (side John-Bill is common to both triangles), and the angle at Point Joe would be its distance angle, regardless of its value. A distance angle is an angle in a triangle opposite the known side and the angle opposite the required side (side common to an adjacent triangle). The required side is also known as the forward line or forward base, because it will become the base for the next triangle in the scheme. In a chain of triangles, the last triangle in the scheme is computed as a single triangle, and its distance angles are determined as discussed in paragraph 6-6b. For example, in Figure 6-7, the distance angles in triangle John-Bill-Joe are at points John (angle opposite known side Joe-Bill) and Joe (angle opposite the required side). For triangle Mike-Bill-John, the distance angles are at Point Mike (angle opposite known side John-Bill, which has been solved in triangle John-Bill-Joe) and Point Bill (the stronger of angles at John and Bill).

Figure 6-7. **Relationship of a single triangle to a chain of triangles**



b. The size of the distance angles in a triangle is used as the measure of relative strength of the figure. The strength factor of a triangle is determined by use of a strength of figure factor table. (See Table 6-l.) The distance angles of the triangle serve as arguments for entering the table, the smaller distance angle dictates the column; the larger distance angle, the row. The smaller the factor, the greater the relative strength of the triangle.

c. When the sum of the strength factors of a chain of triangles exceeds 200 or at every fifth triangle, a check base (the required side) and azimuth must be determined. If the difference between the computed length and azimuth and the measured length and azimuth is within prescribed tolerances, the scheme may be continued with the measured data. For fifth-order surveys, the computed length of the check base must agree with the measured length within 1:1,000 (comparative accuracy), and the computed azimuth must agree with the astronomic (astro) or gyroscopic (gyro) azimuth within 0.1 times the number of main scheme angles used to carry the azimuth to the check base. For fourth-order surveys, the check comparisons are 1:3,000 (comparative accuracy) for the base and 0.04 x N, where N is the number of main scheme angles used to carry the azimuth to the check base.

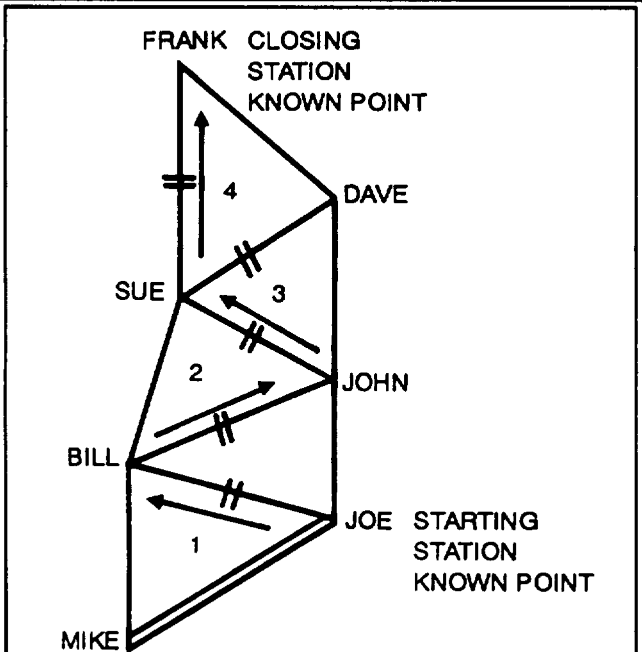
Table 6-1. **Table for determining strength of figure factors (mils)**

MILS	150	200	250	300	350	400	450	500	550	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
150	605																			
200	465	334																		
250	391	272	212																	
300	347	233	176	143																
350	320	210	155	123	104															
400	300	192	139	109	91	78														
450	283	178	127	97	80	68	58													
500	272	169	119	90	73	61	52	46												
550	264	162	112	84	68	56	47	41	37											
600	257	157	108	80	64	53	44	38	34	31										
700	245	147	99	72	57	46	38	32	28	25	20									
800	236	139	93	67	52	41	33	28	24	21	17	13								
900	229	133	88	62	48	38	30	25	21	19	14	11	9							
1000	223	129	84	59	45	35	27	23	19	17	12	9	7	6						
1100	218	125	81	56	43	33	25	21	17	15	11	8	6	5	4					
1200	215	123	79	55	41	31	24	20	16	14	10	7	5	4	3	2				
1300	211	119	76	52	39	29	22	18	15	13	9	6	4	3	2	2	1			
1400	207	117	74	51	37	28	21	17	14	12	8	5	4	3	2	1	1	0		
1500	205	115	72	49	36	27	20	16	13	11	7	5	3	2	1	1	1	0	0	
1600	202	112	71	48	35	26	19	15	12	10	7	4	3	2	1	1	0	0	0	0
1700	199	110	69	46	34	25	19	14	12	10	6	4	3	2	1	1	0	0	0	
1800	196	108	67	45	33	24	18	14	11	9	6	4	2	2	1	1	0	0		
1900	193	106	66	44	32	23	17	13	11	9	6	4	2	1	1	1	0			
2000	190	104	64	42	30	22	16	13	10	8	5	3	2	2	1	1				
2100	187	102	63	41	30	22	16	12	10	8	5	3	2	2	1					
2200	184	99	61	40	29	21	15	12	9	8	5	3	2	2						
2300	180	97	59	39	28	20	15	11	9	8	5	4	3							
2400	176	95	57	38	27	20	15	11	9	8	6	4								
2500	171	92	55	36	26	20	15	12	10	9	7									
2600	166	89	54	36	26	20	16	13	11	10										
2650	164	88	53	36	26	20	16	14	12											
2700	161	86	53	36	27	21	17	15												
2750	159	85	53	37	28	23	19													
2800	155	84	54	38	31	26														
2850	153	85	56	42	35															
2900	151	87	60	48																
2950	153	94	71																	
3000	163	112																		
3050	202																			

> **Note.** The accuracy of the check azimuth must be considered.

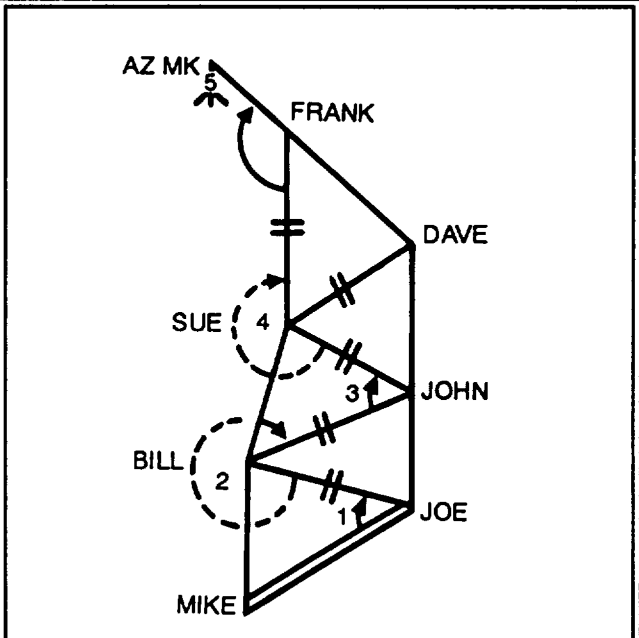
d. A chain of triangles does not provide enough internal checks for an estimation of the accuracy of the work performed. As a check, the length of the last computed side of the final triangle is measured and the computed and measured lengths are compared. The results of this comparison must produce a comparative accuracy as shown in c above. The azimuth of the last computed side must be determined by astro or gyro observation as soon as possible. Error in azimuth is determined by comparing the astro or gyro azimuth with the azimuth computed through the scheme as described in c above. If the scheme closes on a known point, an accuracy ratio must be determined. The total length used for computing the accuracy ratio is the sum of the lengths of the sides of the triangles used to compute coordinates in the scheme from starting station to closing station. The azimuth is verified by turning a closing angle to an azimuth mark. The sum of the closing angle and the azimuth of the base must agree with the known azimuth within the accuracies stated in c above. (See Figures 6-8 and 6-9.)

Figure 6-8. **Determining distance for accuracy ratio**



Note. Arrows indicate the sides of the triangle used to compute coordinates.

Figure 6-9. **Determining number of angles for azimuth closure**



Note. Main scheme angles that are used to extend azimuth are numbered. Angles shown in dashed lines are not turned but are derived through computation.

6-8. TRIANGLE CLOSURE

When interior angles of a triangle are measured in the field, the sum of the angles may vary from 3,200 mils by a small amount. The term used to describe this variance is triangle closure. If the variance is within tolerance (Appendix B), the angles are adjusted to equal 3,200. The BUCS will automatically do this by distributing the closure variance equally among the three angles. The BUCS will display the closure. (See Figures 6-10,6-11, and 6-12 for triangulation computations.)

6-9. DA FORM 5592-R

a. DA Form 5592-R is used for computing triangulation schemes. The front of the form is designed for the solution of one triangle and for entering the field data for a second triangle.

b. DA Form 5592-R has five major sections used for computations. These sections are described in (1) through (5) below in the sequence in which they should be computed.

(1) The SKETCH: block is provided for the user to draw a sketch of the triangulation scheme or the single triangle. The sketch should be properly labeled with the station angles, station names and numbers, the starting base, and all the required sides for determining data.

(a) Label triangle 1 as follows: Station A is always located at the first unknown point (station opposite the starting base), and then stations B and C are labeled in a clockwise manner. In Figure 6-10, station Sue is labeled “A”; station Rob, "B;" and station Ben, “C.” For succeeding triangles, the station that is opposite the side common to both triangles (see paragraph 6-7a) is labeled "A," and so forth.

(b) Before starting computations, the stations must be numbered. Station 1 is located at one end of the starting base (BC), This is the station where the known side and required side meet, Station 2 is the first unknown point (Station A), the succeeding unknown stations will be labeled in order of computation. In Figure 6-10, Station Ben is number one because it is the point where the known and required side meet. Station Sue is labeled “#2,” since it is the first unknown point. The next unknown station (Bill) is labeled “#3.”

(2) Steps 1 through 8 of the DATA RECORD section are used to record the data for the starting known point (B or C), to include the azimuth and distance of the starting base. If there is more than one triangle to be computed, data from subsequent triangles are also recorded in this section. (See Figure 6-11.)

Note. When you are entering the base distance, BUCS will prompt for grid or horizontal distance. If the base is measured, the base is a horizontal base. If the base is computed by using known coordinates, it is a grid base. If the base distance was determined by SEDME-MR, it must be converted to a horizontal distance before entering the data into the BUCS.

(3) Steps 9 through 12 of the DATA RECORD section are provided for the field data as determined by the angle-measuring party (horizontal and vertical angles).

Note. Specify whether the vertical angle is reciprocal or nonreciprocal. Refer to note in paragraph 6-5d.

(4) Steps 1 through 13 of the DATA RECORD section on the reverse of the form are used when the triangulation scheme is closed on a known point. The known data of the point must be provided so the BUCS can compute the azimuth error, height error, radial error and the accuracy ratio for the triangulation scheme. Refer to paragraph 6-7d.

(5) Steps 1 through 6 of the DATA RECORD section on the bottom reverse of the form are used when the triangulation scheme requires a check base, For guidance on when to compute a check base, refer to paragraphs 6-7c and d.

Figure 6-10. **DA Form 5592-R (front)**

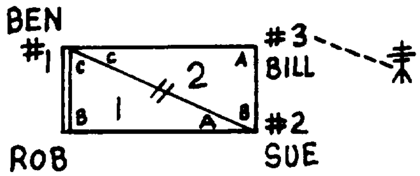
COMPUTATION OF PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES, AND VERTICAL ANGLES (BUCS)

For use of this form, see FM 6-2, the proponent agency is TRADOC

COMPUTER SSG PENA	NOTEBOOK REFERENCE	DATE 20 FEB 92
CHECKER SSG ANDERSON	AREA WEST RANGE	SHEET 1 OF 2 SHEETS

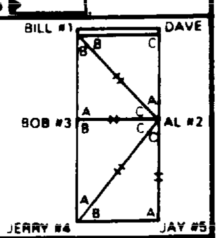
NOTES:
1. IF STEP 21 IS Y, PROGRAM GOES TO STEP 1, BACK OF FORM.
2. IF STEP 21 IS N, PROGRAM GOES TO STEP 22.
3. STEP 22 IS Y IF STATION IS START POINT FOR COMPUTATIONS. NEXT PROMPT IS "END OF TRIANGLE # ____." THEN PROGRAM GOES TO STEP 9.
4. STEP 22 IS N IF STATION IS NOT START POINT. PROGRAM THEN GOES TO STEP 23.
5. STEP 23 ENTER STATION NUMBER OF START POINT, THEN PROGRAM GOES TO STEP 9.
6. SEE BACK OF FORM FOR SURVEY CLOSURE.
7. ENTER FIELD DATA IN BLOCKS MARKED ▶.

SKETCH: (DRAW SKETCH, AND LABEL STATIONS BY NAME AND NUMBER.)



SAMPLE SKETCH:

NOTES: 1. DRAW A DIAGRAM OF THE TRIANGLE SCHEME, AND LABEL STARTING BASE, REQUIRED SIDE, INTERIOR ANGLES AND STATIONS BY NAME.
2. NUMBER THE STATIONS IN THE ORDER THAT THE STATIONS ARE COMPUTED. THE STARTING STATION IS NUMBER 1.



INSTRUCTIONS

STEP	PROMPT		PROCEDURE
1			CALL PROGRAM 3
2	TRIANGULATION		
3	EAST B/C:	0.00	ENTER EASTING OF B OR C
4	NORTH B/C:	0.00	ENTER NORTHING
5	HT B/C:	0.0	ENTER HEIGHT
6	AZ BASE:	0.000	ENTER AZIMUTH OF BASE
7	BASE DIST:	0.000	ENTER BASE DISTANCE
8	GRID BASE (Y/N):		ENTER Y OR N
9	ANGLE A:	0.000	ENTER ANGLE A
10	ANGLE B:	0.000	ENTER ANGLE B
11	ANGLE C:	0.000	ENTER ANGLE C
12	VA (+/-):	0.000	ENTER VERTICAL ANGLE
13	RECIP VA (Y/N):		ENTER Y OR N
14	CLOSURE IS:	0.000	CHECK SPECIFICATIONS ON CLOSURE
15	SIDE BA=1 CA=2:	0	ENTER 1 OR 2
16	E OF _:	0.00	RECORD EASTING
17	N OF _:	0.00	RECORD NORTHING
18	HT OF _:	0.0	RECORD HEIGHT
19	AZ TO REAR:	0.000	RECORD AZIMUTH TO REAR
20	BASE DIST:	0.000	RECORD NEXT BASE
21	CLOSE (Y/N):		ENTER Y OR N
22	STA _ START (Y/N):		ENTER Y OR N
23	# OF START PT: _	00	ENTER NUMBER

SAMPLE

DATA RECORD

REAR STATION: ROB	REAR STATION: BEN
STATION NAME: BEN NUMBER:	STATION NAME: SUE NUMBER: 2
EASTING: 555464.95	EASTING: 556961.03
NORTHING: 3835677.00	NORTHING: 3836567.77
HEIGHT (METERS): 333.8	HEIGHT (METERS): 343.6
AZIMUTH OF BASE (MILS): 1765.550	AZIMUTH OF BASE (MILS): 4252.982
BASE DISTANCE (METERS): 1267.70	BASE DISTANCE (METERS): 1741.189
(GRID/~~HORIZONTAL~~)	(GRID/~~HORIZONTAL~~)
ANGLE A (MILS): ▶ 0828.872	ANGLE A (MILS): ▶ 1430.020
ANGLE B (MILS): ▶ 1658.560	ANGLE B (MILS): ▶ 1367.510
ANGLE C (MILS): ▶ 0712.568	ANGLE C (MILS): ▶ 0402.479
VERTICAL ANGLE (MILS): ▶ 5.742	VERTICAL ANGLE (MILS): ▶ 6.481
(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)

REMARKS:

TRIANGLE CLOSURES

1. 0.000 2.–.009

DA FORM 5592-R, DEC 86

Figure 6-11. **DA Form 5592-R (front) (continued)**

COMPUTATION OF PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES, AND VERTICAL ANGLES (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC

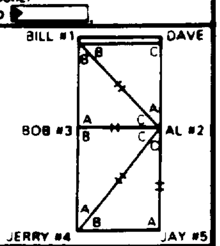
COMPUTER SSG PENA	NOTEBOOK REFERENCE	DATE 20 FEB 92
CHECKER SSG ANDERSON	AREA	SHEET 2 OF 2 SHEETS

NOTES: 1. IF STEP 21 IS Y PROGRAM GOES TO STEP 1, BACK OF FORM.
2. IF STEP 21 IS N, PROGRAM GOES TO STEP 22.
3. STEP 22 IS Y IF STATION IS START POINT FOR COMPUTATIONS. NEXT PROMPT IS "END OF TRIANGLE # ___. THEN PROGRAM GOES TO STEP 9.
4. STEP 22 IS N IF STATION IS NOT START POINT. PROGRAM THEN GOES TO STEP 23.
5. STEP 23 ENTER STATION NUMBER OF START POINT, THEN PROGRAM GOES TO STEP 9.
6. SEE BACK OF FORM FOR SURVEY CLOSURE.
7. ENTER FIELD DATA IN BLOCKS MARKED ▶.

SKETCH: (DRAW SKETCH, AND LABEL STATIONS BY NAME AND NUMBER.)

SAMPLE SKETCH:

NOTES: 1. DRAW A DIAGRAM OF THE TRIANGLE SCHEME, AND LABEL STARTING BASE, REQUIRED SIDE, INTERIOR ANGLES, AND STATIONS BY NAME.
2. NUMBER THE STATIONS IN THE ORDER THAT THE STATIONS ARE COMPUTED. THE STARTING STATION IS NUMBER 1.



INSTRUCTIONS

STEP	PROMPT		PROCEDURE
1			CALL PROGRAM 3
2	TRIANGULATION		
3	EAST B/C:	0.00	ENTER EASTING OF B OR C
4	NORTH B/C:	0.00	ENTER NORTHING
5	HT B/C:	0.0	ENTER HEIGHT
6	AZ BASE:	0.000	ENTER AZIMUTH OF BASE
7	BASE DIST:	0.000	ENTER BASE DISTANCE
8	GRID BASE (Y/N):		ENTER Y OR N
9	ANGLE A:	0.000	ENTER ANGLE A
10	ANGLE B:	0.000	ENTER ANGLE B
11	ANGLE C:	0.000	ENTER ANGLE C
12	VA (+/-):	0.000	ENTER VERTICAL ANGLE
13	RECIP VA (Y/N):		ENTER Y OR N
14	CLOSURE IS:	0.000	CHECK SPECIFICATIONS ON CLOSURE
15	SIDE BA=1 CA=2:	0	ENTER 1 OR 2
16	E OF _:	0.00	RECORD EASTING
17	N OF _:	0.00	RECORD NORTHING
18	HT OF _:	0.0	RECORD HEIGHT
19	AZ TO REAR:	0.000	RECORD AZIMUTH TO REAR
20	BASE DIST:	0.000	RECORD NEXT BASE
21	CLOSE (Y/N):		ENTER Y OR N
22	STA _ START (Y/N):		ENTER Y OR N
23	# OF START PT: _	0	ENTER NUMBER

SAMPLE

DATA RECORD

REAR STATION: BEN	REAR STATION:
STATION NAME: BILL NUMBER: 3	STATION NAME: NUMBER:
EASTING: 556490.19	EASTING:
NORTHING: 3837057.95	NORTHING:
HEIGHT (METERS): 322.9	HEIGHT (METERS):
AZIMUTH OF BASE (MILS): 3850.506	AZIMUTH OF BASE (MILS):
BASE DISTANCE (METERS): 1719.923	BASE DISTANCE (METERS):
(GRID/HORIZONTAL)	(GRID/HORIZONTAL)
▶ ANGLE A (MILS):	▶ ANGLE A (MILS):
▶ ANGLE B (MILS):	▶ ANGLE B (MILS):
▶ ANGLE C (MILS):	▶ ANGLE C (MILS):
▶ VERTICAL ANGLE (MILS): ±	▶ VERTICAL ANGLE (MILS): ±
(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)

REMARKS:

DA FORM 5592-R, DEC 86

Figure 6-12. **DA Form 5592-R (reverse)**

CLOSURE ON KNOWN POINT OR CHECK BASE

SAMPLE

INSTRUCTIONS (KNOWN POINT)				DATA RECORD
STEP	**PROMPT**		**PROCEDURE**	
1	KN PT = 1, CK BASE = 2:	0	ENTER 1	KNOWN POINT: (TRIG LIST) BILL
2	CLOSING <:	0.000	ENTER CLOSING ANGLE	CLOSING ANGLE (MILS): 2706.320
3	CMPTD AZ:	0.000	RECORD COMPUTED AZIMUTH TO AZIMUTH MARK	COMPUTED AZIMUTH (MILS): 0156.826
4	KN AZ FWD:	0.000	ENTER KNOWN AZIMUTH	KNOWN AZIMUTH (MILS): 0156.779
5	AZ ERROR:	0.000	RECORD TOTAL AZIMUTH ERROR	AZIMUTH ERROR (MILS): .047
6	KN HT:	0.0	ENTER KNOWN HEIGHT	KNOWN HEIGHT (METERS): 322.8
7	HT ERROR:	0.0	RECORD TOTAL HEIGHT ERROR	HEIGHT ERROR (METERS): .1
8	KN EAST:	0.00	ENTER KNOWN EASTING	KNOWN EASTING: 556490.21
9	KN NORTH:	0.00	ENTER KNOWN NORTHING	KNOWN NORTHING: 3837057.98
10	TOTAL DIST:	0.000	RECORD TOTAL MAIN SCHEME DISTANCE	TOTAL DISTANCE (METERS): 1719.923
11	RE:	0.00	RECORD RADIAL ERROR	RADIAL ERROR (METERS): .04
12	AR: 1/		RECORD ACCURACY RATIO	ACCURACY RATIO: 1/44800 (CHECK SPECIFICATIONS)
13	END OF MSN (Y/N):		ENTER Y OR N	

INSTRUCTIONS (CHECK BASE)				DATA RECORD
STEP	**PROMPT**		**PROCEDURE**	
1	KN PT = 1, CK BASE = 2:		ENTER 2	CHECK BASE:
2	MEASURED AZ:	0.000	ENTER MEASURED AZIMUTH	MEASURED AZIMUTH (MILS):
3	MEAS BASE:	0.000	ENTER MEASURED BASE	MEASURED BASE (METERS):
4	AZ ERROR:	0.000	RECORD AZIMUTH ERROR	AZIMUTH ERROR (MILS):
5	CA: 1/		RECORD COMPARATIVE ACCURACY	COMPARATIVE ACCURACY: (CHECK SPECIFICATIONS)
6	END OF MSN (Y/N):		ENTER Y OR N	

REMARKS:

REVERSE OF DA FORM 5592-R, DEC 86

Table 6-2. **Instructions for computing DA Form 5592-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 3. At this point, the computer will enter the survey module and call the required program.
2	The prompt TRIANGULATION appears. There is nothing in the PROCEDURE column. At this point, press the END LINE key. (When the PROCEDURE column is blank, the procedure is to always press the END LINE key.)
Note. After each step, you must press the END LINE key.	
3	The prompt EAST B/C: 0.00 appears. The procedure is ENTER EASTING OF B OR C. At this point, enter the known easting of the starting point. Record it in the EASTING: block in the DATA RECORD section.
4	The prompt NORTH B/C: 0.00 appears. The procedure is ENTER NORTHING. At this point, enter the known northing of the starting point. Record it in the NORTHING: block in the DATA RECORD section.
5	The prompt HT B/C 0.0 appears. The procedure is ENTER HEIGHT. At this point, enter the height of the starting point. Record it in the HEIGHT (METERS): block in the DATA RECORD section.
6	The prompt AZ BASE: 0.000 appears. The procedure is ENTER AZIMUTH OF BASE. At this point, enter the azimuth from the starting point to the other end of the base. Record it in the AZIMUTH OF BASE (MILS): block in the DATA RECORD section.
7	The prompt BASE DIST: 0.000 appears. The procedure is ENTER BASE DISTANCE. At this point, enter the distance from Point B to Point C. Record it in the BASE DISTANCE (METERS): block in the DATA RECORD section.
8	The prompt GRID BASE (Y/N): appears. The procedure is ENTER Y OR N. At this point, enter Y or N. If the base is a grid base (computed), enter Y. If the base was determined by any other means, enter N.
Note. The blocks designated for field data are marked with dark arrows.	
9	The prompt ANGLE A: 0.000 appears. The procedure is ENTER ANGLE A. At this point, enter the value of angle A. Record this value in the ANGLE A (MILS): block in the DATA RECORD section.
10	The prompt ANGLE B: 0.000 appears. The procedure is ENTER ANGLE B. At this point, enter the value of angle B. Record this value in the ANGLE B (MILS): block in the DATA RECORD section.
11	The prompt ANGLE C: 0.000 appears. The procedure is ENTER ANGLE C. At this point, enter the value of angle C. Record this value in the ANGLE C (MILS): block in the DATA RECORD section.
12	The prompt VA (+/-):0.00 appears. The procedure is ENTER VERTICAL ANGLE. At this point, enter the value of the vertical angle. Record this value in the VERTICAL ANGLE (MILS): block in the DATA RECORD section
13	The prompt RECIP VA (Y/N): appears. The procedure is ENTER Y OR N. Enter Y if the vertical angles were measured reciprocally. Enter N if they were not.
14	The prompt CLOSURE IS: 0.000 appears. The procedure is CHECK SPECIFICATIONS ON CLOSURE. This closure refers to triangle closure that is discussed in paragraph 6-8. For reference, this can be recorded in the REMARKS: block of the form that is below the DATA RECORD section. (See Figure 6-10.) At this point, check the specifications for the type of triangulation you are performing to ensure that closure is within limitations. (See Appendix B.)
15	The prompt SIDE BA=1, CA=2: 0 appears. The procedure is ENTER 1 OR 2. At this point, enter the number that corresponds to the side that is to be computed.
16	The prompt E OF_: 0.00 appears. The procedure is RECORD EASTING. At this point, BUCS displays the easting coordinates of the unknown point (A). The blank after the word OF on the form will be replaced with a point number on the BUCS. Also, the 0.00 will be replaced with the easting coordinates of the unknown point. These data are to be recorded in the DATA RECORD section of the form. If the DATA RECORD section is already full, record the data in the first column of the DATA RECORD section of a second form.
17	The prompt N OF_: 0.00 appears. The procedure is RECORD NORTHING. At this point, record the northing of the unknown point in the same way as the easting was recorded.
18	The prompt HT OF_: 0.0 appears. The procedure is RECORD HEIGHT. At this point, record the height of the unknown point in the same way as the easting and northing were recorded.

Table 6-2. **Instructions for computing DA Form 5592-R (continued)**

STEP	INSTRUCTION
19	The prompt AZ TO REAR: 0.000 appears. The procedure is RECORD AZIMUTH TO REAR. At this point, record the azimuth in the AZIMUTH OF BASE (MILS): block in the DATA RECORD section.
20	The prompt BASE DISTANCE: 0.000 appears. The procedure is RECORD NEXT BASE. This is the length of the side that was just computed, which will be used as the base distance for the next triangle. Record this value in the BASE DISTANCE (METERS): block in the DATA RECORD section.
21	The prompt CLOSE Y/N: appears. The procedure is ENTER Y OR N. At this point, the BUCS is asking if this is the end of the survey. If it is the last triangle, enter Y; if not, then enter N. If no (N), it will advance to step 22. If the answer is yes (Y), the program will prompt KN PT=1, CK BASE=2: 0. At this point, you would enter either 1 or 2 to select the type of closure to be performed. (The back of the form has the instructions for computing closure.) (See Figure 6-12.)
22	The prompt STA_ START (Y/N): appears. The procedure is ENTER Y OR N. At this point, the BUCS is asking if the point shown is going to be the start point for computing the next triangle. The point number will be in the space after the word *STA* in the prompt. This point should match the point number on the sketch. (The first unknown point should be number 2, the second unknown number 3, and so on.) If the answer is yes (Y), the program will prompt END OF TRIANGLE #_. Press the END LINE key. The program returns to step 9. If the answer is no (N), the program goes to step 23.
23	The prompt # OF START PT: _00 appears. The procedure is ENTER NUMBER. If step 22 was answered yes, this step will be skipped. If step 22 was answered no, the BUCS prompts the computer to tell it the number of the point from which the next triangle will be computed. After the number is entered, the program will return to step 9.

Table 6-3. **Closure on known point computation, reverse of DA Form 5592-R**

STEP	INSTRUCTION
1	The prompt KN PT = 1, CK BASE = 2 appears. The procedure in the PROCEDURE column is ENTER 1. Enter the number 1.
2	The prompt CLOSING ∠: 0.000 appears. The procedure is ENTER CLOSING ANGLE. At this point, enter the value of the closing angle. Record this value in the CLOSING ANGLE (MILS): block in the DATA RECORD section.
3	The prompt COMPTD AZ: 0.000 appears. The procedure is RECORD COMPUTED AZIMUTH TO AZIMUTH MARK. This step gives the azimuth that was computed from the final station to the azimuth mark. Record this value in the COMPUTED AZIMUTH (MILS): block in the DATA RECORD section.
4	The prompt KN AZ FWD: 0.000 appears. The procedure is ENTER KNOWN AZIMUTH. This step asks you to enter the known azimuth to the closing azimuth mark so a comparison can be made with the computed azimuth. Record this value in the KNOWN AZIMUTH (MILS): block in the DATA RECORD section.
5	The prompt AZ ERROR: 0.000 appears. The procedure is RECORD TOTAL AZIMUTH ERROR. This is the difference between the known azimuth to the azimuth mark and the computed azimuth. (Check survey specifications.) Record the azimuth error in the in the AZIMUTH ERROR (MILS): block in the DATA RECORD section.
6	The prompt KN HT: 0.0 appears. The procedure is ENTER KNOWN HEIGHT. This step asks for the known height for comparison with computed height. Record the known height in the KNOWN HEIGHT (METERS): block in the DATA RECORD section.
7	The prompt HT ERROR: 0.0 appears. The procedure is RECORD TOTAL HEIGHT ERROR. Record this value in the HEIGHT ERROR (METERS): block in the DATA RECORD section. This step shows the difference between the known and computed height.

Table 6-3. **Closure on known point computation, reverse of DA Form 5692-R (continued)**

STEP	INSTRUCTION
8	The prompt KN EAST: 0.00 appears. The procedure is ENTER THE KNOWN EASTING. This step asks for the known easting coordinates of the closing point. Record the value in the KNOWN EASTING: block in the DATA RECORD section.
9	The prompt KN NORTH: 0.00 appears. The procedure is ENTER KNOWN NORTHING. This step asks for the known northing coordinates of the closing point. Record the value in the KNOWN NORTHING: block in the DATA RECORD section.
10	The prompt TOTAL DIST: 0.000 appears. The procedure is RECORD TOTAL MAIN SCHEME DISTANCE. This is the total distance that is used to compute the accuracy of the survey. Record this value in the TOTAL DISTANCE (METERS): block in the DATA RECORD section. (See paragraph 6-7d.)
11	The prompt RE: 0.00 appears. The procedure is RECORD RADIAL ERROR. The radial error is the distance from the actual to the computed location of the closing station. Record the information in the RADIAL ERROR (METERS): block in the DATA RECORD section.
12	The prompt AR: 1/ appears. The procedure is RECORD ACCURACY RATIO. The accuracy ratio is the total distance divided by the radial error. It must be compared with the specifications of the type of survey being performed to ensure that the survey was performed to the required standards. (See Appendix B.) Record the accuracy ratio in the ACCURACY RATIO: block in the DATA RECORD section.
13	The prompt END OF MISSION (Y/N): appears. The procedure is ENTER Y OR N. At this point, the computer determines if he is finished with the triangulation computations. If all of the specifications are met and all the data are recorded, the computer enters Y. The BUCS will return to SURVEY PGM MENU REV1. If a problem exists in the closure specifications, enter N. The program will return to step 12.

Table 6-4. **Check base computation, reverse of DA Form 5592-R**

STEP	INSTRUCTION
1	The prompt KN PT = 1, CK BASE = 2 appears. The procedure in the PROCEDURE column is ENTER 2. Enter the number 2.
2	The prompt MEASURED AZ: 0.000 appears. The procedure is ENTER MEASURED AZIMUTH. This step asks for the azimuth that was measured along the base. Record this value in the MEASURED AZIMUTH (MILS): block in the DATA RECORD section.
3	The prompt MEAS BASE: 0.000 appears. The procedure is ENTER MEASURED BASE. This step is asking for the distance of the check base that was measured. Record this value in the MEASURED BASE (METERS): block in the DATA RECORD section.
4	The prompt AZ ERROR: 0.000 appears. The procedure is RECORD AZIMUTH ERROR. This step shows you the difference between the computed and the measured azimuth. Record the data in the AZIMUTH ERROR (MILS): block in the DATA RECORD section.
5	The prompt CA: 1/ appears. The procedure is RECORD COMPARATIVE ACCURACY. This step does a comparative accuracy of the measured and computed length of the base, similar to a comparative accuracy of taped distances. Record the data in the COMPARATIVE ACCURACY: block in the DATA RECORD section.
6	This step is the same as step 13 in Table 6-3.

Section IV

INTERSECTION

Intersection is a method of survey used to locate an unknown point by determining azimuths from two or more known points. This method of survey is used as a means of establishing control to desired positions and of checking the locations of points established by other survey methods. A point established by the intersection method should be observed from at least two known stations of equal or higher order of survey than the survey being conducted. One of the points is designated as 01. The height of 01 must also be known. The location and height of the unknown are computed from 01.

6-10. LIMITATIONS

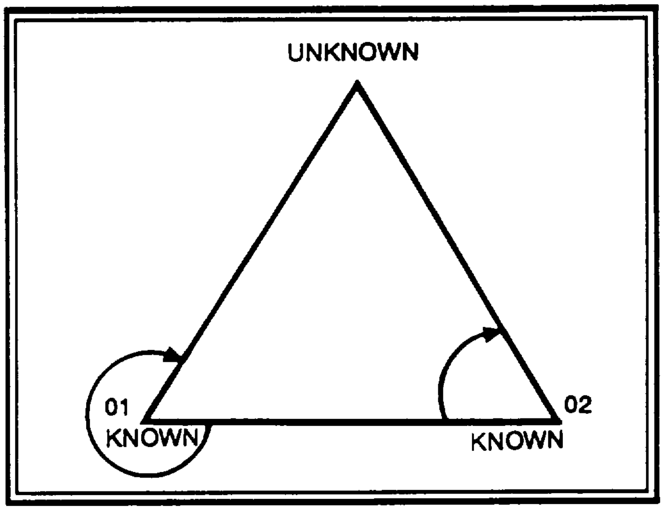
Limitations for the apex angle are the same as the limitations for distance angles discussed in paragraph 6-6c. (The exception to this is when intersection is used in target area survey. In this case, the apex angle must be at least 150 mils and preferably 300 mils.)

6-11. POINT VISIBILITY

The known points can be either intervisible or nonintervisible.

a. If the points are intervisible (Figure 6-13), measure a horizontal angle from each point to the unknown point, using the other point as the rear station. Measure a vertical angle from 01 to the unknown point. Compute the azimuth between the two points by using DA Form 5590-R. Then separately add each angle to the azimuth or back-azimuth to determine the azimuths from 01 and 02 to the unknown point.

Figure 6-13. **Intervisible points**



EXAMPLE

Horizontal angle at 01:	5549.113	Horizontal angle at 02:	1415.894
Azimuth 01 to 02:	+ 4957.572	Azimuth 02 to 01:	+ 1757.572
	10506.685	Azimuth to unknown	3173.466
	– 6400.000[1]		
Azimuth to unknown:	4106.685		

[1] If azimuth is over 6,400 mils, subtract 6,400 mils.

b. Determine if the apex angle meets the requirements (see paragraph 6-10) by doing the procedure below.

(1) Determine the back-azimuths from the unknown point back to the known points by adding or subtracting 3,200 mils

EXAMPLE

Azimuth 01 to unknown point:	4106.685	Azimuth 02 to unknown point:	3173.466
	– 3200.000		3200.000
Azimuth unknown point to 01:	0906.685	Azimuth unknown point to 02:	6373.466

(2) Imagine yourself standing at the unknown point looking back at the known points. (See Figure 6-13.) Point 02 is located to the left side and Point 01 to the right. Subtract the azimuths from left to right.

EXAMPLE

Azimuth unknown point to 01:	0906.685
	+6400.000[1]
	7306.685
Azimuth unknown point to 02:	−6373.466
Apex angle:	0933.219

[1] If the azimuth to the right is smaller than the azimuth to the left, add an entire circle (6,400 mils) to the azimuth on the right.

c. If the points are nonintervisible (Figure 6-14), do the procedure below. (See the example below.)

(1) Measure a horizontal angle from both points to the unknown point by using a point with a known azimuth as a rear station. Each angle is then added separately to the known azimuth to determine the azimuths from 01 and 02 to the unknown point.

(2) Determine if the apex angle meets the requirements as described in paragraph 6-1 lb.

6-12. INTERSECTION COMPUTATIONS

Intersection computations are done on DA Form 5604-R (Computation of Coordinate and Height by Intersection (BUCS)). (See Figure 6-15.) (A reproducible copy of this form is at the back of this book.) (Table 6-5 gives the instructions for computing DA Form 5604-R.)

EXAMPLE

Azimuth 01 azimuth mark:	4095.1	Azimuth 02 to azimuth mark:	2594.8
Angle 01 to the unknown:	3015.5	Angle 02 to unknown:	+ 3576.0
	7110.6	Azimuth 02 to unknown:	6170.8
	− 6400.0		
Azimuth 01 to unknown	0710.6		

Figure 6-14. **Nonintervisible points**

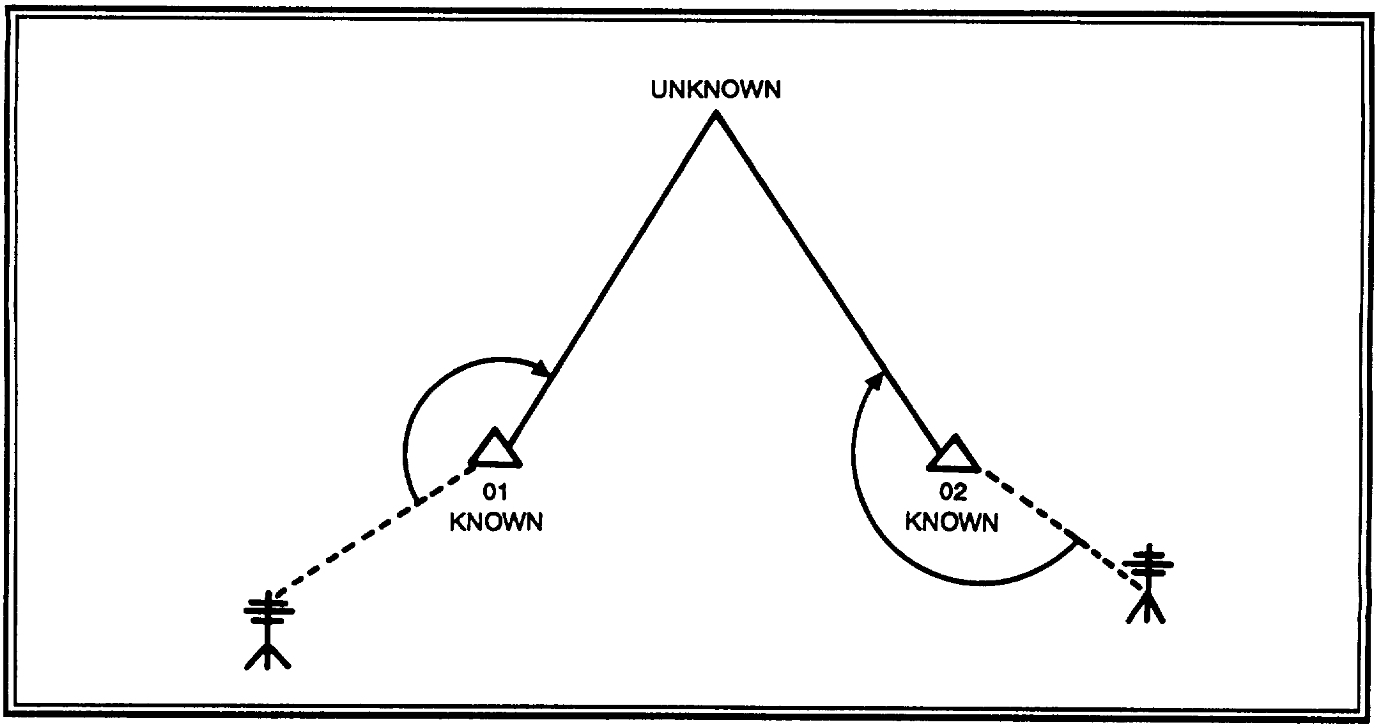


Figure 6-15. **DA Form 5604-R**

COMPUTATION OF COORDINATES AND HEIGHT BY INTERSECTION (BUCS)

For use of this form, see FM 6-2, the proponent agency is TRADOC.

COMPUTER SSG PENA	NOTEBOOK REFERENCE	DATE 20 FEB 92	
CHECKER SSG ANDERSON	AREA FT. SILL	SHEET 1 OF 1 SHEETS	

NOTES:
1. IF STEP 17 IS Y PROGRAM GOES TO STEP 18.
2. IF STEP 17 IS N PROGRAM GOES TO STEP 19.
3. IF STEP 18 IS Y PROGRAM GOES TO STEP 10.
4. IF STEP 18 IS N PROGRAM GOES TO STEP 3.
5. TWO INTERSECTION PROBLEMS CAN BE RECORDED PER FORM.
6. ENTER FIELD DATA IN BLOCKS MARKED ▶.

SAMPLE

INSTRUCTIONS				DATA RECORD	
STEP	PROMPT		PROCEDURE		
				(O1) NAME: BUZZARD 2	(O1) NAME: BUZZARD 2
1			CALL PROGRAM 12	(O2) NAME: FLAT TOP 2	(O2) NAME: NAA-1
2	INTERSECTION				
3	EAST 01:	0.00	ENTER EASTING OF O1	EASTING O1: 56080.13	EASTING O1: 560680.13
4	NORTH 01:	0.00	ENTER NORTHING OF O1	NORTHING O1: 3835650.55	NORTHING O1: 3835650.55
5	HT 01:	0.0	ENTER HEIGHT OF O1	HEIGHT O1 (METERS): 371.2	HEIGHT O1 (METERS): 371.2
6	EAST 02:	0.00	ENTER EASTING OF O2	EASTING O2: 559858.43	EASTING O2: 559526.03
7	NORTH 02:	0.00	ENTER NORTHING OF O2	NORTHING O2: 3836637.31	NORTHING O2: 3838568.42
8	*DIST 01/02:	0.000	RECORD DISTANCE FROM O1 TO O2	DISTANCE O1 TO O2 (METERS): 1284.090	DISTANCE O1 TO O2 (METERS): 3137.820
9	AZ 01/02:	0.000	RECORD AZIMUTH FROM O1 TO O2	AZIMUTH O1 TO O2 (MILS): 5692.711	AZIMUTH O1 TO O2 (MILS): 6016.352
10	AZ 01/TGT:	0.000	ENTER AZIMUTH FROM O1 TO TARGET	▶ AZIMUTH O1 TO TARGET (MILS): 4774.1	▶ AZIMUTH O1 TO TARGET (MILS): 4774.1
11	VA 01/TGT:	0.000	ENTER VERTICAL ANGLE FROM O1 TO TARGET	▶ VERTICAL ANGLE O1 TO TARGET (MILS): ± 4.3	▶ VERTICAL ANGLE O1 TO TARGET (MILS): ± 4.3
12	AZ 02/TGT:	0.000	ENTER AZIMUTH FROM O2 TO TARGET	▶ AZIMUTH O2 TO TARGET (MILS): 4527.0	▶ AZIMUTH O2 TO TARGET (MILS): 4100.6
13	*TARGET #:	—	RECORD TARGET NUMBER	TARGET NUMBER: 01	TARGET NUMBER: 01
14	EAST:	0.00	RECORD EASTING OF TARGET	EASTING: 555814.73	EASTING: 555816.38
15	NORTH:	0.00	RECORD NORTHING OF TARGET	NORTHING: 3835526.81	NORTHING: 3835626.83
16	HT:	0.0	RECORD HEIGHT OF TARGET	HEIGHT (METERS): 352.3	HEIGHT (METERS): 352.3
17	ADD TGTS (Y/N):		ENTER Y OR N		
18	SAME OPS (Y/N):		ENTER Y OR N		
19	END OF MSN (Y/N):		ENTER Y OR N		

REMARKS:
O1A TO UNK: AZ 4774.100 DIST.: 4866.973
O1B TO UNK: AZ 4774.101 DIST.: 4866.323
UNK TO UNK: AZ 1368.669 DIST.: (RE): 650
ACCURACY RATIO: 1/7400
E: 555815.055 N. 3835526.82 EL: 352.3

DA FORM 5604-R, DEC 86

Table 6-5. **Instructions for computing DA Form 5604-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 12. At this point, call Program 12.
2	The prompt INTERSECTION appears. There is no procedure in the PROCEDURE column. Press the END LINE key to continue the program.
Note. After each step, you must press the END LINE key.	
3	The prompt EAST O1: 0.00 appears. The procedure is ENTER EASTING OF O1. At this point, enter the easting coordinates of O1. Record this value in the EASTING O1: block in the DATA RECORD section.
4	The prompt NORTH O1: 0.00 appears. The procedure is ENTER NORTHING OF O1. At this point, enter the northing coordinates of O1. Record this value in the NORTHING O1: block in the DATA RECORD section.
5	The prompt HT O1: 0.0 appears. The procedure is ENTER HEIGHT OF O1. At this point, enter the height of O1. Record this value in the HEIGHT O1 (METERS): block in the DATA RECORD section.
6	The prompt EAST O2: 0.00 appears. The procedure is ENTER EASTING OF O2. At this point, enter the easting coordinates of O2. Record this value in the EASTING O2: block in the DATA RECORD section.
7	The prompt NORTH O2: 0.00 appears. The procedure is ENTER NORTHING OF O2. At this point, enter the northing coordinates of O2. Record this value in the NORTHING O2: block in the DATA RECORD section.
8	The prompt ^DIST O1/O2: 0.000 appears. The procedure is RECORD THE DISTANCE FROM O1 TO O2. At this point, the BUCS will give the distance in meters from O1 to O2. Record this information in the DISTANCE O1 TO O2 (METERS): block in the DATA RECORD section.
9	The prompt AZ O1/O2: 0.000 appears. The procedure is RECORD AZIMUTH FROM O1 TO O2. At this point, the BUCS will give the azimuth from O1 to O2. Record this value in the AZIMUTH O1 TO O2 (MILS): block in the DATA RECORD section.
10	The prompt AZ O1/TGT: 0.000 appears. The procedure is ENTER AZIMUTH FROM O1 TO TARGET. At this point, enter the azimuth requested. Record this value in the AZIMUTH O1 TO TARGET (MILS): block in the DATA RECORD section.
11	The prompt VA O1/TGT: 0.000 appears. The procedure is ENTER VERTICAL ANGLE FROM O1 TO TARGET. At this point, enter the angle requested. Record this value in the VERTICAL ANGLE O1 TO TARGET (MILS): block in the DATA RECORD section.
12	The prompt AZ O2/TGT: 0.000 appears. The procedure is ENTER AZIMUTH FROM O2 TO TGT. At this point, enter the azimuth requested. Record this value in the VERTICAL ANGLE O2 TO TARGET (MILS): block in the DATA RECORD section.
13	The prompt ^TARGET #: _ appears. The procedure is RECORD TARGET NUMBER. At this point, the BUCS will assign a number to the unknown point being solved. Record the number in the TARGET NUMBER: block in the DATA RECORD section.
14	The prompt EAST: 0.00 appears. The procedure is RECORD EASTING OF TARGET. At this point, the BUCS will give the easting coordinates of the target. Record these coordinates in the EASTING: block in the DATA RECORD section.
15	The prompt is NORTH: 0.00. The procedure is RECORD NORTHING OF TARGET. At this point, the BUCS will give the northing coordinates of the target. Record these coordinates in the NORTHING: block in the DATA RECORD section.

Table 6-5. **Instruction for computing DA Form 5604-R (continued)**

STEP	INSTRUCTION
16	The prompt HT: 0.0 appears. The procedure is RECORD HEIGHT OF TARGET. At this point, the BUCS will give the height of the target. Record this height in the HEIGHT (METERS): block in the DATA RECORD section.
17	The prompt ADD TGTS (Y/N): appears. The procedure is ENTER Y OR N. At this point, the BUCS is asking if the computer wishes to compute additional targets. If finished, the computer answers N (no). If not finished, the computer answers Y (yes). If Y is the choice, the program goes to step 18. If N is the choice, the program goes to step 19.
18	The prompt SAME OPS (Y/N): appears. The procedure is ENTER Y OR N. At this point, the BUCS wants to know if the computer is going to use the same points to compute another target. If the computer chooses Y (yes), the program goes to step 10. If the computer chooses N (no), the program goes to step 3.
19	The prompt END OF MSN (Y/N): appears. The procedure is ENTER Y OR N. At this point, the BUCS wants to know if the computer is finished with this program. If the computer chooses Y (yes), the program will return to SURVEY PGM MENU REV1. If the computer chooses N (no), the program will return to step 17.

6-13. INTERSECTION ACCURACY

To determine the accuracy of an intersection, do the procedure below.

a. Compute another intersection to the unknown (unk) point by using a different Point 01, Point 02, or Points 01 and 02.

b. Compute a DA Form 5590-R from the points designated as 01 to the unknown point.

c. Then compute a DA Form 5590-R from the computed coordinates of the first intersection to the computed coordinates of the second intersection. (This will be the radial error.)

d. Divide the radial error into the shorter of the two distances (dis), 01A to the unknown point or 01B to the unknown point. This will be the accuracy ratio of the intersection. The accuracy ratio must agree within the prescribed accuracy limits for the type of survey being performed (1:1,000 for fifth order, 1:3,000 for fourth order).

$$AR = 1/\frac{\text{Distance 01A to unk or 01B to unk (whichever is shortest)}}{\text{radial error (dis between the unk)}}$$

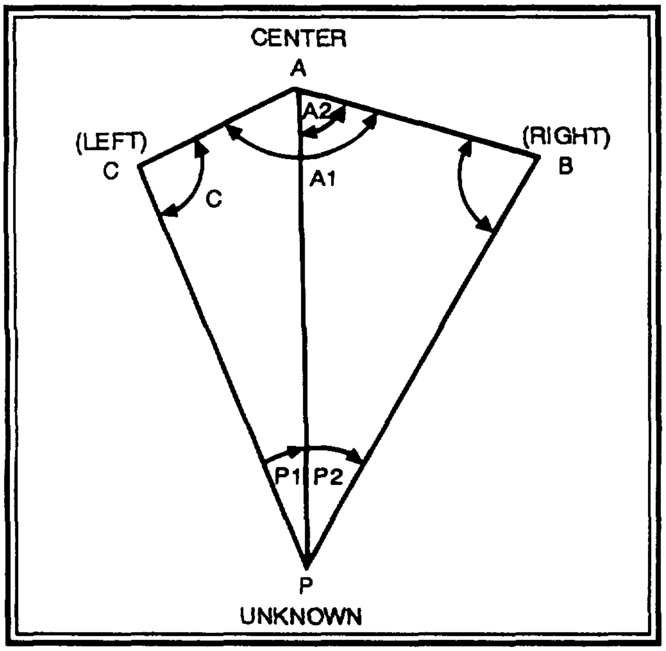
e. Once the accuracy ratio has been computed and meets specifications described in d above, determine the mean coordinates and elevation for the unknown point. (See Figure 6-15, REMARKS: block.)

Section V

THREE-POINT RESECTION

Three-point resection is a method of survey used to obtain control for an unknown point on the basis of three inaccessible known points. However, before the fieldwork is begun, several factors must be considered. In Figure 6-16, Stations A, B, and C are the known points and Station P is the occupied station for which coordinate are to be determined. All points must be selected so that Angles P1, P2, C, and B (Figure 6-16) are at least 400 mils The preferred value for the angles is 533 rnils. Also, if the sum of the Angles P1, P2, and Al is between 2,845 mils and 3,555 mils no valid solution is possible. This simply means that Station P lies on or near a circle passing through Stations A, B, and C. To eliminate the possibility of this occurring, a map reconnaissance must be made. The fieldwork consists of measuring horizontal Angles P1 and P2 and the vertical angle to the center station. Resection field notes are recorded in the field notebook in the same basic format as triangulation field notes except that the height of target (known or estimated) and the height of instrument (measured to the nearest 0.1 meter) are recorded in the remarks section. A three-point resection may be considered a closed survey if a fourth known point is used to compute a second resection, the solutions are compared, and the accuracy ratio meets the specified position closure requirement. The points used for three-point resection should be fourth-order or better. For an example of the field notes of a three-point resection, see Figure 4-11 in Chapter 4.

Figure 6-16. **Three-point resection**



6-14. DA FORM 5593-R

a. DA Form 5593-R (Computation of Coordinates and Height by Three-Point Resection (BUCS)) is shown in Figure 6-17. (A reproducible copy of this form is included at the back of this book.) The top of the form is for recording administrative data, These data include the following:

- Computer's name.
- Checker's name.
- Area in which survey was performed.
- Notebook reference.
- Date the computations were performed.
- Identification of the sheet number.

b. The next part of the form provides notes for specific operations of the program and other notes necessary for completion of this form.

c. The form is divided into two major sections. The section on the left provides instructions for the computer. The right section (DATA RECORD) is for recording data-both field and computed. Two resections can be computed on each form. The left section is divided into three columns—STEP, PROMPT, and PROCEDURE, The STEP column is the numerical sequence the operator uses as he proceeds down the form The PROMPT column tells the operator what will appear on the BUCS display at each particular step. The PROCEDURE column tells the computer the action he will take at each particular step or prompt.

d. Entries required are the coordinates of Points A, B, and C, the horizontal and vertical angles measured at Point P; and the height of Point A. The points used for three-point resection should be of fourth-order or higher accuracy.

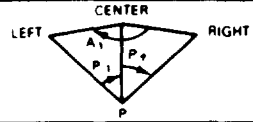
Figure 6-17. **DA Form 5593-R**

COMPUTATION OF COORDINATES AND HEIGHT BY THREE-POINT RESECTION (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER SSG PENA	NOTEBOOK REFERENCE	DATE 18 MAR 91	
CHECKER SFC KING	AREA WEST RANGE	SHEET 1 OF 1 SHEETS	

NOTES:
1. FOR STEP 15, SEE FM 6-2, CHAPTER 6.
2. IF STEP 20 IS Y, PROGRAM GOES TO STEP 21.
3. IF STEP 20 IS N, PROGRAM GOES TO STEP 22.
4. IF STEP 21 IS Y, PROGRAM GOES TO STEP 10.
5. IF STEP 21 IS N, PROGRAM GOES TO STEP 3.
6. ENTER FIELD DATA IN BLOCKS MARKED ▶.



INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE		
1		CALL PROGRAM 4		
2	RESECTION			
3	E LFT STA: 0.00	ENTER EASTING OF LEFT STATION	EASTING OF LEFT: 555644.74	EASTING OF LEFT: 555644.74
4	N LFT STA: 0.00	ENTER NORTHING OF LEFT STATION	NORTHING OF LEFT: 3834516.25	NORTHING OF LEFT: 3834516.25
5	E CTR STA: 0.00	ENTER EASTING OF CENTER STATION	EASTING OF CENTER: 554490.21	EASTING OF CENTER: 554549.44
6	N CTR STA: 0.00	ENTER NORTHING OF CENTER STATION	NORTHING OF CENTER: 3834939.72	NORTHING OF CENTER: 3835212.92
7	HT CTR STA: 0.00	ENTER HEIGHT OF CENTER STATION	HEIGHT OF CENTER: 362.5	HEIGHT OF CENTER: 357.4
8	E RT STA: 0.00	ENTER EASTING OF RIGHT STATION	EASTING OF RIGHT: 553398.40	EASTING OF RIGHT: 553398.40
9	N RT STA: 0.00	ENTER NORTHING OF RIGHT STATION	NORTHING OF RIGHT: 3835130.22	NORTHING OF RIGHT: 3835130.22
10	< LF TO CTR: 0.000	ENTER ANGLE P	▶ HORIZONTAL ANGLE P (MILS): 0765.6	▶ HORIZONTAL ANGLE P (MILS): 0607.0
11	< CTR TO RT: 0.000	ENTER ANGLE P	▶ HORIZONTAL ANGLE P (MILS): 1167.4	▶ HORIZONTAL ANGLE P (MILS): 1326.0
12	VA P – CTR: 0.000	ENTER VERTICAL ANGLE FROM P TO CENTER	VERTICAL ANGLE FROM P TO CENTER ▶ (MILS): ⊕ 9.7	VERTICAL ANGLE FROM P TO CENTER ▶ (MILS): ⊖ 4.0
13	HT/T AT CTR: 0.0	ENTER HEIGHT OF TARGET AT CENTER	HEIGHT OF TARGET (METERS): 4.7	HEIGHT OF TARGET (METERS): 4.7
14	HT/I AT P: 0.0	ENTER HEIGHT OF INSTRUMENT AT P	HEIGHT OF INSTRUMENT (METERS): 1.4	HEIGHT OF INSTRUMENT (METERS): 1.4
15	SUM OF <'S: 0.000	CHECK SPECIFICATIONS (2845-3555 INVALID 3-PT)	SUM OF ANGLES: 4950.864	SUM OF ANGLES: 4482.901
16	E OF P: 0.00	RECORD EASTING OF P	EASTING OF P: 554454.50	EASTING OF P: 554454.35
17	N OF P: 0.00	RECORD NORTHING OF P	NORTHING OF P: 3835671.31	NORTHING OF P: 3835671.31
18	HT OF P: 0.0	RECORD HEIGHT OF P	HEIGHT OF P (METERS): 358.8	HEIGHT OF P (METERS): 358.8
19	AZ P TO CTR: 0.000	RECORD AZIMUTH FROM P TO CENTER	AZIMUTH FROM P TO CENTER (MILS): 3150.322	AZIMUTH FROM P TO CENTER (MILS): 2991.660
20	ANOTHER 3-PT (Y/N):	ENTER Y OR N	REMARKS: P-A AZ: 3150.320 DIST: 732.461 P1-A AZ: 2991.655 DIST: 468.149 P-P1 AZ: 4800,000 DIST: (RE): .150 A-R: 1/3100 E. 554454.42 N. 3835671.31 HEIGHT: 358.8	
21	SAME L/R/CTR (Y/N):	ENTER Y OR N		
22	END OF MSN (Y/N):	ENTER Y OR N		

DA FORM 5593-R, DEC 86

Table 6-6. **Instructions for computing DA Form 5593-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 4. Enter the survey module, and call Program 4.
2	The prompt RESECTION appears. There is no procedure. Press the END LINE key to continue the program.
Note. After each step, you must press the END LINE key.	
3	The prompt E LFT STA: 0.00: appears. The procedure is ENTER EASTING OF LEFT STATION. At this step, enter the easting coordinates of the left station. Record this value in the EASTING OF LEFT: block in the DATA RECORD section.
4	The prompt N LFT STA: 0.00: appears. The procedure is ENTER NORTHING OF LEFT STATION. At this step, enter the northing coordinates of the left station. Record this value in the NORTHING OF LEFT: block in the DATA RECORD section.
5	The prompt E CTR STA: 0.00: appears. The procedure is ENTER EASTING OF CENTER STATION. At this step, enter the easting coordinates of the center station. Record this value in the EASTING OF CENTER: block in the DATA RECORD section.
6	The prompt N CTR STA: 0.00: appears. The procedure is ENTER NORTHING OF CENTER STATION. At this step, enter the northing coordinates of the center station. Record this value in the NORTHING OF CENTER: block in the DATA RECORD section.
7	The prompt HT CTR STA: 0.00: appears. The procedure is ENTER HEIGHT OF CENTER STATION. At this step, enter the height of the center station. Record this value in the HEIGHT OF CENTER: block in the DATA RECORD section.
8	The prompt E RT STA: 0.00: appears. The procedure is ENTER EASTING OF RIGHT STATION. At this step, enter the easting of the right station. Record this value in the EASTING OF RIGHT: block in the DATA RECORD section.
9	The prompt N RT STA: 0.00: appears. The procedure is ENTER NORTHING OF RIGHT STATION. At this step, enter the northing of the right station. Record this value in the NORTHING OF RIGHT: block in the DATA RECORD section.
10	The prompt ∠ LF TO CTR: 0.000: appears. The procedure is ENTER ANGLE P1. At this step, enter the value of angle P1. Record this value in the HORIZONTAL ANGLE P1 (MILS): block in the DATA RECORD section.
11	The prompt ∠ CTR TO RT: 0.000: appears. The procedure is ENTER ANGLE P2. At this step, enter the value of angle P2. Record this value in the HORIZONTAL ANGLE P2 (MILS): block in the DATA RECORD section
12	The prompt VA P-CTR: 0.000: appears. The procedure is ENTER VERTICAL ANGLE FROM P TO CENTER. At this step, enter the value of the vertical angle. Record this value in the VERTICAL ANGLE FROM P TO CENTER (MILS): block in the DATA RECORD section.
13	The prompt HT/T AT CTR: 0.0: appears. The procedure is ENTER HEIGHT OF TARGET AT CENTER. At this step, enter the height of the target at the center station. Record this value in the HEIGHT OF TARGET (METERS): block in the DATA RECORD section.
14	The prompt HT/I AT P: 0.0: appears. The procedure is ENTER HEIGHT OF INSTRUMENT AT P. At this step, enter the measured height of the instrument used to measure the vertical angle. Record this value in the HEIGHT OF INSTRUMENT (METERS): block in the DATA RECORD section.
15	The prompt SUM OF ∠ 'S: 0.000: appears. The procedure is CHECK SPECIFICATIONS (2845-3555 INVALID 3-PT). This step gives the operator the sum of angles P1, P2, and A1. If the sum falls between the noted values in the procedure, the BUCS will display NO VALID SOLN. Record the sum of angles in the SUM OF ANGLES: block in the DATA RECORD section.
16	The prompt E OF P: 0.00 appears. The procedure is RECORD EASTING OF P. At this step, record the easting coordinates of Point P in the EASTING OF P: block in the DATA RECORD section.
17	The prompt N OF P: 0.00 appears. The procedure is RECORD NORTHING OF P. At this step, record the northing coordinates of Point P in the NORTHING OF P: block in the DATA RECORD section.

Table 6-6. **Instructions for computing DA Form 5593-R (continued)**

STEP	INSTRUCTION
18	The prompt HT OF P: 0.0 appears. The procedure is RECORD HEIGHT OF P. At this step, record the height of Point P in the HEIGHT OF P (METERS): block in the DATA RECORD section.
19	The prompt AZ P TO CTR: 0.000 appears. The procedure is RECORD AZIMUTH FROM P TO CENTER. At this step, record the azimuth in the AZIMUTH FROM P TO CENTER (MILS): block in the DATA RECORD section.
20	The prompt ANOTHER 3-PT (Y/N): appears. The procedure is ENTER Y OR N. At this step, the program is asking if the computer wishes to compute another resection. If the computer answers Y (yes), the program will go to step 21. If the computer answers N (no), the program will go to step 22.
21	The prompt SAME L/R/CTR (Y/N): appears. The procedure is ENTER Y OR N. At this step, the program is asking if the next resection problem will use the same known stations that were used for the last resection. Answer yes if all three stations are the same. If the answer is Y (yes), the program returns to step 10. If the answer is N (no), the program returns to step 3.
22	The prompt END OF MISSION (Y/N): appears. The procedure is ENTER Y OR N. If the answer is N (no), the program will return to step 21. If the answer is Y (yes), the program will go to SURVEY PGM MENU REV1.

6-15. CHECKS AND CLOSURE

When possible, the checks below are made to verify data obtained by three-point resection.

a. A horizontal angle to a fourth known station is measured. This will give another three-point resection from which the coordinates of Point PI (a second location of P) may be determined. (See Figure 6-18.) An accuracy ratio is computed by the following formula:

$$AR = 1/\frac{\text{Distance P to CENTER or P1 to CENTER 1 (whichever is shortest)}}{\text{radial error (P - P1)}}$$

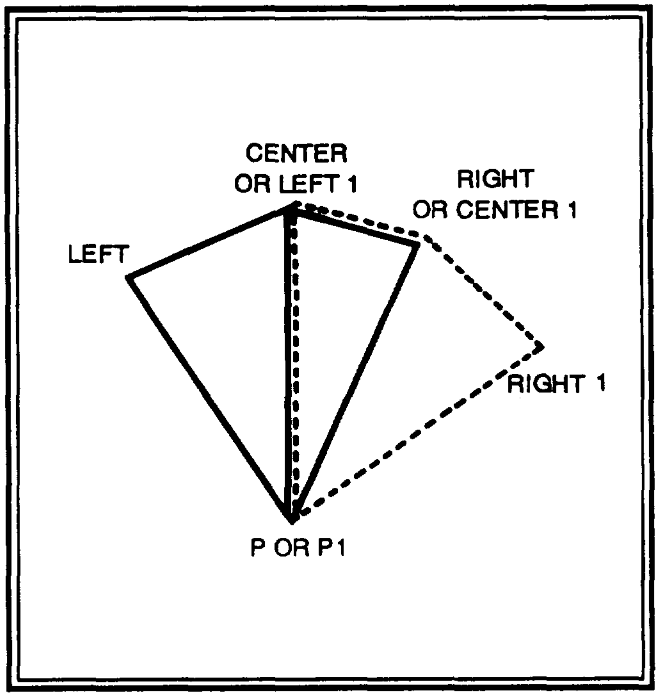
(1) Compute DA Form 5590-R by using the coordinates of the established point to the center station of the first resection (P-CENTER). (See Figure 6-17, REMARKS: block.)

(2) Then compute DA Form 5590-R from the computed coordinates of the second resection to the center station (P1-CENTER 1).

(3) Compute DA Form 5590-R from the computed coordinates of the first resection to the computed coordinates of the second resection (T-P1). The distance will be the radial error.

(4) Divide the radial error into the shorter of the two distances—P-CENTER or P1-CENTER 1. The result is the accuracy ratio of the intersection. The accuracy ratio must agree within the prescribed accuracy limits for the type of survey being performed (1:1,000 for fifth order, 1:3,000 for fourth order).

Figure 6-18. **Three-point resection, fourth known station**



b. An astronomic azimuth or gyroscopic azimuth is determined to check the azimuth.

c. If a fourth point (a above) is not known, then Point P must be verified by some other method of survey before it can be used to extend control.

6-16. LAW OF SINES

As shown in Figure 6-19, the law of sines is a straight proportion-type formula which states that the sine of the angle at A is to its opposite side as the sine of the angle at B is to its opposite side or the sine of the angle at C is to its opposite side. If the value of each of the interior angles of the triangle were known and the length of side a were known, the law of sines would be transposed as shown in b and c below.

a. Ensure the BUCS is operating in degrees. (Type DEGREES, and press the END LINE key.)

b. To determine the length of side b, use the following formula:

$$\text{side b} = \frac{\text{side a x sin Angle B}}{\text{sin Angle A}}$$

The formula when using the BUCS is as follows:

side b = side a * SIN(Angle B * .05625)/ SIN(Angle A * .05625) END LINE

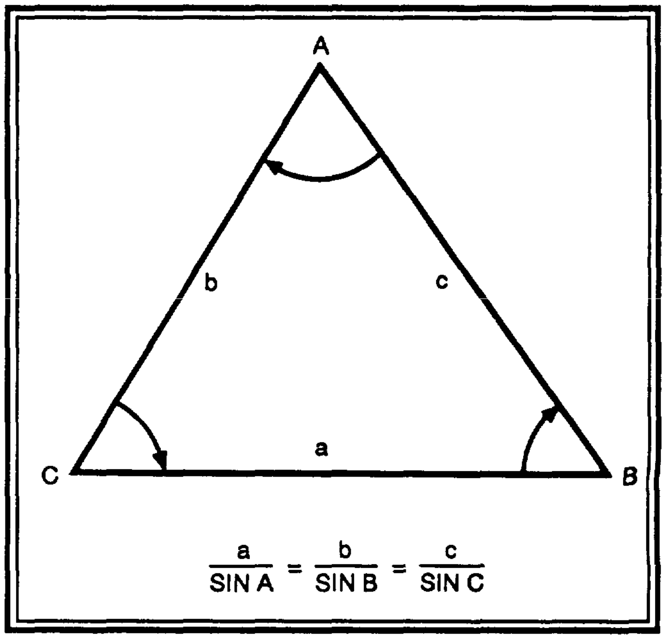
c. To determine the length of side c, use the following formula:

$$\text{side c} = \frac{\text{side a x sin Angle C}}{\text{sin Angle A}}$$

The formula when using the BUCS is as follows:

side c = side a * SIN(Angle C * .05625)/ SIN(Angle A * .05625) END LINE.

Figure 6-19. **Law of sines as it applies to a basic triangle**



CHAPTER 7

ASTRONOMY FOR FIELD ARTILLERY

The FA surveyor can determine an accurate azimuth rapidly and easily by observation of the sun or stars. These astro observations provide true azimuths, which are converted to grid azimuths by applying grid convergence.

Section I

BASIC ASTRONOMY

The FA surveyor uses practical astronomy to perform his mission. Practical astronomy is used to determine time, position, and azimuth. The FA surveyor observes celestial bodies only to determine azimuth. High-order survey organizations determine position by astro observation. The key to gaining a working knowledge of practical astronomy is learning its terms. The following paragraphs and the Glossary define the common astronomic terms.

7-1. EARTH

a. The earth has the shape of a flattened sphere. The line connecting the flattened ends of the earth is the axis of the earth. The points at either end of this axis are the North and South Poles.

b. The earth has two important motions to the surveyor-rotation and revolution.

(1) Rotation. Rotation refers to the turning of the earth on its axis. The earth rotates from west to east, making one complete rotation in a period of about 24 hours. (See Figure 7-l.)

(2) Revolution. The earth revolves about the sun on a 600-million-mile orbit at a speed of about 18.5 miles per second. The average distance to the sun is 93 million miles. The earth's orbit is an ellipse, having the sun at one focus. The axis of the earth is tilted 23.5° from the perpendicular to the plane of its orbit around the sun. This tilting gives us our seasons. On the first day of spring and of fall, about the same amount of sunlight is received in both the Northern and Southern Hemispheres. During the winter in the Northern Hemisphere, no sunlight reaches the north arctic regions, which causes wintry weather to extend south to the lower latitudes. The reverse is true during the summer in the Northern Hemisphere. (See Figure 7-2.)

Figure 7-1. **Rotation of the earth**

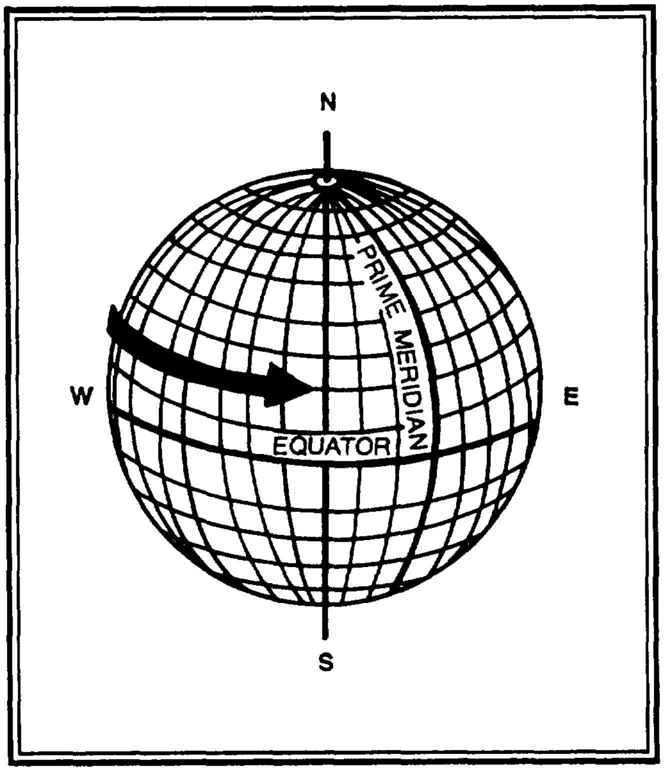
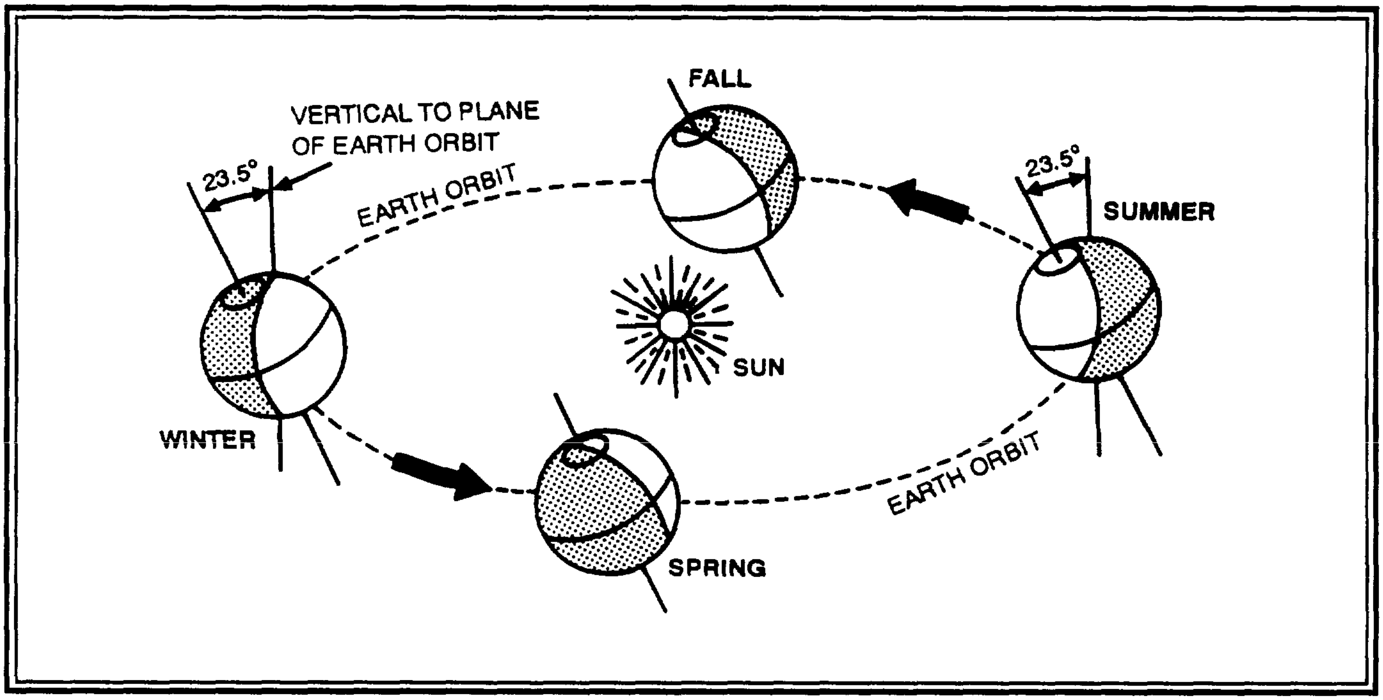


Figure 7-2. **Earth's orbit about the sun**



c. Since adapting a rectangular coordinate system to a sphere is impractical, a system using angular measurements was adopted.

(1) Latitude. Planes were passed through the earth, all parallel to each other and perpendicular to the rotating axis of the earth. The lines that these planes inscribe on the earth's surface are called parallels of latitude. The parallel of latitude halfway between the poles is called the equator. This parallel is given a value of 0° and is used as the basis for measuring latitude. Latitude is measured in units of degrees, minutes, and seconds north or south of the equator (34°48'12" N or 30°12'16" S) Up to 90°.

(2) Longitude. Other planes were passed through the earth so they intersect at both poles. The lines these planes inscribe on the surface of the sphere are called meridians of longitude. A baseline for measurement was established with the meridian that passed through Greenwich, England, and was given a value of 0°. Longitude is measured in units of degrees, minutes, and seconds east (E) and west (W) of the Greenwich meridian (for example, 90°24'18" W or 40°12'43" E) up to 180°.

7-2. CELESTIAL SPHERE

a. In practical astronomy, the sun and stars are considered fixed onto a sphere of infinite radius. At the center of this sphere is the eye of an observer. The observer is resumed to be located at the center of the earth. This imaginary sphere of infinite radius is called the celestial sphere. The celestial sphere allows us to solve all problems of astro observations by using spherical trigonometry.

b. The celestial sphere appears to rotate about an axis. However, this apparent rotation is due to rotation of the earth about its axis from west to east in a counterclockwise movement and is opposite in direction to that in which the stars appear to move. In practical astronomy, the earth is regarded as stationary and the celestial sphere revolves about the earth from east to west.

7-3. SPHERICAL COORDINATES

a. Reference points, such as the poles, the equator, meridians of longitude, and parallels of latitude, are used to determine the location of points on the surface of the earth. Spherical coordinates are used to determine the location of points on the celestial sphere. There are two systems of spherical coordinate—the horizon system and the equator system. The artillery surveyor uses the equator system.

b. Since the earth is assumed to be the center of the celestial sphere, the North and South Poles of the earth can be extended to the sphere where they become the celestial North and South Poles. Likewise, the plane of the earth's equator, extended to the celestial sphere, becomes the celestial equator, (See Figure 7-3.)

c. The observer's position on earth is located by latitude established on the sphere. The arc distance between the zenith of the observer and the celestial equator is the same as the arc distance, in latitude, between his position on the surface of the earth and the earth's equator. The longitude of the observer is the arc on the equator between the Greenwich meridian (0° prime meridian) and the observer's meridian. On the celestial sphere, the longitude is the are on the celestial equator between the planes of the Greenwich meridian and the meridian of the observer extended to intersect the celestial sphere. (It is also the angle at the pole between the planes of the two meridians.) When latitude and longitude are used in this manner and projected to the celestial sphere, the position of the observer's instrument is fixed at a point on the celestial sphere known as the zenith. (See Figure 7-4.)

d. The FA surveyor uses right ascension and declination to identify the location of a star on the celestial sphere. In the equator system of spherical coordinates, there must be points of origin. The points of zero reference in the equator system are the vernal equinox (VE) and the celestial equator.

Figure 7-3. **Celestial sphere**

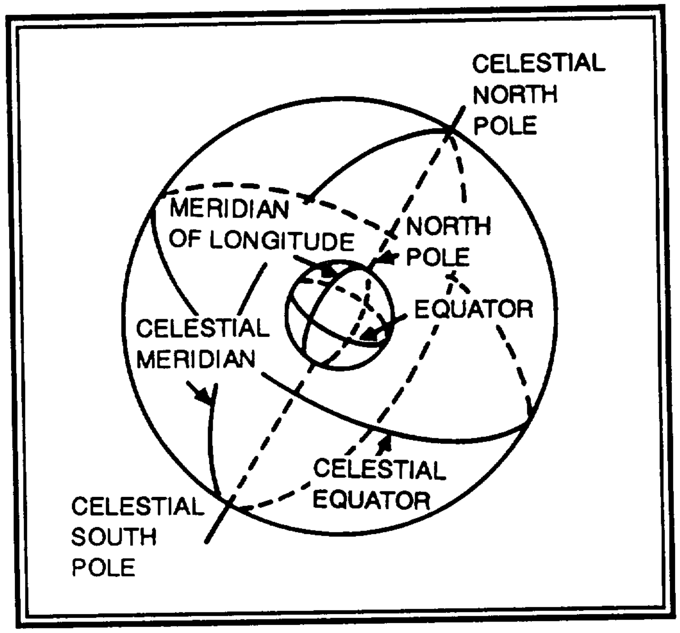
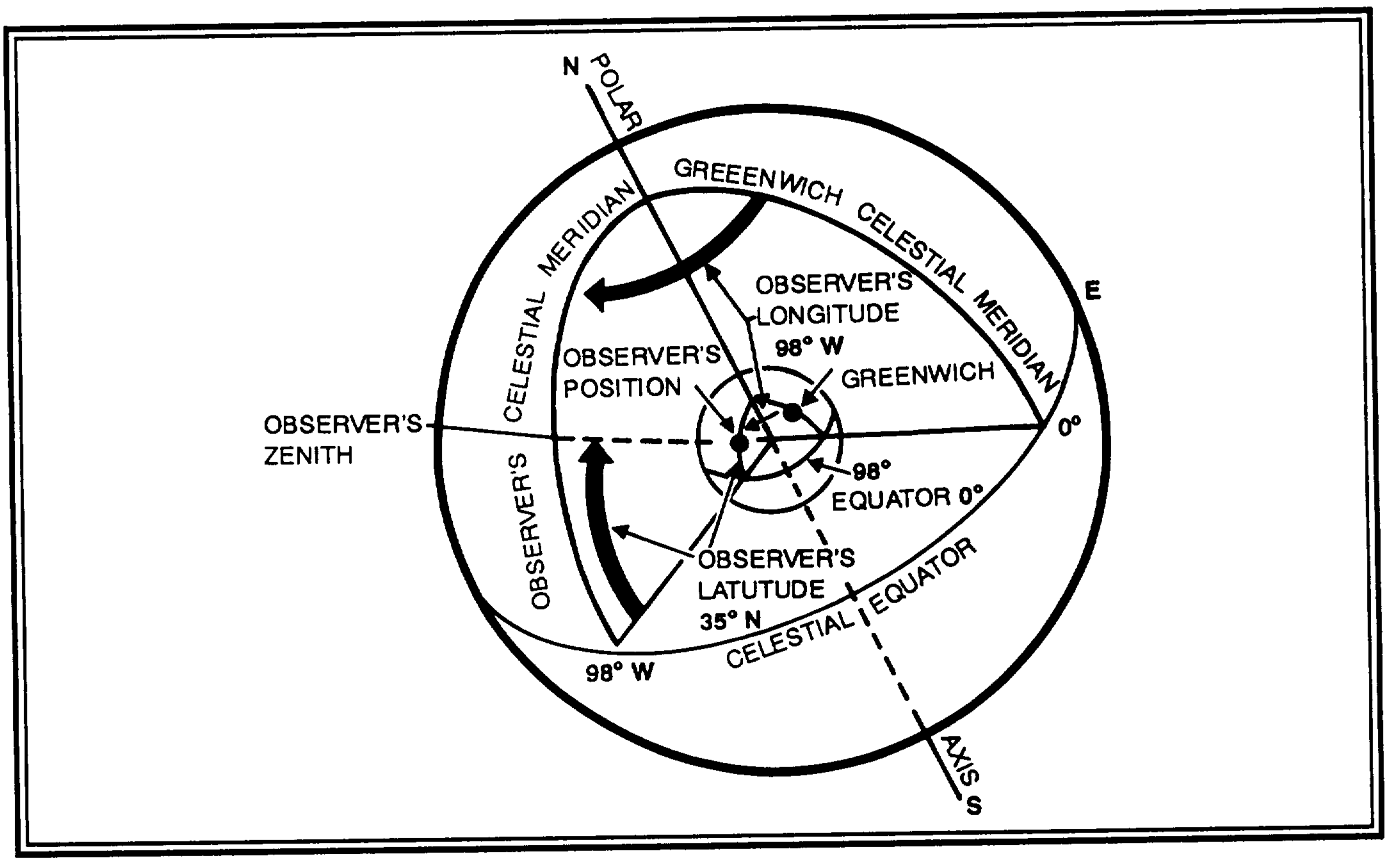


Figure 7-4. **Celestial sphere—geographic coordinate relationship**



(1) During each year, the sun traces a path, called the ecliptic, on the celestial sphere. This path is caused by the tilt of the minor axis of the earth with respect to the plane of its orbit. (See Figure 7-5.) This path of the sun moves from the Southern Hemisphere of the celestial sphere to the Northern Hemisphere and back. The point where the sun crosses the celestial equator in its movement from south to north along the ecliptic is known as the vernal equinox, the first day of spring. The vernal equinox is the first point of reference in the equator system of spherical coordinates. It also is used in the same manner that the prime meridian of Greenwich is used as a point of reference.

(2) The celestial equator, the plane of the earth equator extended to the celestial sphere, is the second point of reference. It divides the celestial globe into celestial Northern and Southern Hemispheres. The declination (see Glossary) of the celestial equator is 0° or 0 mils (e(2) below), just as the earth's equator is 0° or 0 mils latitude.

e. Since the stars appear to rotate about the earth, it is necessary to have a fixed point that can be readily identified and whose location in time relative to the Greenwich meridian can be computed for any given moment, (See the discussion of sidereal time in paragraph 7-7.) The fixed point is the vernal equinox, the point where thes un crosses the celestial equator from south to north on or about March 21, the first day of spring. Once the position of the vernal equinox is known, it is possible to identify the relative location of any prominent star by knowing how far it is from the vernal equinox and whether it is north or south of the celestial equator, the second fixed reference. (See Figure 7-6.)

(1) The spherical coordinate right ascension (RA) is the arc distance eastward along the celestial equator from the vernal equinox to the hour circle (see Glossary) of the star. It may be measured in degrees (°), minutes ('), and seconds (") of arc or in hours (h), minutes (m), and seconds (s) of time. The latter is the normal means of expression and can be from 0^h to 24^h east of the vernal equinox.

(2) Declination, the second spherical coordinate, is the star's angular distance north or south of the celestial equator measured on the hour circle of the body. North declination is plus (+), and south declination is minus (-). Declination can be from 0 mils to 1,600 mils north or south of the celestial equator. (See Figure 7-6.)

f. The observer's horizon is the plane tangent to the earth at the observer's position and perpendicular to his plumb line extended to the celestial sphere. The observer's horizon is used as a reference for determining the altitude of a celestial body. It is discussed in detail in paragraph 7-4.

Figure 7-5. **Ecliptic, equinoxes, and solstices**

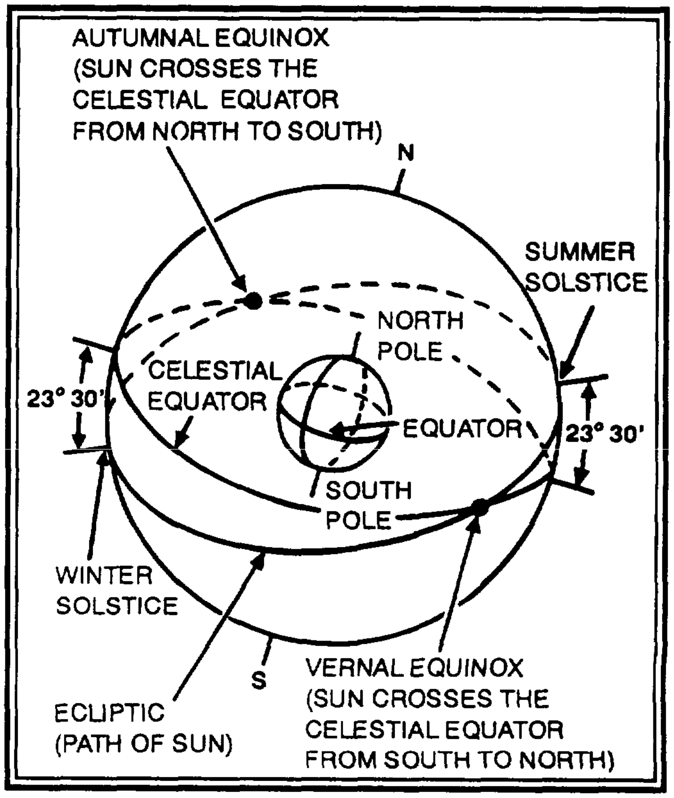
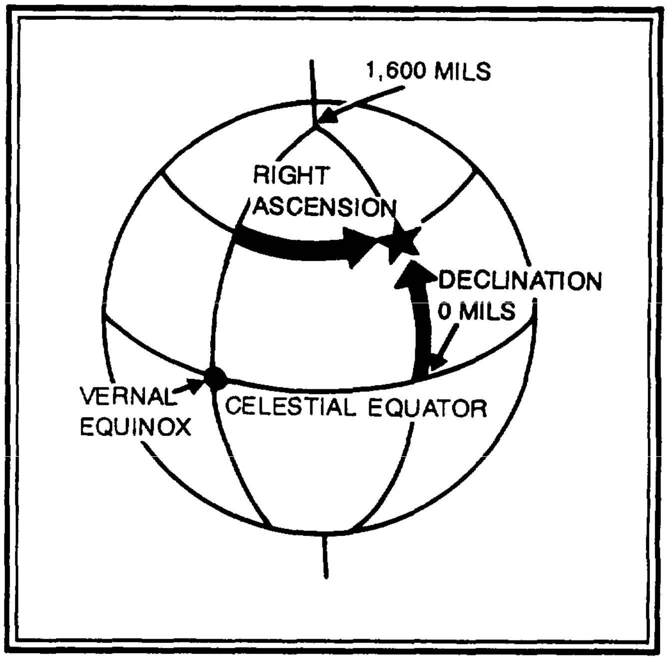


Figure 7-6. **Equatorial system of locating a celestial body**



7-4. ASTRONOMIC TRIANGLE

a. In FA survey, the determination of astro azimuth is based on the solution of a spherical triangle, a triangle located on the celestial sphere. The celestial spherical triangle has the vertices of the pole (P), the observer's zenith (Z), and the sun or star (S). This triangle is known as the astronomic, or PZS, triangle (See Figure 7-7.)

b. The sides of the PZS triangle are segments of great circles passing through any two of the vertices. Hence, the sides are arcs and are measured with angular values. The angular value of each side is determined by the angle that the side subtends on the earth. (See Figure 7-8.) The three sides of the PZS triangle are the polar distance, the coaltitude, and the colatitude.

(1) Polar distance. The side of the PZS triangle from the celestial North Pole to the celestial body is called the polar distance (See Figure 7-9.) The value of the polar distance side is determined from the declination of the celestial body observed. Declination may be defined as the angular distance from a celestial body to the celestial equator. When the celestial body lies north of the celestial equator, the declination is plus. When the body lies south of the celestial equator, the declination is minus. The polar distance side is determined by algebraically subtracting the declination of the celestial body from 1,600 mils.

Figure 7-7. **PZS triangle**

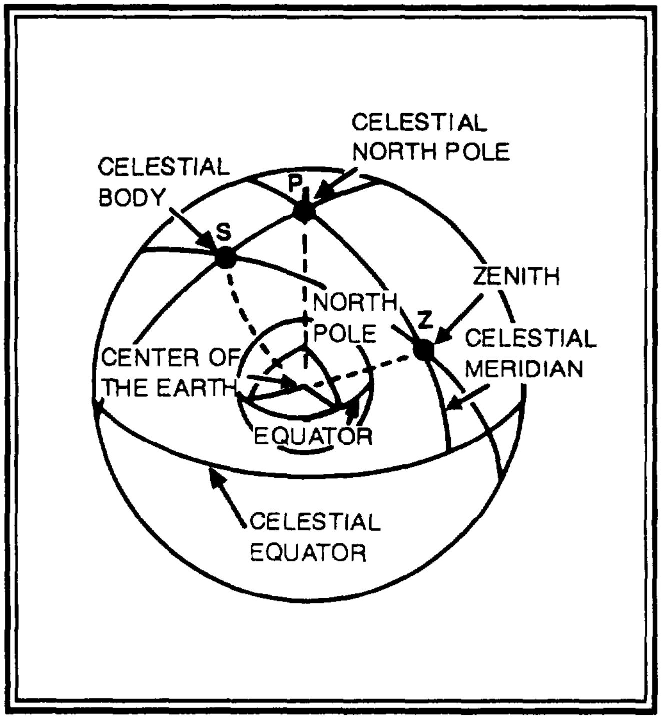


Figure 7-8. **Three sides of the PZS triangle**

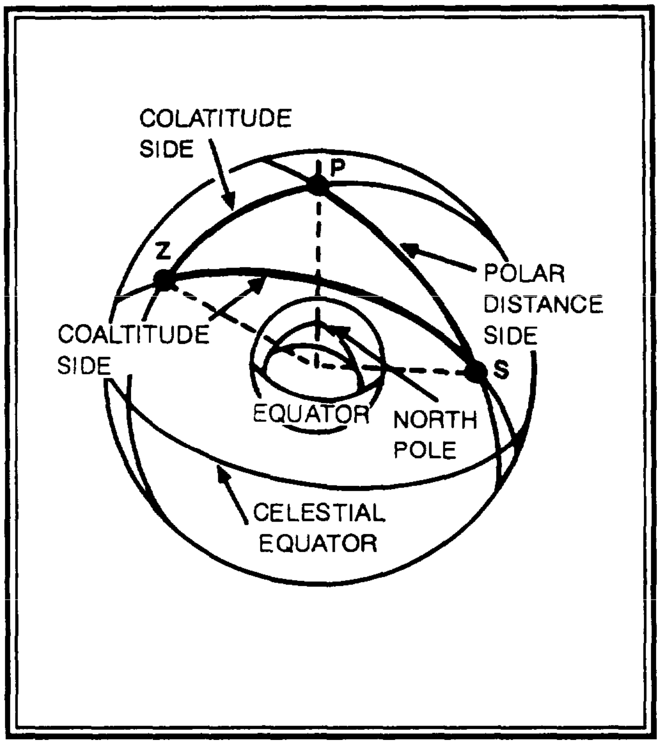
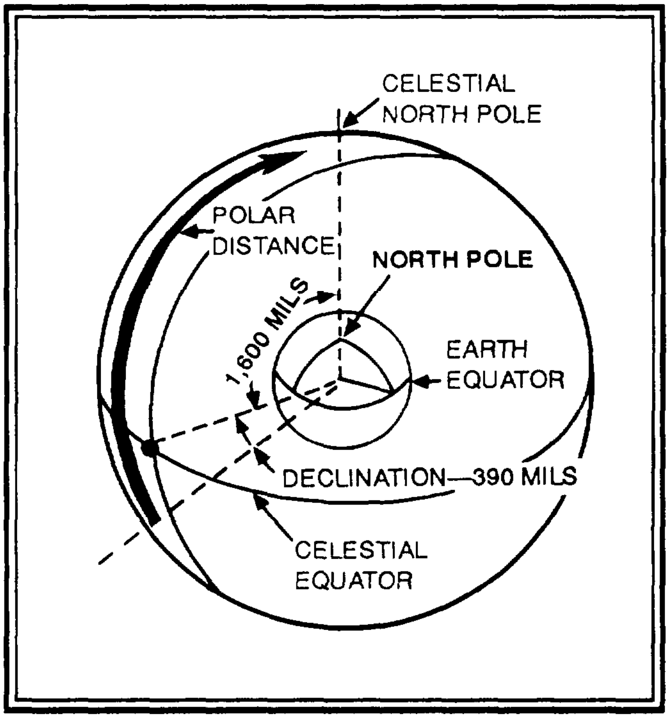
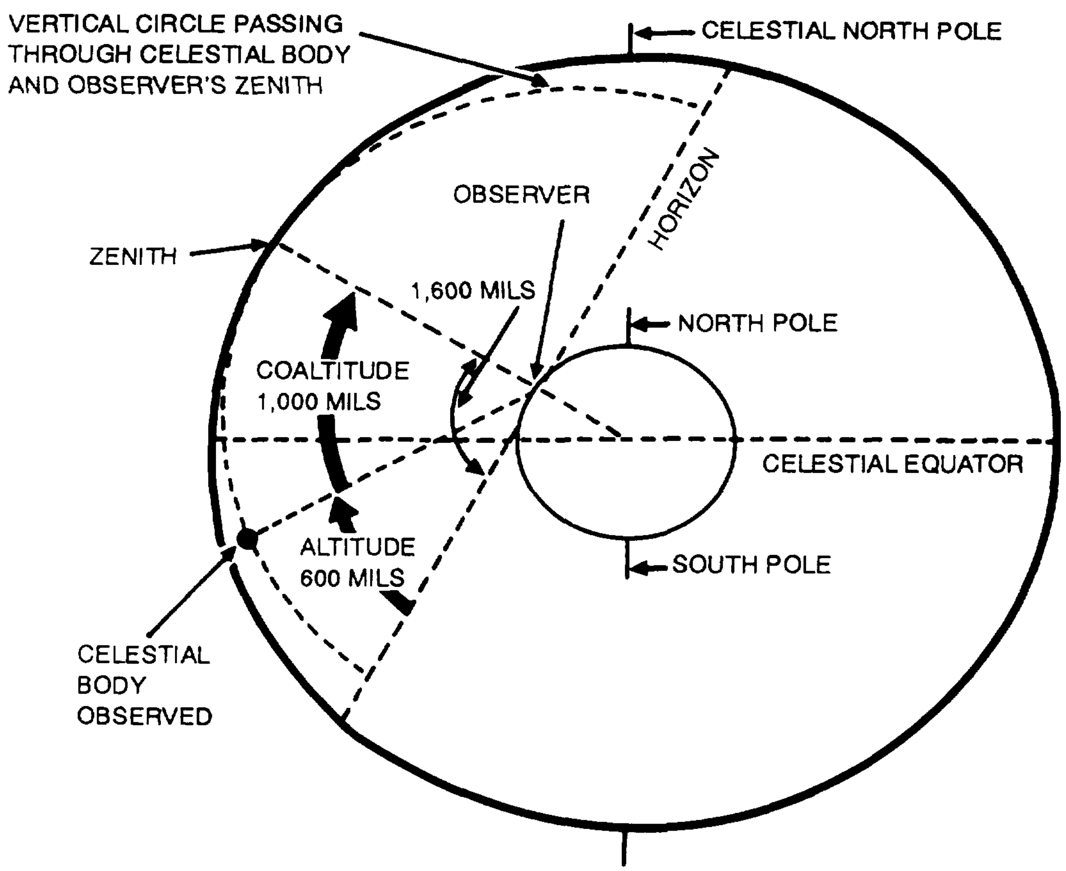


Figure 7-9. **Polar distance side of the PZS triangle**



(2) *Coalitude.* The side of the PZS triangle from the celestial body to the zenith is called coaltitude. (See Figure 7-10.) The coaltitude is the arc distance from a celestial body to the observer's zenith (zenith distance). This arc distance value is determined by subtracting the observed altitude of the celestial body (the sun corrected for refraction and parallax and stars corrected only for refraction) from 1,600 mils.

Figure 7-10. **Coaltitude side of the PZS triangle**



Note. Coaltitude = **1,600 mils** – altitude = **1,600 mils – 600 mils = 1,000 mils**

(3) Colatitude. The colatitude is the side of the triangle extending from the celestial North Pole to the zenith. (See Figure 7-11.) It is determined by subtracting the latitude of the observer from 900 (1,600 roils) when the observer is in the Northern Hemisphere. If the observer is in the Southern Hemisphere (that is, from 0° to 900 south), the colatitude is 90° (1,600 roils) plus the amount of south latitude.

c. The three angles formed by the three sides of the PZS triangle are the pallactic angle; the zenith, or azimuth angle; and the time angle (angle t). (See Figure 7-12.)

(1) The interior angle at the celestial body formed by the intersection of the polar distance side and the coalititude side is called the parallactic angle. It is used in determining azimuth by the arty astro] method but cancels out in the computations.

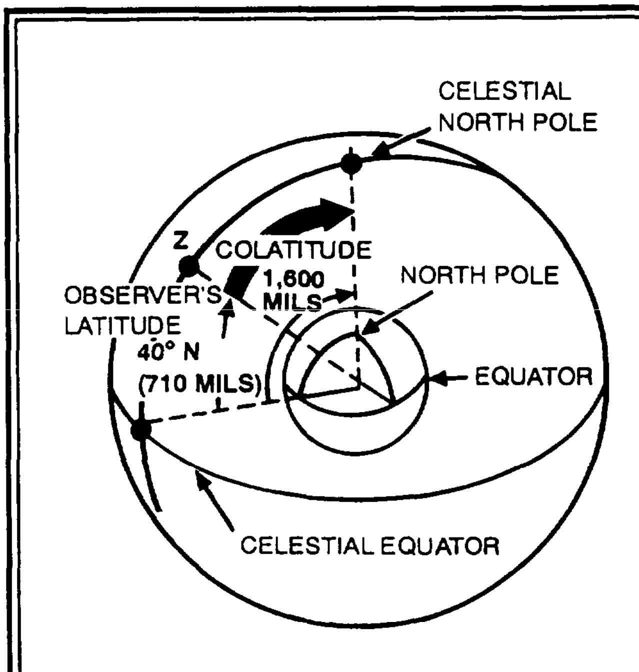
(2) The interior angle at the zenith formed by the intersection of the coaltitude side and the colatitude side is referred to as the zenith, or azimuth angle. This angle is the product of the computations and is used to determine true azimuth from the observer to the celestial body. When the celestial body is in the east, the azimuth angle is equal to the true azimuth. When the celestial body is in the west, true azimuth equals 6,400 roils minus the azimuth angle.

(3) The interior angle of the PZS triangle formed at the pole by the intersection of the polar distance side and the colatitude side is called the time angle, or angle t.

d. If the artillery surveyor knows any three elements of the PZS triangle, the other elements can be determined by spherical trigonometry. The element the artillery surveyor always solves for is the angle from the pole to the celestial body measured at the zenith (azimuth angle). This angle is used in establishing a true azimuth on the ground. Once the artillery surveyor becomes familiar with the procedures for measuring and recording the field data necessary to solve the azimuth angle of this triangle, he finds that the solution is no more difficult than solving a plane triangle established on the earth's surface. Therefore, the artillery surveyor must understand how to obtain the essential astro field data. Obtaining these data requires a limited knowledge of star identification and how to use the Army ephemeris and DA forms designed to simplify the solution of the various formulas.

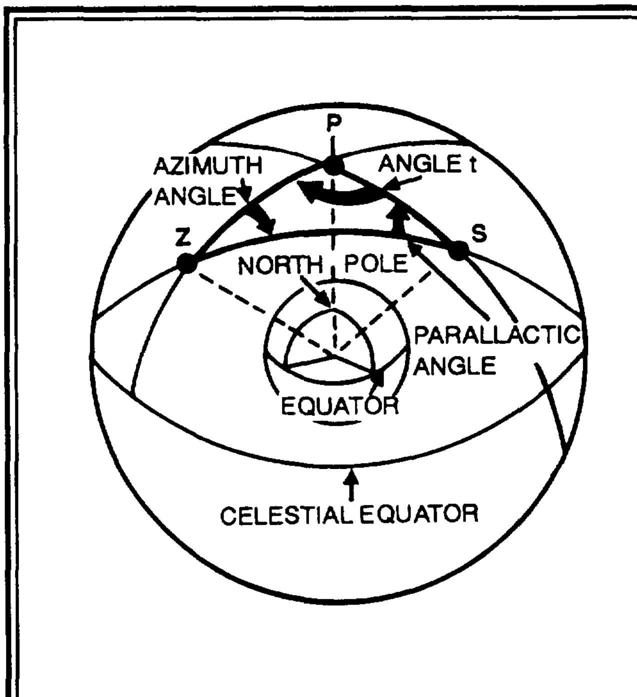
e. Since each PZS triangle is constantly changing because of the apparent rotation of the celestial sphere, the solution for the unknown must be related to specific time. Therefore, accurate time becomes a highly significant consideration in astro survey operations.

Figure 7-11. **Colatitude side of the PZS triangle**



Note. Colatitude = **1,600 mils** - latitude = **1,600 mils - 710 mils = 890 mils**

Figure 7-12. **Three angles of the PZS triangle**



7-5. TIME

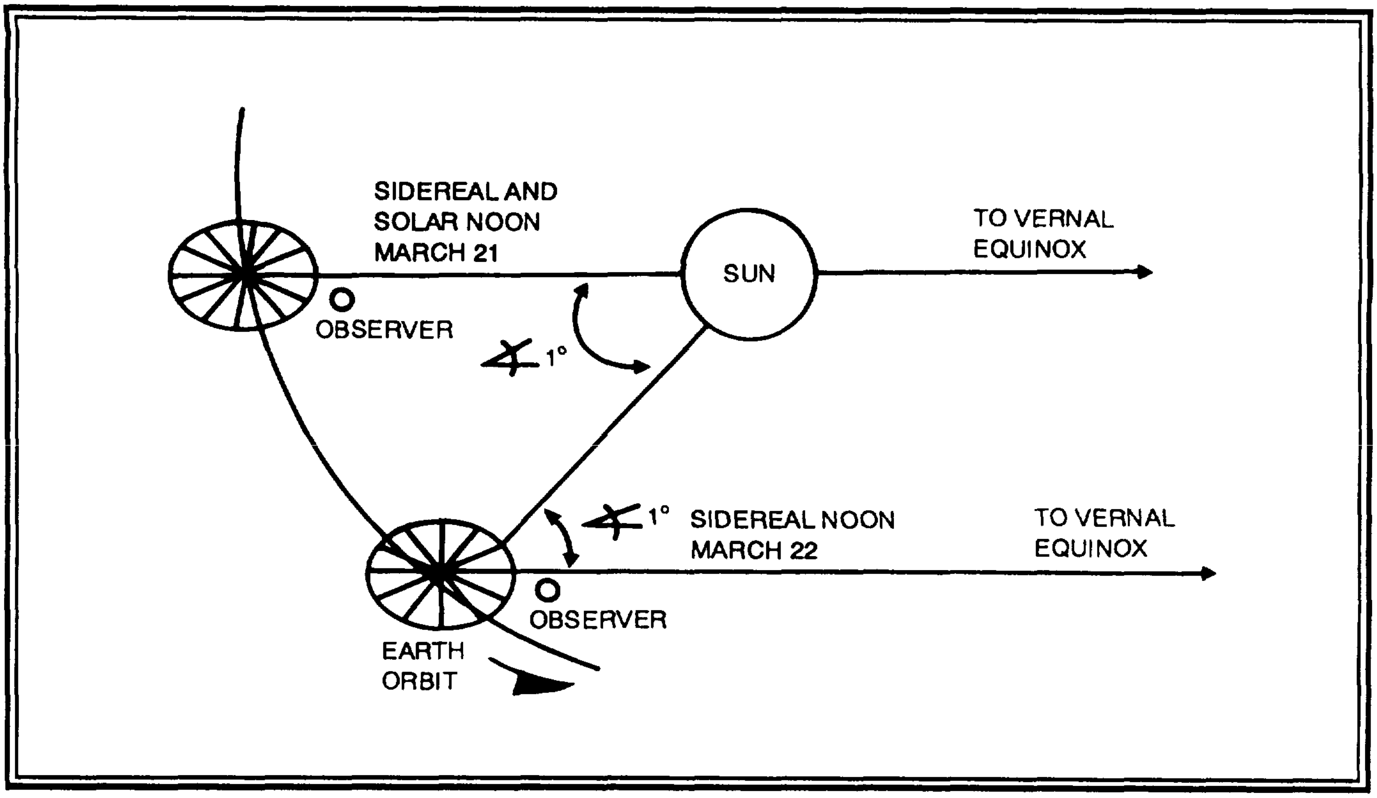
a. All astro observations are made on celestial objects that are in constant apparent motion with respect to the observer. To make use of these observations and to solve the PZS triangle, the surveyor must have one other factor. He must know the precise time of the observation so that he can fix the position of the terrestrial or horizon system of coordinates in relation to the celestial coordinate system. In the field of practical astronomy, two categories of time are used. These are sun (or solar) time and star (or sidereal) time.

b. Both classes of time are based on one rotation of the earth with respect to a standard reference line. Because of the motion of the earth in the plane of its orbit around the sun once each year, this reference line to the sun is continually changing (Figure 7-13) and the length of the solar day is not the true time of one rotation of the earth on its axis. For the purpose of practical astronomy, the true rotation of the earth is based on one rotation of the earth on its polar axis with respect to the vernal equinox and is known as the sidereal day. Therefore, the lengths of the sidereal day and the solar day differ. The solar day is longer by 3 minutes and 56 seconds. The FA surveyor does not have to understand this differential in the lengths of the solar and sidereal days to compute azimuth data derived from astro observations. However, he will be more effective if he does, because he can then more readily adjust to the continually changing view of the stars overhead. The explanation of the differential, while it is simple, requires a departure from the concepts of a motionless earth and a revolving celestial sphere and sun. Instead, the concept of a motionless celestial sphere with the sun as the center and the earth in motion is used as the basis for the explanation.

e. Since the earth completes one orbit of the sun in 365 and a fraction days, it may be stated that because of the orbital motion of the earth, the sun has an apparent eastward motion among the stare of about 1° per day. This motion of the sun makes the intervals between the sun transits of the observer's meridian about 4 minutes greater than the interval between transits of the VE of the observer's meridian. Therefore, the solar day is nearly 4 minutes longer than the sidereal day. (See Figure 7-13.)

d. Because for purpose of practical astronomy one apparent rotation of the celestial sphere is completed in a sidereal day, a star rises at nearly the same sidereal time throughout the year. On solar time, it rises about 4 minutes earlier from night to night, or 2 hours earlier from month to month. Thus, at the same hour, day by day, the stars move slowly westward across the sky as the year lengthens.

Figure 7-13. **Solar day-sidereal day comparison**



7-6. SOLAR TIME

a. The solar day, or the time corresponding to one rotation of the earth with respect to the direction of the sun, is the most natural unit of time for ordinary purposes. If time was regulated by stars, sidereal noon would occur at night during half the year. For obvious reasons, this would not be a satisfactory condition. Also, to begin the solar day when the sun crosses the observer's meridian would result in confusion. So to keep an orderly scheme of things, we start the solar day when the sun crosses the lower meridian of the observer. The instant of time when the sun is on the lower branch of the observer's meridian is defined as solar midnight. When the sun crosses the upper branch of the observer's meridian, it is solar noon at the observer's location. This arrangement would be satisfactory except that the solar day varies in length. This is because the rate at which the sun moves along the ecliptic is inconsistent and the orbital path of the earth around the sun is elliptical. This deviation in the length of the solar day varies from season to season, which makes using this variable day as a base for accurate time almost impossible. Modem conditions demand accurate measurement of time. Therefore, the mean solar day, an invariable unit of time, was devised. It is based on a fictitious, or mean, sun which is imagined to move at a uniform rate in its apparent path about the earth. It makes one apparent revolution around the earth in 1 year, as does the actual sun. The average apparent solar day was used as a basis for the mean solar day. The time indicated by the position of the mean sun is called mean solar time. The time indicated by the position of the actual sun is called apparent solar time. The difference between the two times is called the equation of time, and it varies from minus 14^m (mean sun fast) to plus 16^m (mean sun slow), depending on the season of the year. (See Figure 7-14.)

b. The year defined by the fictitious, or mean, sun (tropical year) is divided into 365.2422 mean solar days. Time based on these days of constant length is called mean solar time, or civil time. Since the mean sun appears to revolve around the earth every 24 hours of mean time, the apparent rate of movement of the mean sun is 15° of arc, or longitude, per hour (360 + 24 = 15).

c. In the geographic coordinate system (latitude and longitude), the primary and secondary planes of reference are the earth equator and the meridian that passes through Greenwich, England (the prime meridian), respectively. When the Greenwich meridian is used as a basis of reference, time at a point 15° west of the Greenwich meridian is 1 hour earlier than the time at the Greenwich meridian, because the sun passes the Greenwich meridian 1 hour before it crosses the meridian lying 15° to the west. The opposite is true of the meridian lying 15° to the east, where time is 1 hour later, since the sun crosses this meridian 1 hour before it arrives at the Greenwich meridian. Therefore, the difference in local time between two places equals the difference in longitude between the places. (See Figure 7-15.) To further expedite time conversions, two basic reference meridians have been selected as common references. These are the Greenwich meridian and the 180th meridian. The main classes of time used by the artillery surveyor in his use of practical astronomy are, in some manner, related to these basic reference meridians. Subsequent definitions and explanations make use of these basic reference meridians.

Figure 7-14. **Mean and apparent solar time**

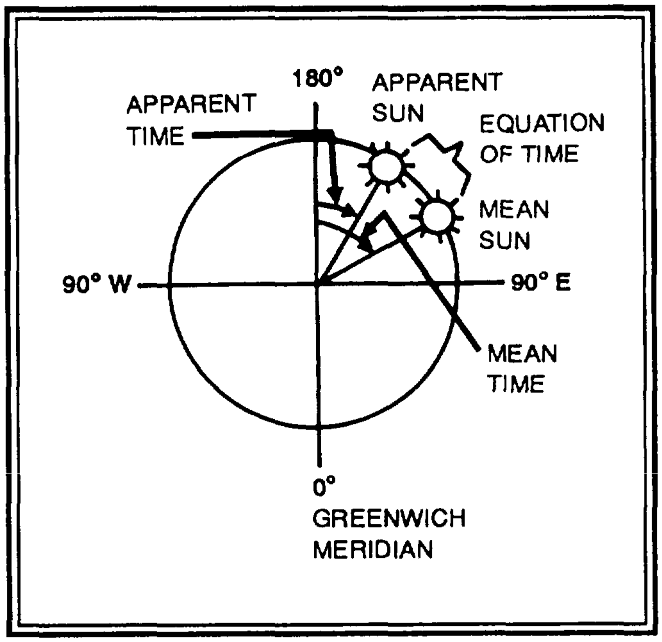
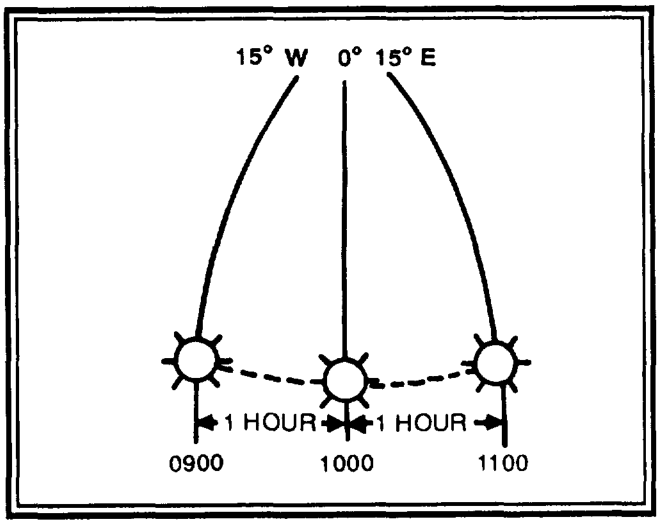


Figure 7-15. **Apparent motion of the sun**



d. Since the mean solar day has been divided into 24 equal units of time, there are 24 time zones, each 15° wide, around the earth. With the Greenwich meridian, 0° longitude, used as the central meridian of a time zone and the zero reference for the computation of time zones, each 15° zone extends 7.5° east and west of the zone central meridian. Therefore, the central meridian of each time zone, east or west of the Greenwich meridian, is a multiple of 15°. For example, the time zone of the 90° meridian extends from 82°30' to 97°30'. (See Figure 7-16.) Each 15° meridian, or multiple of, east or west of the Greenwich meridian is called a standard time meridian. Four of these meridians (75°, 90°, 105°, and 120°) cross the United States. (See Figure 7-17.)

e. Standard time zone boundaries are often irregular, especially over land areas. Standard time zone boundaries follow the 7.5° rule to each side of the zone central meridian, approximately, having been shifted wherever necessary to coincide with geographical or political boundaries. Standard time, a refinement of mean solar time, is further identified by names and/or letter designations. For example, the central standard time (CST) zone, time based on the 90° meridian, is also the S standard time zone. (See Figure 7-18.) The artillery surveyor uses the term *focal mean time* (LMT) in referring to standard time. It refers to the standard time in the referenced locale. Local mean time in artillery survey operations means the standard time for the area in which the observer is located. Therefore, LMT is clock time in the area unless the area is using nonstandard time such as daylight saving time.

Figure 7-16. **Time zone boundaries**

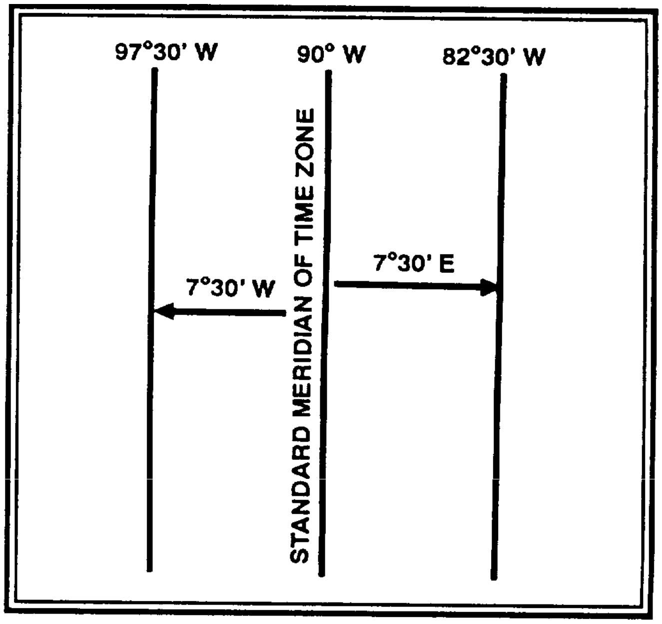
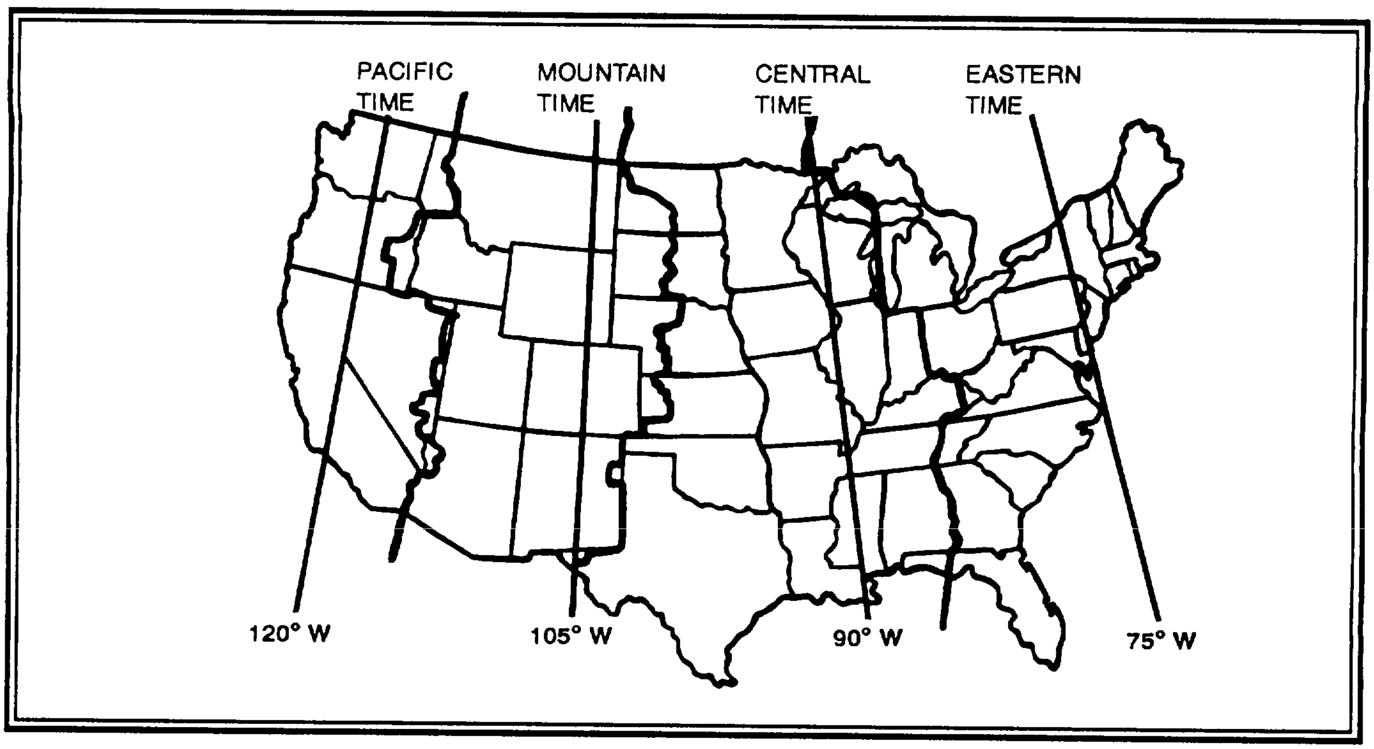


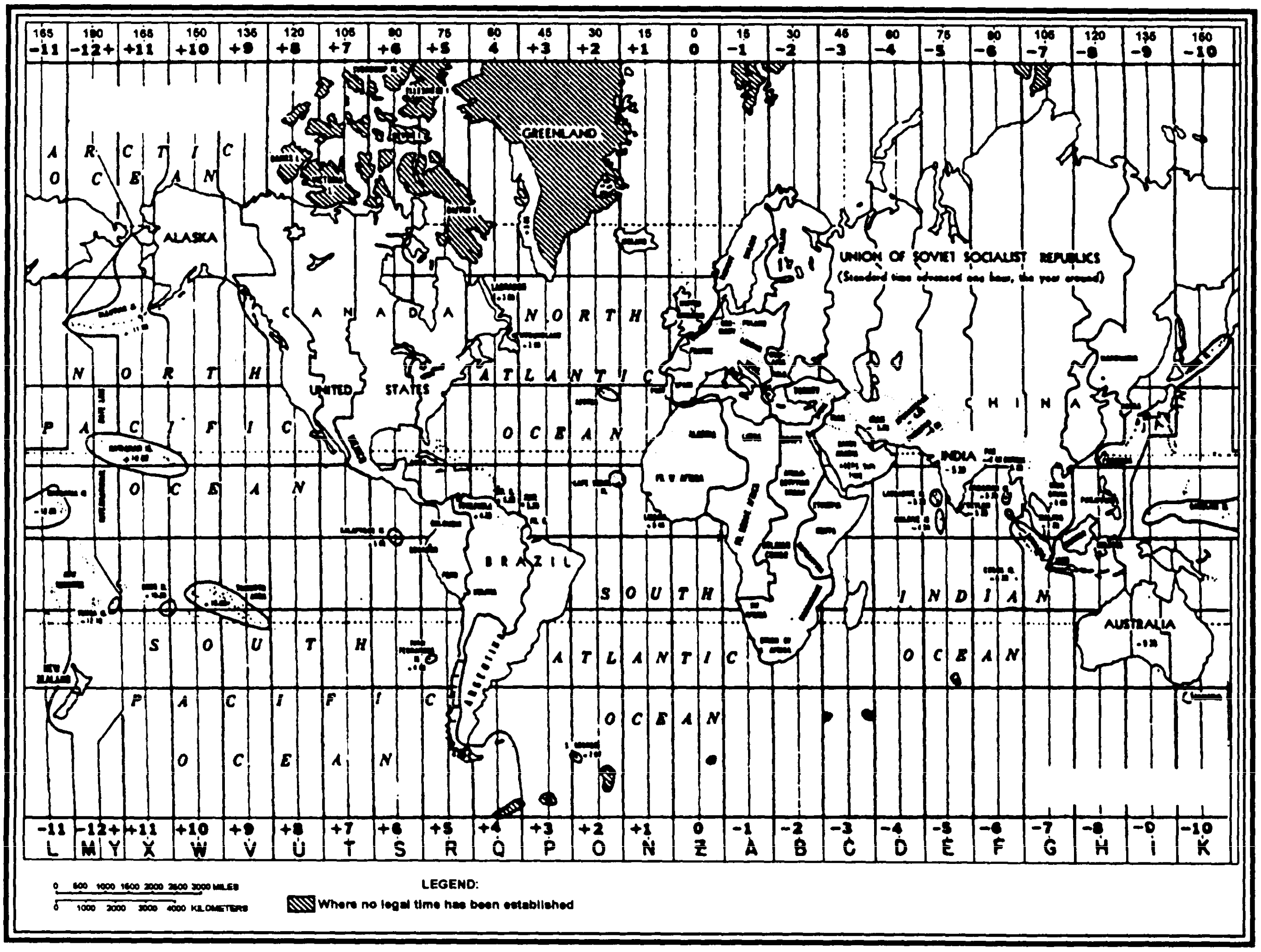
Figure 7-17. **United States standard time zones**



f. To preclude the problem of compiling time data for each of 24 standard time zones of the world, it was decided to compute time data pertaining to mean solar time for only one of the standard time zones. Standard time zone Z (Figure 7-18), which uses the Greenwich meridian as its basic time meridian, was the zone chosen. Greenwich standard time, also known as Greenwich mean time (GMT) or Universal time, is defined as the length of time since the mean sun last crossed the 180th meridian (lower branch of the Greenwich Meridian) or solar midnight. This time can be expressed as the reading of the standard 24-hour clock at the Greenwich Observatory, Greenwich, England, at the moment an observation is made on a celestial body; hence, it is the same time throughout the world. Therefore, since the observer's watch is usually set on the standard time observed in his area, that time (LMT) must be converted to GMT. The data published in FM 6-300 are tabulated with respect to the Greenwich meridian and O^h Greenwich time.

> ★ **Note.** When local time for an area of o ration is unknown or suspect, use universal time Zulu time) and a time zone correction of O hours. When the prompt is for time zone letter instead of time zone correction, use "Z." Universal time can be obtained from the survey time cube, GPS, or the SPCE.

Figure 7-18. **World time zone map**



g. To convert local mean time to Greenwich mean time when the observer is located in west longitude, divide the value of the central meridian of the time zone in degrees of longitude by 15°. This equals the time zone correction in hours. Add to the LMT the difference in time between the standard time zone of the observer's position and GMT to determine the GMT of observation. (See Figure 7-19.) If the result is greater than 24 hours, drop the amount over 24 hours and add 1 day to obtain the Greenwich time and date. When the observer is located in east longitude, subtract the time difference from the LMT to determine the Greenwich mean time of observation. If subtraction cannot be performed, add 24 hours to the LMT and drop 1 day to determine the Greenwich date of observation.

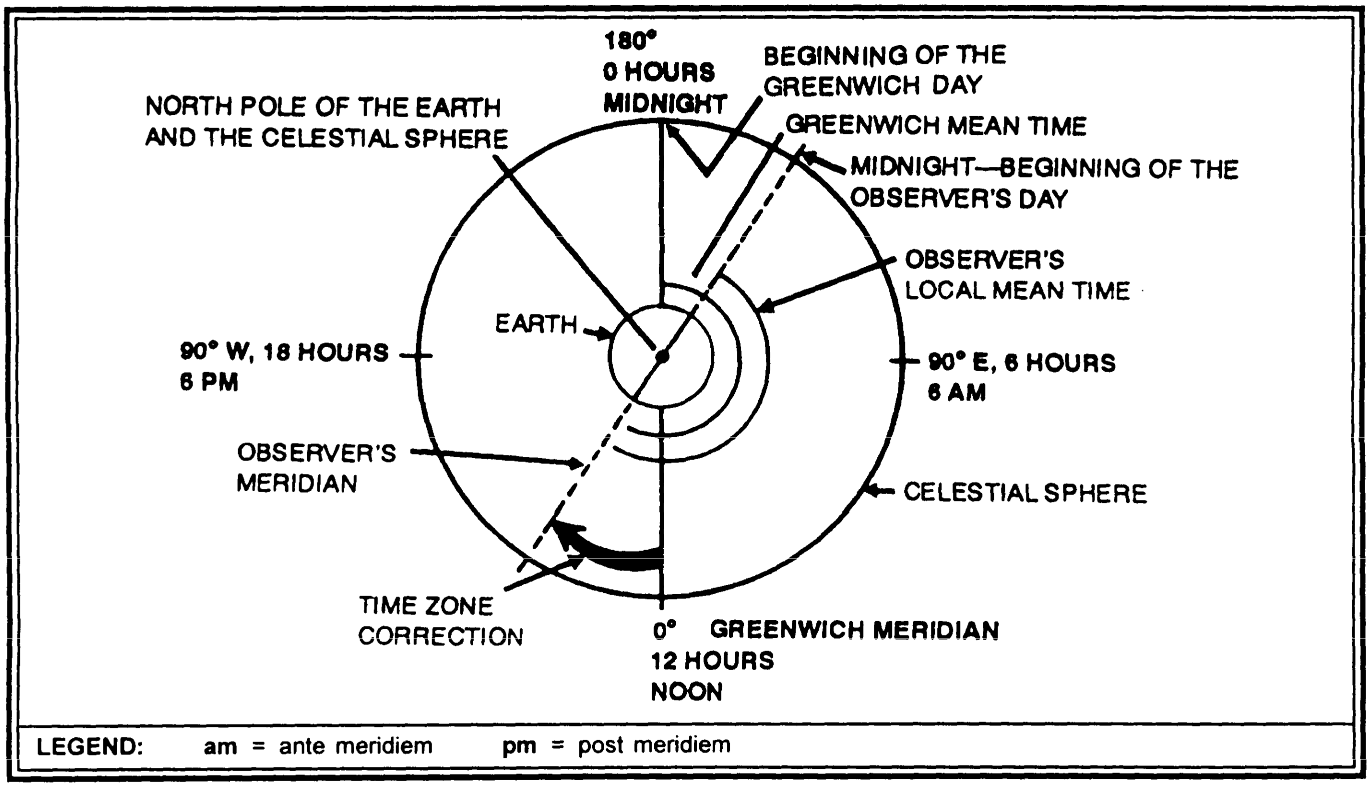
h. When the artillery surveyor makes observations on the sun, obviously he observes the apparent sun instead of the mean sun on which his time is based. Consequently, the observer must convert the Greenwich apparent time (GAT) of observation to the GMT. The date of observation is used as an argument to enter Table 2 of FM 6-300, and the value of the equation of time for zero hours GMT (O^h) is extracted along with the daily change. The resultant equation of time value for the date and time of observation is then added algebraically to the GMT of observation.

i. Determining the local hour angle (LHA) of the sun, a value necessary for some astro formulas, requires several steps in addition to those in the example above. When the position of the apparent sun at the time of observation has been determined and related to the Greenwich meridian, the time is referred to as Greenwich apparent time. By simply adding 12 hours to, or subtracting it from, the GAT (the result cannot exceed 24 hours), the surveyor determines the value of the Greenwich hour angle (GHA). The Greenwich hour angle is the amount of time that has elapsed since the sun last crossed the Greenwich upper meridian. The next step is to convert both the observer's longitude, extracted from a trig list or scaled from a map, and the Greenwich hour angle to mils of arc. The arc distance (in mils) measured from the Greenwich meridian to the observer's meridian is added to the GHA in roils if the observer is located in east longitude. It is subtracted from the GHA in mils if he is located in west longitude. The result is the local hour angle of the apparent sun expressed in mils of arc. The final step is to determine angle t, the angle at the polar vertex of the PZS triangle, Angle t is determined as discussed below,

(1) If the local hour angle is greater than 3,200 mils, angle t equals 6,400 mils minus LHA.

(2) If the local hour angle is less than 3,200 mils, angle t equals LHA.

Figure 7-19. **Application of the time zone correction to local mean time to obtain Greenwich mean time**



7-7. SIDEREAL TIME

a. The sidereal day is defined by the time interval between successive passages of the vernal equinox over the upper meridian of a given location. The sidereal year is the interval of time required for the earth to orbit the sun and return to its same position in relation to the stars. Since the sidereal day is 3 minutes 56 seconds shorter than the solar day, this differential in time results in the sidereal year being 1 day longer than the solar (tropical) year, or a total of 366.2422 sidereal days. Since the vernal equinox is used as a reference point to mark the sidereal day, the sidereal time for any point at any instant is the hours, minutes, and seconds that have elapsed since the vernal equinox last passed the meridian of that point.

b. In general, it can be stated that observations on the sun involve apparent solar time, whereas observations on the stars are based on sidereal time. The computations using either apparent solar time or sidereal time are similar in that they do nothing more than fix the locations of both the celestial body and the observer in relation to the Greenwich meridian. Once a precise relationship has been established, it is a simple matter to complete the determination of azimuth to the celestial body.

Section II

ASTRONOMIC OBSERVATION TECHNIQUES

The technique used to observe a celestial body depends on the azimuth determination method used (altitude, arty astro observation, or Polaris tabular) and the type of celestial body being observed. Using the proper techniques will ensure more accurate results.

7-8. PURPOSE OF ASTRONOMIC OBSERVATIONS

Astro observations can be used for, but are not limited to, the following survey operations:

- Determining or checking a starting azimuth for a conventional survey.
- Determining or checking the closing azimuth of a conventional survey.
- Checking the azimuth of any line in a survey.
- Providing orienting azimuths for cannons and associated fire control equipment.
- Determining azimuths for the declination of aiming circles.
- Providing orienting azimuths for radars and OPs.

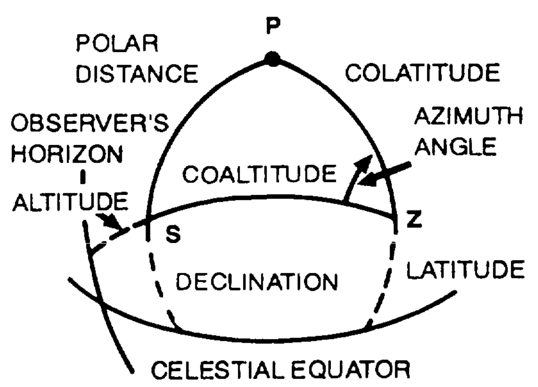
7-9. METHODS OF DETERMINING AZIMUTH

The artillery surveyor uses three basic methods to determine azimuth by astro observation-the altitude method, arty astro observation, and Polaris tabular method. All three methods require a horizontal angle from an azimuth mark to the observed body to materialize the astro azimuth on the ground.

a. In the **altitude method** (Figure 7-20), the PZS triangle is solved by using the known data and the three sides of the triangle. In addition to the angle from a ground point to the celestial body, three elements must be determined. These elements are as follows:

- Latitude for determining the side colatitude.
- Declination of the body for determining the side polar distance.
- Attitude for determining the side coaltitude.

Figure 7-20. **Altitude method of solving the PZS triangle**



b. In the **arty astro method** (Figure 7-21), the azimuth angle is determined from two sides and the included angle. The sides are the polar distance and colatitude and must be determined as described in paragraph 7-4b. The angle at P (Figure 7-21) is angle t. The value of the local hour angle is computed by using the time of the observation and is then used to compute angle t.

Figure 7-21. **Arty astro method of solving the PZS triangle**

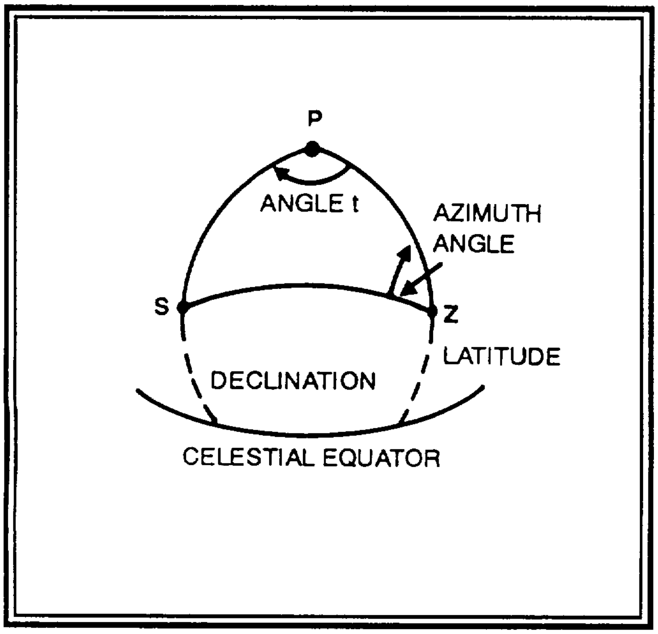
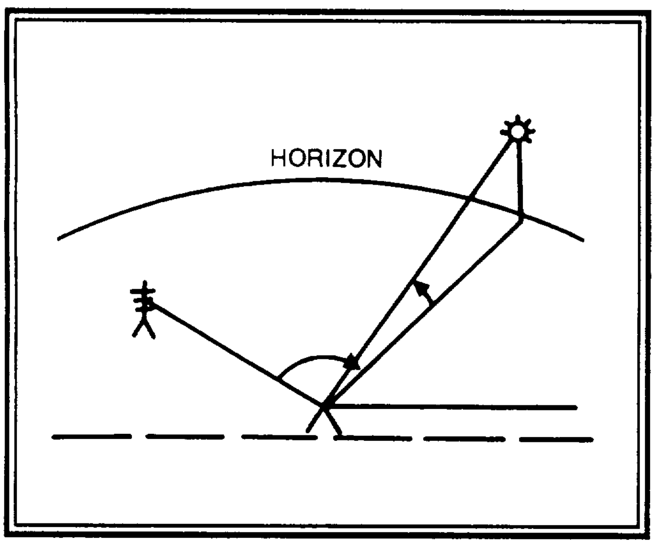


Figure 7-22. **Measuring horizontal and vertical angles from azimuth mark to celestial body**



c. In the Polaris tabular method, the azimuth to Polaris is tabulated in the Army ephemeris for every 3 minutes of local sidereal time (LST). The listed azimuth is corrected for the observer's latitude and the date of observation. This method avoids lengthy PZS triangle solutions, but it can be used only in the Northern Hemisphere.

> **Note.** The methods of determining azimuth are discussed in detail and compared in Sections V, VI, VII, and VIII.

7-10. FIELD REQUIREMENTS FOR ASTRONOMIC OBSERVATIONS

a. Each of the three methods of determining azimuth by astro observation requires the measurement of the horizontal angle from the azimuth mark to the celestial body. The altitude method also requires measurement of the vertical angle. (See Figure 7-22.) Except for the method of pointing on the celestial body, horizontal and vertical angles are measured in the same way that angles are measured in traverse. A set of astro observations consists of horizontal angles measured one position and vertical angles measured by one direct and one reverse pointing.

b. In all astro observations, the instrument must be perfectly level with reference to the most sensitive bubble the instrument has. An appreciable error, which cannot be eliminated by direct and reverse pointing, is introduced into the measurement of a horizontal angle between two objects of considerable difference in elevation if the vertical axis of the instrument is not vertical.

7-11. FIELD DATA REQUIREMENTS

Data required for computing astro azimuth differ slightly according to the method used.

a. Altitude and Polaris tabular methods require the following data

- Latitude of the observer (correct to the nearest second).
- Longitude of the observer (correct to the nearest second).
- Horizontal angle from the desired azimuth mark to the celestial body.
- Approximate azimuth to the desired azimuth mark. A magnetic or map-spotted azimuth will suffice.
- Date of observation.

b. In addition to the data in a above, the altitude method requires the following data:

- Temperature (correct to nearest 50)
- Vertical angle to the celestial body.

- Time of observation.
  - – Sun (accurate to the nearest 5 minutes).
  - – Star (accurate to the nearest day).

c. In addition to the data in a above, the Polaris tabular method requires time accurate to the nearest minute.

d. The arty astro method of observation requires the following data:

- UTM coordinates (casting and northing) map-spotted to within 150 meters.
- Horizontal reading from the desired azimuth mark to the celestial body.
- Approximate azimuth to the desired azimuth mark. A magnetic or map-spotted azimuth will suffice.
- Date of observation (manual input or BUCS time module).
- Time of observation (manual input or BUCS time module).
  - - Sun (accurate to 1 second).
  - - Star (accurate to 1 second).
  - - Polaris (accurate to 10 seconds).

e. Special requirements are discussed below.

(1) For the sun to be suitable for use with the altitude method, it should be within 530 mils of the observer's prime vertical. To determine if it is, algebraically subtract the declination of the sun on the local date from the latitude of the observer's station. The remainder is the angle from the prime vertical to the sun at noon, When he is observing the stars, the observer will have little difficulty in selecting stars that fall within the 530-mil requirement. The celestial bodies (sun or stars) should be observed between 175 mils and 800 mils in altitude. The sun should not be observed within 2 hours local apparent time of the observer's meridian, because there is no valid solution when the coaltitude side of the triangle is less than 30° (2 hours).

> **Note.** The restriction has been placed on vertical angles over 800 mils because of the error introduced into the horizontal angle measurement when the instrument has not been leveled perfectly. The error in the horizontal angle is equal to the tangent of the altitude of the celestial body multiplied by the error in leveling the plate of the instrument. In the case of the T11 or T2 theodolite, one division of error in the plate level bubble is equal to an error of about 0.1 mil if the altitude angle is 800 mils. If the altitude angle is 1,000 mils, the error in the horizontal angle will be about 0.2 mil. For this reason, special precautions must be taken in leveling the instrument when a vertical angle between 800 and 1,100 mils is required.

(2) When the arty astro method is used, the sun should not be observed within 1 hour local apparent time of the observer's meridian. This is because there is no valid solution when angle t is less than 15° (1 hour).

(3) The selection of Polaris in the Northern Hemisphere or Alpha Acrux (Southern Cross Star) in the Southern Hemisphere should be automatic. The altitude of Polaris roughly coincides with the north latitude of the observer, Circumpolar stars are preferred to east-west stars.

(4) The arty astro method is the only acceptable method used with circumpolar stars other than Polaris.

(5) For best results, stars should be below 800 mils in altitude.

7-12. TEMPERATURE AND TIME

a. Temperature and a time correction should be obtained at the time of observation and checked after the final observation. The temperature may be obtained from meteorological (met) stations, powder thermometers, or any thermometer available. Time may be obtained from radio time signals (paragraph 7-32) or from the div arty SPCE. Message center and commercial radio times are generally accurate enough for altitude observations.

b. The BUCS contains an accurate quartz-crystal clock. Properly set, it will keep accurate time, within tenths of a second, until battery life expires or the memory is cleared. Any good watch with a sweep second hand is adequate for timekeeping, if a correction is carried. For astro observation, a good watch is one that gains or loses a constant amount of time over a given period. The timekeeper should not try to set his watch to the exact time, but he must ensure that the second hand is in the vicinity of 12 when the minute hand is on a minute mark. (This will preclude a 30-second error.) The timekeeper will determine the amount his watch is in error and note the correction, with the proper sign, in the remarks section of the recorded field notes.

7-13. POINTING TECHNIQUES

a. When the sun is being observed, special pointing techniques are required to resolve its center because of the size and brilliance of the sun. Since the angular diameter of the sun is about 9.5 mils of arc, an accurate pointing cannot be made on the center of its disk without the use of special aids and/or techniques.

b. One of the special pointing aids is the solar circle etched on the reticle of the observing instrument. Most theodolites have the solar circle etched on the reticle, (See Figure 3-4.) No special pointing technique is required with these instruments, but the sun must be centered in the circle. The sun will not always fit exactly into the circle. However, the amount of overlap, or spacing, will not affect the final result.

c. Pointings on stars are made so the intersection of the vertical and horizontal cross hairs bisects the star.

7-14. TRACKING AND OBSERVING PROCEDURES

★ **a.** The instrument operator sets up his instrument as prescribed in Chapter 3. With the instrument telescope in the direct position, he points the telescope at the azimuth mark. After the initial circle setting has been recorded in the recorder's book, the instrument operator and recorder perform the steps discussed below.

★ *(1)* The instrument operator places the sun filter on the telescope and turns the instrument until the sun is near the center of the solar circle. He announces TRACKING.

> **CAUTION**
> The sun must never be viewed through the telescope without a sun filter. The filter should be inspected before use to ensure that the coated surface is free from scratches or other defects. Serious eye damage will result if proper precautions are not taken.

> **Note.** If the sun filter has been damaged or lost, a solar observation may be completed by use of the card method. The image of the sun is projected onto a card held 3 to 6 inches behind the eyepiece, and the telescope is focused so that the cross hairs are clearly defined.

★ *(2)* on the instrument operator's announcement of TRACKING, the recorder begins keeping time without lifting his eyes from the watch. At the instrument operator's announcement of TIP, the recorder notes the exact uncorrected time and records it in the field notebook. If the BUCS is being used as a time piece, the recorder presses END LINE at the announcement of TIP. If the forward entry device, meteorological/survey (FED MSR) is being used, the use of the time module is also an option.

★ *(3)* The instrument operator reads the horizontal circle reading and announces it to the recorder, levels the split bubble, and announces the vertical circle reading.

> **Note.** Vertical angles are not measured for the arty astro or Polaris tabular methods.

★ *(4)* The instrument operator then plunges the telescope to the reverse position, again sights on the sun, and announces TRACKING. The steps in (2) and (3) above are then repeated. The observer then sights on the azimuth mark and reads the horizontal circle reading. The recorder records the reading and determines the mean data. This completes one set of observations.

> ★ **Note.** When using the arty astro method of observation, the instrument operator takes three direct readings to the celestial body, then plunges the telescope, and sights back on the azimuth mark. A second set should be taken with three readings in the reverse position as a check on the instrument and operator. As a rejection criteria, the closing readings on the azimuth mark should agree with the initial circle setting by the known spread of the instrument. In addition, the mean of the two sets of readings should agree with both sets within prescribed accuracies.

b. Three sets of observations must be made normally by the procedures in a above. However, a well-trained observer may use a modified form of these procedures. A modified form would be to take three direct observations and then three reverse observations before closing the angles on the azimuth mark. Care must be taken in recording the observations.

c. Pointings on the stars are made in the same manner as pointings on the sun except that at the instant TIP is announced the cross hairs should bisect the star.

> **Note.** When the observer is observing the stars, it is advantageous for him to have the telescope blacked out until the star is identified. When the star has been identified, the telescope light rheostat is turned up so that as many stars as possible, other than the desired one, will be obliterated by the light in the telescope.

7-15. RECORDING AND MEANING DATA

a. The format for recording field data and determining the mean angles is generally the same as that for other angle measurements except for the large spread between the direct and reverse readings and that the times of observation are recorded. The mean time of observation is determined from the times recorded for the direct and reverse pointing. The same format is used for observations with the T16 and T2 theodolites. Sun observations are recorded in the same manner as star observations, Figures 4-12, 4-13, 4-15, and 4-20 show how data are recorded in a field notebook for astro observations.

b. Extreme care must be taken in meaning time. Time is recorded in three units-hours, minutes, and seconds. If using a watch to record time, record seconds first, followed by minutes and hours. Time should be meaned by using the method described in the following example.

> **EXAMPLE**
> **Add the times recorded for the direct (D) and reverse (R) observations.**

D	$09^h\ 58^m\ 57^s$
R	$10^h\ 13^m\ 13^s$
Sum	$19^h\ 71^m\ 70^s$

Determine if the sums of the hours and minutes are even or odd numbers.

$$\begin{array}{lccc} \text{Sum} & 19^h & 71^m & 70^s \\ \hline & \text{odd} & \text{odd} & \end{array}$$

If necessary, make the number in the hours column even. If the number in the hours column is an odd number and the number in the minutes column is **more** than 60, subtract 60 minutes from the minutes column and add 1 hour to the hours column.

$$\begin{array}{cc} 19^h & 71^m \\ +1 & -60 \\ \hline 20^h & 11^m \end{array}$$

If the number in the hours column is an odd number and the number in the minutes column is **less** than 60, subtract 1 hour from the hours column and add 60 minutes to the minutes column.

$$\begin{array}{cc} 19^h & 03^m \\ -1 & +60 \\ \hline 18^h & 63^m \end{array}$$

Once the number in the hours column is an even number, then make the number in the minutes column even, if necessary. If the number in the minutes column is an odd number and the number in the seconds column is **more** than 60, subtract 60 seconds from the seconds column and add 1 minute to the minutes column.

$$\begin{array}{ccc} 20^h & 11^m & 70^s \\ & +1 & -60 \\ \hline 20^h & 12^m & 10^s \end{array}$$

If the number in the minutes column is an odd number and the number in the seconds column is **less** than 60, subtract 1 minute from the minutes column and add 60 seconds to the seconds column.

$$\begin{array}{ccc} 20^h & 11^m & 70^s \\ & -1 & +60 \\ \hline 20^h & 10^m & 70^s \end{array}$$

Now that the numbers in the hours and minutes columns are even numbers, divide each unit (hours, minutes, and seconds) by 2. Express the mean time to the nearest second.

$$\begin{array}{r} 10^h \;\; 06^m \;\; 05^s \;=\; \text{mean time} \\ 2 \overline{)\, 20^h \;\; 12^m \;\; 10^s} \end{array}$$

Section III

THE ARMY EPHEMERIS

The Army ephemeris (FM 6-300) is a condensation of data from the *American Ephemeris and Nautical Almanac.* Units must request FM 6-300 from the AG Publications Center or be on pinpoint distribution. It is issued to artillery units equipped to perform astro observations. Data in the tables of FM 6-300 are required in computing direction from astro observations. All data extracted from the ephemeris tables will be expressed to the accuracy of the ephemeris. The use of the ephemeris tables is explained in this section. Sample problems are based on data in the ephemeris for 1993 through 1997. Only the tables used by the artillery surveyor are explained herein.

7-16. TABLE 1b, ASTRONOMIC REFRACTION CORRECTED FOR TEMPERATURE (MILS)

a. Table 1b of FM 6-300 is used to determine the value of the refraction correction. This correction is applied to vertical angles measured to either the sun or the stars. Refraction is the apparent displacement of a celestial body caused by the bending of light rays passing through layers of air of varying density. The celestial body appears higher than it really is. Therefore, the sign of the correction is always minus.

b. To determine the value of the refraction correction, use as arguments the mean vertical angle (observed altitude) and the mean temperature at the time of observation. Arguments for temperature increase in units of 10° from -30°F to + 130°F. Arguments for observed altitude increase in units of 10 roils from 0 roils through 1,200 mils. When the observed altitude and temperature are not tabulated in the table, enter the table with the values nearest those observed. For example, to determine the refraction correction for a mean vertical angle of 697 roils and a temperature of +93°F at the time of observation, examine the table. The nearest tabulated altitude is 700 roils, and the nearest temperature is +90°F. Enter the table at 700 roils, and move right to the column for 90°F. Extract the refraction correction of 0.32 mil. Should the mean vertical angle fall exactly halfway between two tabulated altitudes, use the higher tabulated altitude. Should the temperature fall exactly halfway between two tabulated temperatures, use the lower tabulated temperature. For example, to determine the refraction correction for a mean vertical angle of 745 mils, which is halfway between two tabulated altitudes (740 mils and 750 mils), select the higher value (750 mils). For a temperature of 95°, halfway between two tabulated temperatures (+90° and +100°), select the lower (90°). Extract the refraction correction of 0.29mil.

7-17. TABLE 2, SUN (CURRENT YEAR) FOR ZERO HOURS UNIVERSAL TIME (GMT)

Table 2 is divided into three major parts-apparent declination (shown in both degrees and mils), equation of time, and sidereal time. Each of the major parts is discussed separately. The first column is common to all three parts of Table 2 and contains the Greenwich dates and days of the week for the entire year.

a. Apparent Declination. The declination of a celestial body is the angular distance from the celestial equator measured along the hour circle of the body. Declination, which is positive when the body is north of the celestial equator and negative when it is south of the celestial equator, corresponds to latitude on earth. The declination of the sun is tabulated for 0 hours GMT for each day of the year, and the daily change in declination is shown in the DAILY CHANGE (SEC) column. The algebraic signs of the declination and the daily change are critical and must be included. When the BUCS is used, the value of apparent declination in degrees, minutes, and seconds is determined to the nearest second.

b. Sidereal Time. The local sidereal time is the number of hours, minutes, and seconds that have elapsed since the vernal equinox last crossed the observer's meridian. The Greenwich sidereal time is the hours, minutes, and seconds that have elapsed since the vernal equinox last crossed the Greenwich meridian. Sideral time is used when Polaris tabular observations have been made and it is necessary to convert mean time to sidereal time. The sidereal time to the nearest second is extracted from Table 2.

7-18. TABLE 9, ALPHABETICAL STAR LIST

Table 9 is an alphabetical list of 73 stars, the constellation in which each star is found, the number of each star, and the magnitude of each star. This table is used primarily to provide the star numbers to determine data on the stars from Table 10. The constellation and magnitude aid in identifying the star. For example, find the star Enif in the list. The table shows that Enif is in the constellation Pegasus, is star number 70, and has a magnitude of 2.5.

7-19. TABLES 10a (DEGREES) AND 10b (MILS), APPARENT PLACES OF STARS

Tables 10a and 10b contain the declination for all the stars listed in Table 9 except Polaris. In Table 10a declination is in degrees. Table 10b lists declination in mils. Right ascension and declination are given for the first day of each month. Values for other dates are interpolated as discussed below.

a. Determine the difference for both right ascension and declination (in seconds) from the first of the month to the first of the following month. Use the proper algebraic sign.

b. Divide the number of days past the first of the month by 30 days (standard month). Multiply the result by the difference determined in a above to obtain the changes in right ascension and declination from the first of the month.

c. Apply the change determined in b above to the declination at the first day of the month to determine the declination for the given day.

EXAMPLE

Determine the declination for star number 1 (Alpheratz) for 22 March 1993.

Declination	Degrees
1 March 1993	29° 03′14″
1 April 1993	29° 03′09″
Difference	-05″

(22 + 30) x 5 = 3.65 = 04″

Declination for 22 March 1993 = 29° 03′14″ - 04″ = 29° 03′10″

Note. When determining ephemeris data for dates other than those listed, express results of computations to the same value as those in the ephemeris.

7-20. TABLE 11, APPARENT PLACES OF POLARIS (STAR NUMBER 10)

Table 11 contains the declination (in degrees and mils) and the right ascension of Polaris. The values listed are for 0 hours GMT on the 0, 10th, 20th, and 30th days of each month (10-day) intervals). To determine the declination or the right ascension of Polaris for a given day, interpolate between the given values. Data for the 31st day of the month are shown as the0 day of the following month.

EXAMPLE

Determine the declination and right ascension of Polaris on 13 November 1993. Declination in mils is determined and used in the computations to the nearest 0.01 mil.

Declination		Right Ascension
10 Nov 93	+1,586.47 mils	$2^h\ 27^m\ 21^s$
20 Nov 93	+1,586.49 mils	$2^h\ 27^m\ 20^s$
Difference	+0.02	-01^s

3+10 x (0.02) = +0.006   3 + 10 x (-01^s) = -0.3^s

+1,586.470 $21^s - 0.3^s = 20.7^s$

Declination =1,586.476   RA = $2^h 27^m 21^s$

=+1,586.48 mils

7-21. TABLE 12, TO DETERMINE AZIMUTH FROM POLARIS

The artillery surveyor uses Table 12 only to determine azimuth by the Polaris tabular method. Correct time should be known to the nearest 1 minute.

a. Extraction of b_0. The argument used for extracting b_0 is local sidereal time and current year. The hours of local sidereal time are listed in column headings across the page, and the minutes of LST are listed vertically at the left of the hour columns.

EXAMPLE

Find b° for LST $8^h\ 34^m$, 1993.

Move down the column headed 8^h (with the subcolumn heading b_0) until the column intersects the LST column entry closest to 34 minutes (no interpolation necessary), and read -45.8 minutes of arc.

b. Extraction of b_1. The arguments used to extract b_1 are the same hour column used to find b_0 and the observer's latitude.

EXAMPLE

Find b_1 for LST 8^h 34^m, 1993, at latitude 30°40′

Find the intersection of the column headed 8^h (with the subcolumn heading b_1) and the LATITUDE column entry closest to 30° 40′ (no interpolation necessary), and read 0.0 minutes of arc.

c. Extraction of b_2. Find the value of b_2 by entering the bottom section of the table with the hour (same column as for b_0 and b_1) and Greenwich date. From the 1st to the 15th day of the month, use the Greenwich month of observation. From the 16th to the last day of the month, use the month after the Greenwich month of observation.

7-22. TABLE 13, GRID AZIMUTH CORRECTION, SIMULTANEOUS OBSERVATION

Table 13 is a nomograph for determining the grid azimuth correction in a simultaneous observation. Use of this table is explained in Section IX of this chapter.

Section IV

STAR SELECTION AND IDENTIFICATION

There are important advantages to using stars rather than the sun as sources of astro azimuth. Since they appear as pinpoints of light in instrument telescopes, stars are easier to track than the sun. At least one of the 73 stars tabulated in the Army ephemeris can usually be found in a satisfactory position for observation regardless of the time of night or the observer's latitude. The North Star (Polaris) should always be used when the geographical location and tactical situation permit. Polaris is the most desirable source of astro azimuth because it is easily identified and bcause its slow apparent motion makes it easy to track. The Polaris tabular method yields reliable azimuths in considerably less time than any other method. In the low northern latitudes and the Southern Hemisphere, however, east-west (noncircumpolar) stars must be used for night astro azimuth determination. Local weather conditions obscuring Polaris may also make observation of east-west stars necessary. Since so many stars are available for observation, the artillery surveyor must be able to select and identify those most suitable for observation. The star finder and identifier is used to identify them.

7-23. STAR FINDER AND IDENTIFIER

The star tinder and identifier (Figure 7-23) is a device used to determine the approximate (±2°) azimuth and altitude of a given star. This device is issued as a component of the survey set, artillery fire control, fourth-order. The star finder and identifier consists of a base, 10 templates, and a carrying case. The base is reversible with stars of the Northern Hemisphere on one side and stars of the Southern Hemisphere on the other. There is one template for each 10° of latitude from 5° to 85° (5°, 15°, 25°, 35°, and so forth). (The tenth template, designed for plotting the sun and planets, is not used in artillery survey). Each template is reversible with one side for north latitude and the other side for south latitude. The template constructed for the latitude nearest the latitude of the observer should be used. The base of the star finder in Figure 7-23 shows the stars visible in the Northern Hemisphere. The center of the device represents the celestial North Pole. The edge of the base is a circle graduated in degrees and half degrees, representing the local hour angle of the vernal equinox or the local sidereal time. On each template is a series of concentric ellipses. Around the outer edge of these ellipses are two sets of numbers from 0° to 360°. The inner set of numbers starts at the top of the template for north latitude and increases in a clockwise direction. The outer set of numbers starts at the bottom of the template for south latitude and increases in a clockwise direction around the ellipses. In the Northern Hemisphere, the inner figures are used; in the Southern Hemisphere, the outer figures are used. The inner set of figures represents the azimuth from the celestial North Pole to the line that the figures identify. The outer set of figures represents the same thing except that the azimuth is from the celestial South Pole to the line. The series of concentric ellipses represents altitudes above the horizon. The template has the horizon on its circumference, the zenith as its center, and a measure of azimuth around the edge. The 0° to 180° line represents the observer's meridian. Before the star finder can be oriented, the value of the local sidereal time must be determined. The pointer of the template is then placed over the appropriate value on the base of the star limier. Local sidereal time can be determined by using DA Form 7284-R (Computation of Star Identification (BUCS)) or by using the Haught method for orienting the star finder and identifier. (A reproducible copy of DA Form 7284-R is included at the back of this book.)

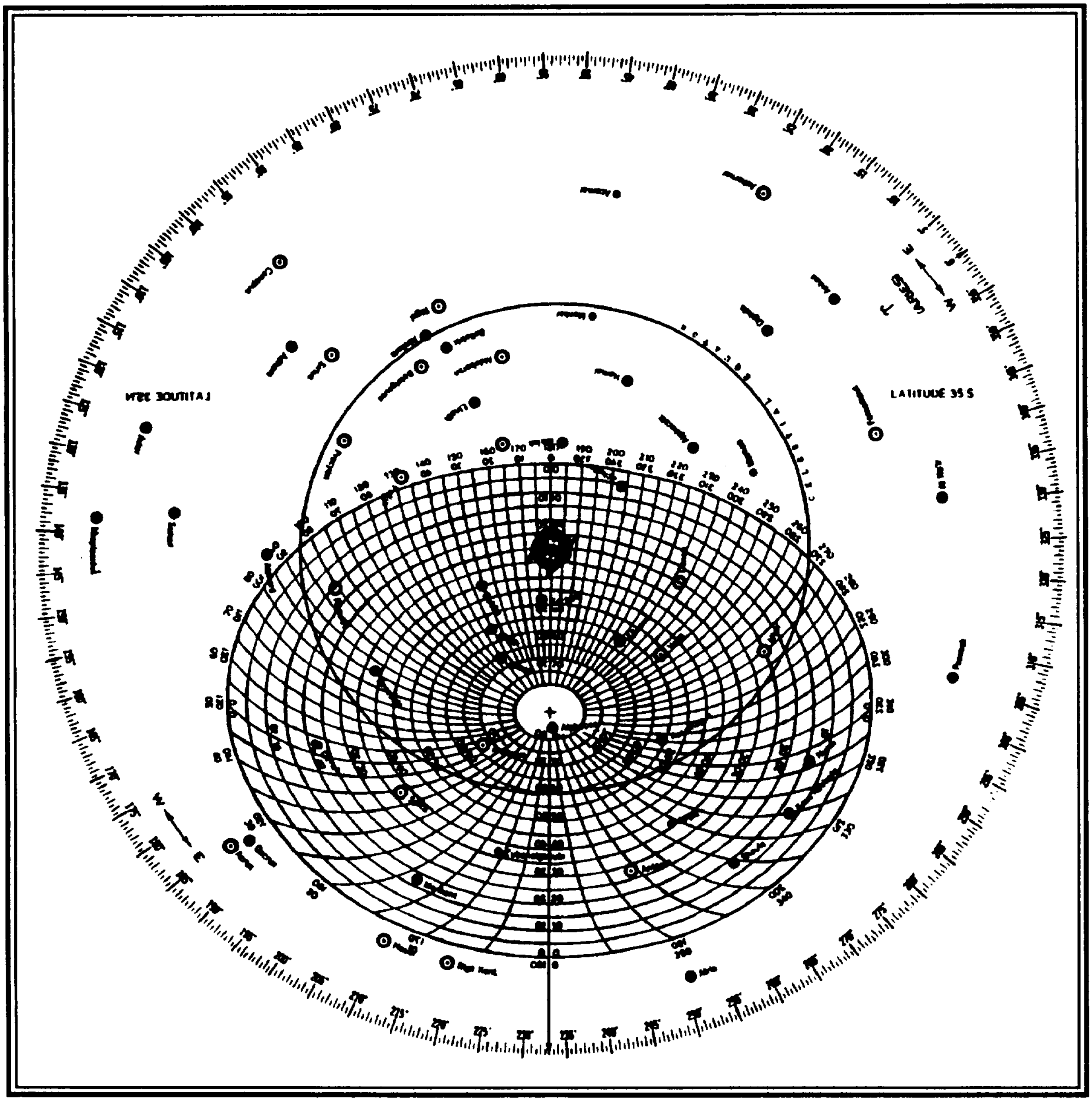


Figure 7-23. **Star finder and identifier**

7-24. HAUGHT (FIELD-EXPEDIENT) METHOD FOR ORIENTING THE STAR IDENTIFIER

This is a simple method of computing the LST for orienting the star finder and identifier. The results are accurate to within 1° and can be used for any time or location. The final result is the LST for 1900 on the date of observation. Use the time-arc relationship to adjust for different observation times. One hour is equal to 15° of shift on the star finder and identifier, and 4 minutes is equal to 1° of shift. To compute the LST by using the Haught method, follow the procedures discussed below.

a. Count the number of months this year preceding the observation month. Multiply that number by 30.

b. Add the observation date.

c. Add a constant of 24.

d. Determine the difference between the observer's longitude and the longitude of the central meridian of the observer's time zone. Add the difference if the observer is east; subtract if west.

e. If using daylight saving time (DST), subtract 15. DST in the US is from the first Sunday in April to the last Sunday in October. The result is the LST (orienting angle) to set on the star identifier for 1900.

f. Determine the difference between 1900 and the time of observation. (Each hour is equal to 15°, and each 4 minutes is equal to 10.) Add if the observation time is after 1900, and subtract if the observation time is before 1900.

EXAMPLE

The observation will be at 2230 on 23 July (the year is not needed). The longitude of the observer is 98° (use closest 1°), and the time zone is S (central meridian = 90°).

Number of full months x 30 =	180
Date of observation	23
Constant	+24
	227
Plus or minus the difference of observer's longitude from the longitude of the central meridian (98 - 90 = 8). (Observer is west.)	-8
	219
Subtract 15 for DST	-15
Result is LST (orienting angle) for 1900	204
The difference between 1900 and 2330 is 3 hours and 30 minutes; therefore, 3 x 15 = 45; 30 + 4 = +7.5	+52.5
Result is LST for 2330 on 23 July	256.5

7-25. SELECTION OF STARS FOR OBSERVATION

a. The apparent motion of a celestial body has two components-a horizontal motion, representing change in azimuth and a vertical motion, representing change in altitude. An error in measuring the altitude of a celestial body will result in a final azimuth error related to the ratio between the two components of the apparent motion of the body. (See Figure 7-24.) When a star is moving at a small angle to the horizon, an error in measuring the altitude will result in a greater error in final azimuth than it would if the star were moving at a large angle to the horizon. (See Figure 7-25.) This relationship is called the star rate, which is the ratio of resulting azimuth error to error in vertical measurement. A star that changes in altitude but not in azimuth will have a star rate of 0, since an error in altitude measurement will result in no error in azimuth. A star that changes so rapidly in azimuth and so slowly in altitude that a 1-mil error in attitude measurement will result in a 3-mil azimuth error has a star rate of 3.

b. For altitude method observations, select the stars with the lowest star rates, since both azimuth and altitude are measured. Low star rates are not essential for arty astro observations, because altitude is not measured. However, stars with low star rates will be moving more slowly in azimuth and will be easier to track than those with high star rates. Although Polaris has a high star rate in its culminations, its apparent motion is so slow that it can be observed successfully at any time. Avoid observing stars below 175 roils in altitude because of possible errors caused by refraction.

Figure 7-24. **Motion of a star viewed through a surveying instrument—high star rate**

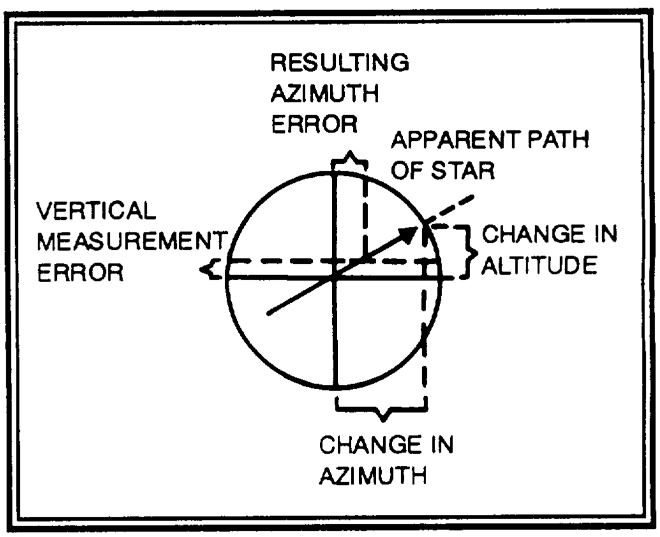
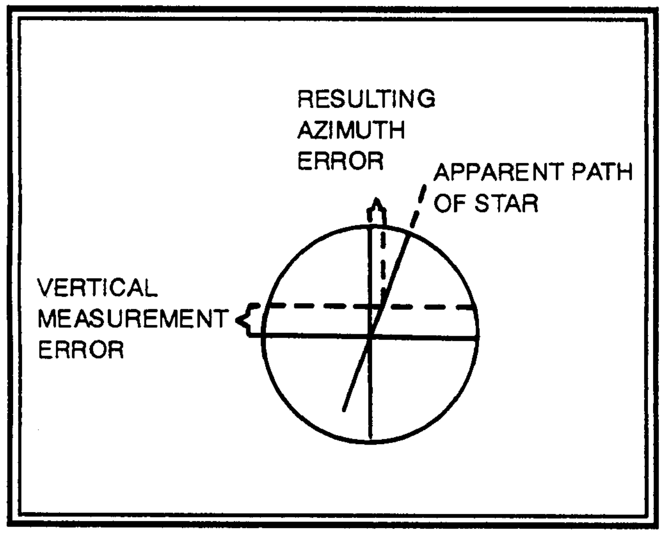


Figure 7-25. **Motion of a star viewed through a surveying instrument—low star rate**



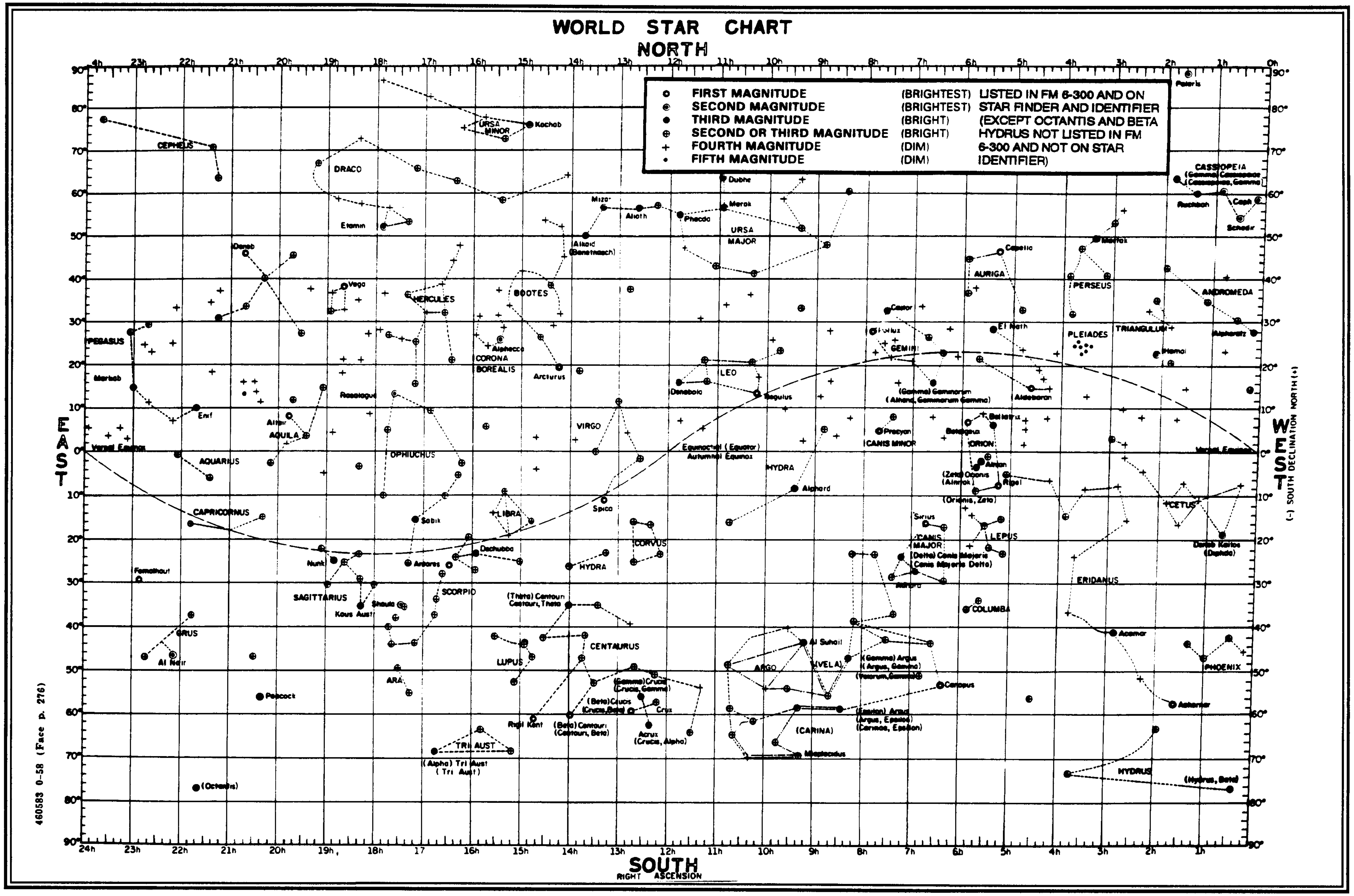
7-26. WORLD STAR CHART

a. A map depicts the prominent points on the earth, and the star chart depicts the prominent points in the sky. (See Figure 7-26.) On the earth latitude and longitude are used to fix the location of points; declination and right ascension are generally used to fix the stare at definite coordinates, Consequently, on a star chart the north-south location of a star is fixed by declination, and the east-west location is fixed by right ascension.

b. The two projections by which star charts are plotted are cylindrical (similar to the mercator projection for world maps) and plane (similar to polar projection for world areas). The cylindrical projection presents great distortion about the poles of the celestial sphere but offers a fairly accurate picture in declination to ±65°, It should be remembered that in such a projection the vertical lines plotted to be parallel actually converge at the poles and are perpendicular to the equator. The plane projection presents a truer picture of the sky, especially if it is used with a mark that blocks out all the sky except that within the horizon for a given area.

c. The brightness of stars is measured in magnitude. Thus, the brightest stars are of the first magnitude, the next in brightness are of the second magnitude, and so forth. Stars in constellations, some of which have individual names (for example, Polaris), are usually named in the constellation in order of their brightness through the use of the Greek alphabet. Thus, in the constellation Orion, from the brightest to the least bright, the stars are named a (Betelgeuse [also Betelgeux]), **β** (Rigel), **λ** (Bellatrix), and so forth. The magnitude of each star is shown on star charts.

Figure 7-26. **World star chart**



d. The following method can be used to orient the world star chart in the Northern Hemisphere.

(1) Determine the LST of observation from Figure 7-27.

(a) Enter the table with the closest date of observation.

(b) From the date, move to the right and stop in the column of the closest hour of observation.

(c) Extract the LST from the hour column.

(2) Locate the celestial equator.

(a) Subtract the observer's latitude from 90°. The result is the distance above the horizon to the celestial equator.

(b) Facesouth, and determine the position of the celestial equator. Remember, at arms length, a finger width is 2°, 1 hand width is 10°, and 1 hand span is 20°.

Figure 7-27. **Local sidereal time**

DATE	EVENING HOURS 2000	MIDNIGHT 2400	MORNING HOURS 0400
JAN 5	3	7	11
20	4	8	12
FEB 4	5	9	13
20	6	10	14
MAR 7	7	11	15
22	8	12	16
APR 7	9	13	17
22	10	14	18
MAY 7	11	15	19
22	12	16	20
JUN 7	13	17	21
22	14	18	22
JUL 7	15	19	23
22	16	20	0
AUG 7	17	21	1
22	18	22	2
SEP 7	19	23	3
21	20	0	4
OCT 6	21	1	5
21	22	2	6
NOV 6	23	3	7
21	0	4	8
DEC 6	1	5	9
21	2	6	10

(3) Hold the world star chart with the word North on top. Locate the graduation at the top the chart that represents the LST. Face south, and align the LST graduation just below the celestial equator along the observer's meridian. The world star chart is now oriented with the stars in the sky.

e. The following method can be used to orient the world star chart in the Southern Hemisphere.

(1) Determine the LST from Figure 7-27 by using the same procedures in subparagraph d.

(2) Locate the celestial equator. This is done the same as in the Northern Hemisphere except the observer must face north and count up from the horizon to locate the celestial equator.

(3) Hold the world star chart with the wo *South* at the top. Locate the graduation at the top of the chart that represents the LST. Face north, and align the LST graduation just below the celestial equator along the observer's meridian.

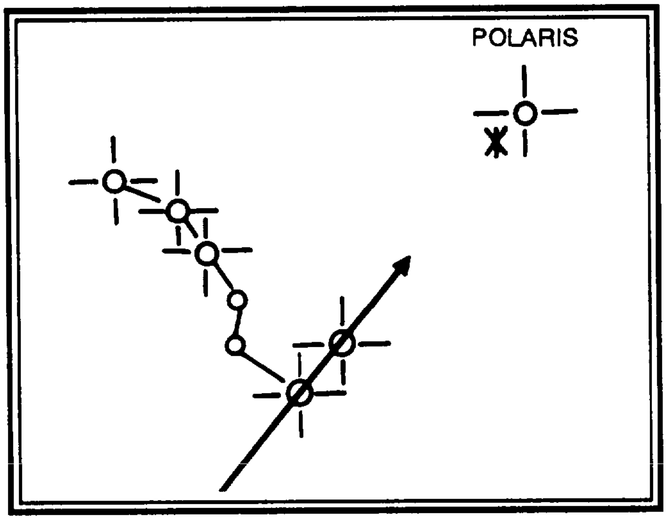
f. To aid the observer, highlight the 30°N and W S lines on the star chart. Also highlight the 0° line, which is the celestial equator. The strip of sky as outlined by the 30°N and 30°S lines will contain the brightest stars (seen at any one time). Keep in mind that the strip of sky being looked at is about 6 hours either side of the LST.

7-27. LOCATING STARS

The easiest way to identify stars and fix their locations in relation to each other is to learn something about constellations. Since stars are fixed in definite points in the sky with relation to each other, the relative position of stars has remained about the same for many centuries. In certain groups of stars, primitive stargazers saw the shapes of creatures or heroes of their folklore. Names were applied to the shapes of these various groups of stare. Later, people saw in the stars the shapes of household implements with which they worked. The development of the names of stars began early in the history of man and finally resulted in a catalog of the visible stars. The named shapes became constellations, and the individual stars were identified by name with the constellation of which they were a part. From this primitive development the constellations were given Latin names. Other groups of stars were assigned names of gods and goddesses and creatures of land and sea that figured in Roman and Greek mythology. Much later in history, our forefather saw in the many constellations objects common to their mode of living. Thus, the Big Bear came to be known as the Big Dipper. To the English, this same constellation is the Plough. Some of the more familiar starts and constellations are described below.

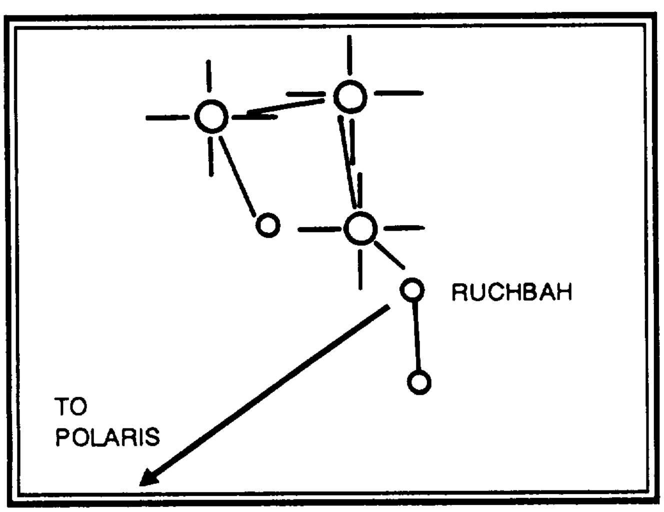
a. The familiar constellation called the Big Dipper is only part of the constellation Ursa Major. (See Figure 7-28.) The seven stars of the dipper are easy to find on almost any clear night. The two outer stars of the bowl point toward the North Star, Polaris, which is about 30° away. The distance between the pointers is about 5°. Both measurements are very helpful when the star finder and identifier is being used.

Figure 7-28. **Ursa Major**



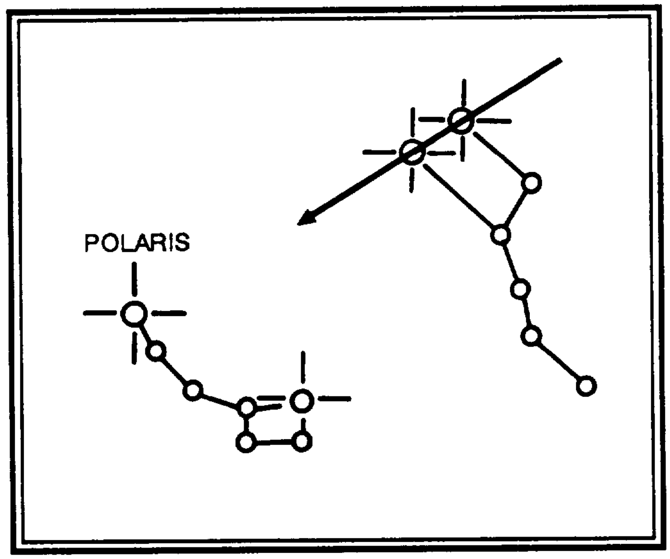
b. Cassiopeia (Figure 7-29), sometimes called the Lady in the Chair, the Running M, or the Lazy W, is a prominent northern constellation. It is found directly across the celestial North Pole, opposite the Big Dipper. When the Big Dipper is below the horizon, Polaris can be found by drawing a line from the star Ruchbah bisecting the angle formed by the shallow side in Cassiopeia. The bisecting line points almost through Polaris.

Figure 7-29. **Cassiopeia**



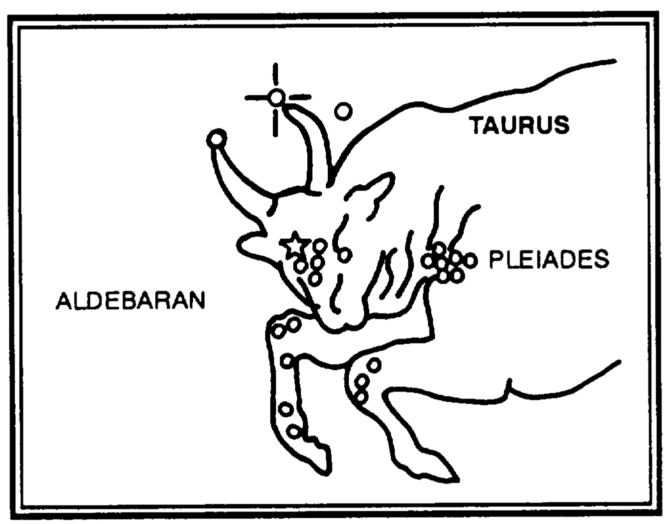
c. Polaris, the polestar, is the alpha star in the constellation Ursa Minor (Figure 7-30), commonly called the Little Dipper. On a clear night, the Little Dipper is easily seen. The handle of the dipper has a reverse curve, and Polaris is the last star in the handle.

Figure 7-30. **Ursa Minor**



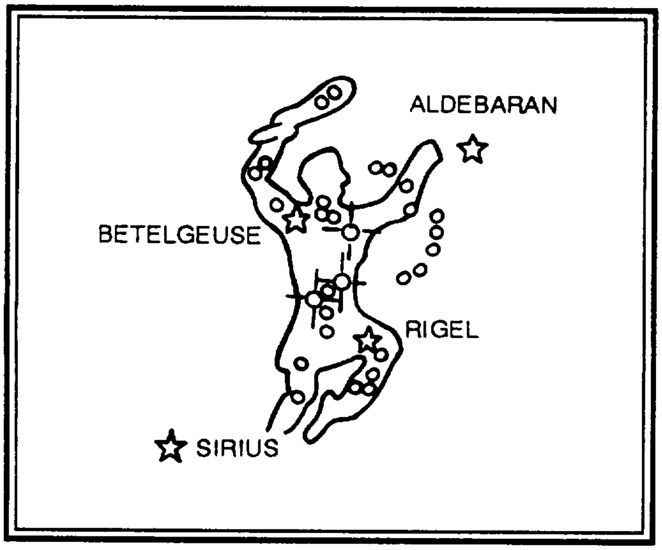
d. The first prominent constellation after the vernal equinox has risen in the east is Taurus, the Bull. (See Figure 7-31.) On the forehead of Taurus is a red star of the first magnitude, Aldebaran. It is a royal star, one of the four stars most commonly used by navigators. On the upper foreleg of Taurus is the Plaeiades. This aggregation is a tight cluster of stars, which is also called the Seven Sisters.

Figure 7-31. **Taurus**



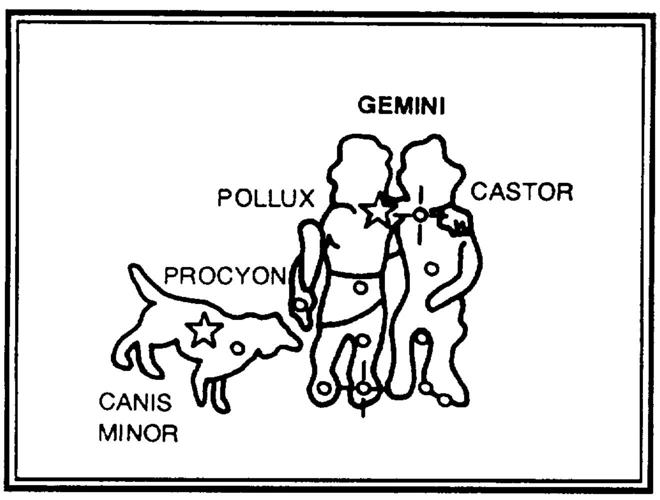
e. Chasing these seven stare and the bull is Orion, the Hunter. (See Figure 7-32.) There are two very bright stars in Orion. The hunter's right shoulder is Betegeuse(α Orionis); his left knee is Rigel (β Orionis). Close on the heels of Orion are his two dogs, Canis Major and Canis Minor. In the big dog is the brightest star in the sky, Sirius. It is a brilliant blue-white star. Slightly behind Canis Major is the smaller dog in which Procyon is found.

Figure 7-32. **Orion**



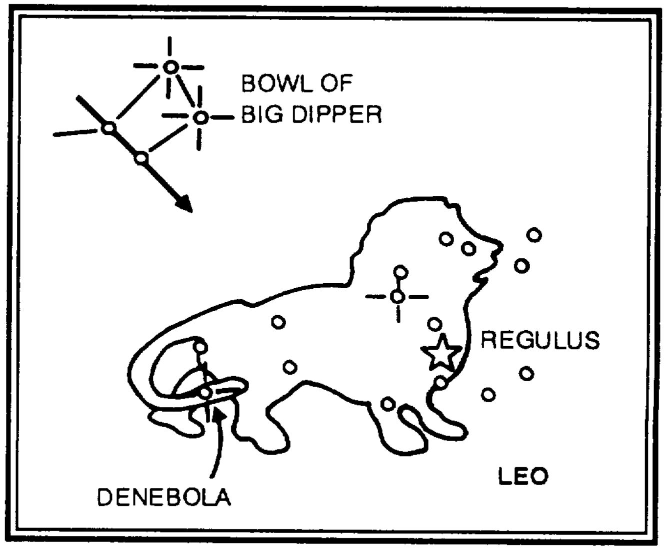
f. At about the same right ascension with the canine constellation is Gemini, the Twins. (See Figure 7-33.) Think of Gemini as a wedge pointed straight toward Orion. The bright star at the base of the wedge is Pollux (ß Geminorum); the one above it is Castor (α Geminorum).

Figure 7-33. **Gemini**



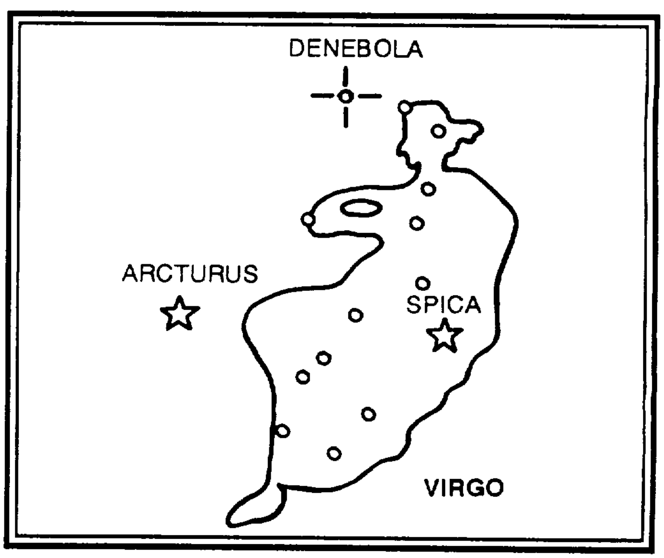
g. About 2 hours behind Gemini and Canis Minor is Leo, the Lion. (See Figure 7-34.) The head and forequarter of Leo are sometimes known as the Sickle. The body and tail extend off to the east. The heart of Leo is Regulus (α Leonis). Regulus is another of the four royal stare. It is brilliant white, whereas the others are red.

Figure 7-34. **Leo**



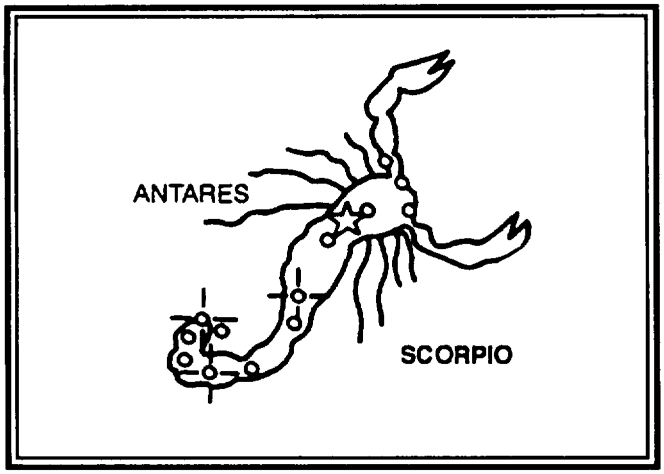
h. As soon as Leo is well up in the sky, Virgo (Figure 7-35) will rise in the east. The bright star in Virgo, called Spica (a Virginis). makes an approximately equilateral triangle with Denebola (ß Leonis) and Arcturus (α Bootis). This triangle is sometimes called the Virgo triangle.

Figure 7-35. **Virgo**



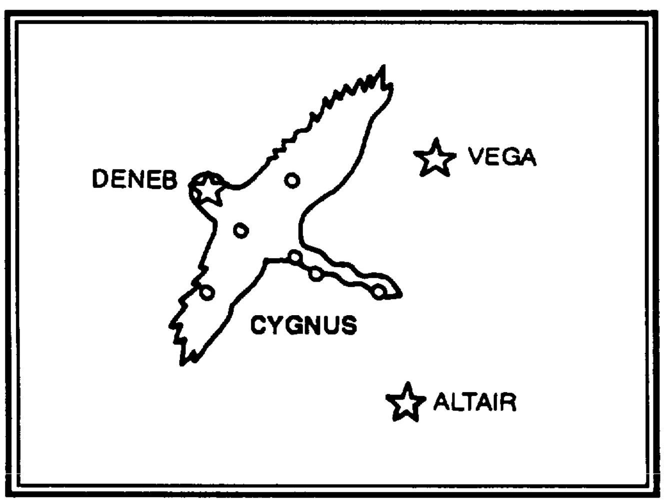
i. One of the most easily recognized constellations is Scorpio. (See Figure 7-36.) However, it is so far south that in northern latitudes it is visible during evening hours only through July and August. Antares (α Scorpii) is another of the four royal stars.

Figure 7-36. **Scorpio**



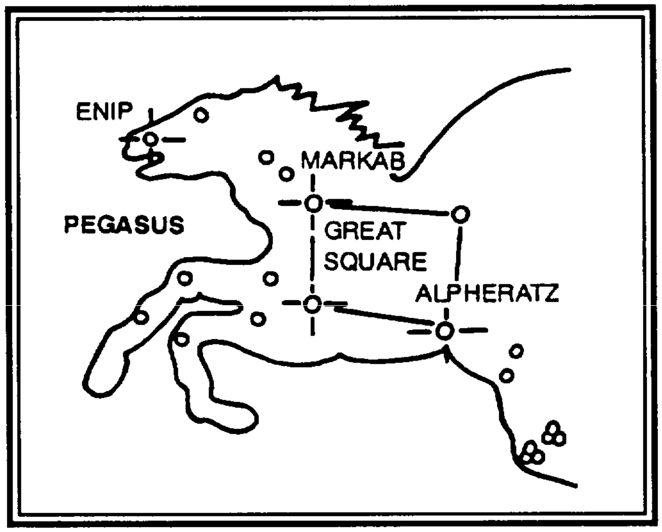
j. The Northern Cross, Cygnus, is found very close to the circumpolar region. (See Figure 7-37.) This is a very prominent constellation, and in northern latitudes in the fall, it will be nearly overhead in the evening. The head of the cross is Deneb (α Cygni). There are two neighbor stars in this sector of the sky-Vega (α Lyrae), which rises just before the cross, and Altair (α Acquilae), which trails it somewhat to the south. Cygnus is imagined by some to be a cross; to others, it takes the shape of a swan from which the name is derived.

Figure 737. **Cygnus**



k. Pegasus (Figure 7-38), which includes the Great Square, straddles the hour circle of the vernal equinox. This is the constellation of the flying horse, a very prominent skymark.

Figure 7-38. **Pegasus**



l. Fomalhaul, the fourth royal star, is a prominent star in the southern sky. It ranks number 13 in brightness of stars visible in the Northern Hemisphere.

7-28. STAR IDENTIFICATION (BUCS)

Approximate azimuth and altitude to a selected survey star at a date and time chosen by the user can be determined by using DA Form 7284-R (Figures 7-39 and 7-40) and Program 7 of the SURVEY REV1 module. This orientation data will help identify survey stars for astro observation or navigation.

a. Capabilities. This program will compute the approximate azimuth and altitude (vertical angle) to any of the 73 survey stars selected by the user. These orientation data are accurate to ±5.0 roils for the date, time, and location selected for observation. The user can determine orientation data for any number of survey stars with the program, but he is limited to six sets of data per form. This program will enhance the surveyor's ability to identify stars in the Northern and Southern Hemispheres. It provides a tool for leaders to train surveyors to respond rapidly to astro observation requirements.

b. Program and Form Instructions. See Table 7-1 for instructions on computing DA Form 7284-R by using Program 7 of the SURVEY REV1 module.

Figure 7-1. **Instructions for computing DA Form 7284-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM. At this point, call Program 7.
2	The display prompts STAR ID. There is nothing in the PROCEDURE column. Press the END LINE key.
3	The display prompts SPHEROID CODE: 0. The procedure is ENTER SPHEROID CODE. Enter the spheroid code for your area of operation. Record the spheroid code in the SPHEROID: block in the DATA RECORD section. **Note.** To review the spheroid codes, continue to press the END LINE key at the prompt SPHEROID CODE: 0. A menu of spheroid codes will be displayed one code at a time as follows: 1=CLARKE 1866: 2=INTERNATIONAL: 3=CLARKE 1880: 4=EVEREST: 5=BESSEL: 6=AUSTRALIAN: 7=WORLD GEO SYS-72: 8=GRS-80: To select the desired spheroid, either press the X key and then the END LINE key when the desired spheroid code is displayed or continue to review all spheroid codes until the display prompt SPHEROID CODE: 0 appears again. Then enter the number of the desired spheroid code, and press the END LINE key. (The GRS-80 constants are the same as WGS-84 constants.)
4	The display prompts EAST: 0.00. The procedure is ENTER EASTING. Enter the UTM easting of the observer's station. Record the easting in the EAST: block in the DATA RECORD section.
5	The display prompts NORTH: 0.00. The procedure is ENTER NORTHING. Enter the UTM northing of the observer's station. Record the northing in the NORTH: block in the DATA RECORD section.
6	The display prompts LATITUDE (N/S): The procedure is ENTER N OR S. Enter N or S.
7	The display prompts GRID ZONE: 00. The procedure is ENTER GRID ZONE. Enter the grid zone number. Record this number in the GRID ZONE: block in the DATA RECORD section.
8	The display prompts OBS DATE (DD.MMYY): The procedure is ENTER DATE OF OBSERVATION (LOCAL DATE). Enter the local date of observation in a day, month, and year format. Record the local date of the observation in the DATE: block in the DATA RECORD section.
9	The display prompts OBS TIME (HH.MMSS): The procedure is ENTER TIME OF OBSERVATION (LOCAL TIME). Enter the local time of observation in an hour, minute, and second format. Record the local time of observation in the TIME: block in the DATA RECORD section.
10	The display prompts TIME ZONE LETTER: The procedure is ENTER TIME ZONE LETTER. Enter the time zone letter of the observer's location. Record the time zone letter in the TZ LTR: block in the DATA RECORD section. Determine the time zone letter from the time zone chart on the back of the arty astro forms. (See paragraph 7-36 for a discussion of this form.) **Note.** At the TIME ZONE LETTER input prompt, the letters A, B, and T represent the respective time zones A, B, and T. Therefore, the ABORT, BACKUP, and TOP OF FILE functions that are normally entered with A, B, and T are disabled for this input line only.
11	The display prompts DAYLT SV TIME (Y/N): The procedure is ENTER Y OR N. Enter Y or N to indicate if local time includes a daylight saving time correction. The answer to this prompt and the time zone letter is used by the program to convert local time to GMT for internal computations.

Table 7-1. **Instructions for computing DA Form 7284-R (continued)**

STEP	INSTRUCTION
12	The display prompts LST (DEGREES):_ _ ._ _. The procedure is RECORD LST. Record the LST in the LST: block in the DATA RECORD section, and press the END LINE key. The LST is used by artillery surveyors to orient star identifiers for star selection.
13	The display prompts STAR #: 00. The procedure is ENTER STAR NO. Enter the number of the star selected for observation. The 73 survey stars are listed alphabetically on the back of the form. Record the star name and number in the STAR NO-STAR NAME: block in the DATA RECORD section.
14	The display prompts AZ TO STAR: ____.___. The procedure is RECORD AZIMUTH TO STAR. Record the approximate grid azimuth to the star in the AZIMUTH (MILS): block of the DATA RECORD section.
15	The display prompts ALT TO STAR: ____.___. The procedure is RECORD ALTITUDE TO STAR. Record the displayed altitude in the ALTITUDE: block on the line for step 15. A negative altitude is an indication that the selected star is below the horizon for the selected date and time of observation. If this occurs, press the END LINE key. The next display prompt is NEW STAR (Y/N):
16	The display prompts NEW STAR (Y/N): The procedure is ENTER Y OR N. Select the appropriate response—Y (yes) or N (no). If the response is Y, the next display prompt is STAR #: 00. Enter the new star number to determine orientation data based on previous time and date. Record the star name and number in the STAR NO-STAR NAME: block on the step 16 line. If the computer's response is N, the NEW OBS TIME (Y/N): prompt appears.
17	The display prompts NEW OBS TIME (Y/N): The procedure is ENTER Y OR N. Select the appropriate response—Y or N. If the response is Y, the next display prompt is OBS TIME (HH.MMSS): Enter the new local time of observation, and perform steps 9 through 15 to determine orientation data based on new local time. If the operator response is N, the next display prompt END OF MSN (Y/N): appears.
18	The display prompts END OF MSN (Y/N): The procedure is ENTER Y OR N. This is the last point at which data can be recalled. Select the appropriate response— Y or N. If the response is N, the previous display prompt is displayed and all data for the current time of observation and selected star can be recalled. If the response is Y, then the next display prompt is SURVEY PGM MENU REV1 and all data in memory are discarded.

Figure 7-39. **Sample DA Form 7284-R**

COMPUTATION OF STAR IDENTIFICATION (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER: SSG ANDERSON	NOTEBOOK REFERENCE: X-3	DATE: 24 JUN 91
CHECKER: SSG PENA	AREA: S ATLANTIC	SHEET 1 OF 1 SHEETS

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE		
1		CALL PROGRAM:	STATION: ANVIL	STATION:
2	STAR ID			
3	SPHEROID CODE: 1 = CLARKE 1866: 2 = INTERNATIONAL: 3 = CLARKE 1880: 4 = EVEREST: 5 = BESSEL: 6 = AUSTRALIAN: 7 = WORLD GEO SYS-72: 8 = GRS-80:	ENTER SPHEROID CODE #7	SPHEROID: #7 WGS-72	SPHEROID:
4	EAST: 0.00	ENTER EASTING	EAST: 736450.00	EAST:
5	NORTH: 0.00	ENTER NORTHING	NORTH: 5012600.00	NORTH:
6	LATITUDE (N/S):	ENTER N OR (S)		
7	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE: 25	GRID ZONE:
8	OBS DATE (DD.MMYY):	ENTER DATE OF OBSERVATION (LOCAL DATE)	DATE: dd 22. mm 09 yy 86	DATE: dd . mm yy
9	OBS TIME (HH.MMSS):	ENTER TIME OF OBSERVATION (LOCAL TIME)	TIME: hh 23. mm 00 ss 00	TIME: hh . mm ss
10	TIME ZONE LETTER:	ENTER TIME ZONE LETTER	TZ LTR:	TZ LTR:
11	DAYLT SV TIME(Y/N):	ENTER Y OR (N)		
12	LST (DEGREES): ---.-	RECORD LST	LST: 346.6 degrees	LST degrees
13	STAR #: 00	ENTER STAR NO	STAR NO-STAR NAME: 42 ACRUX	STAR NO-STAR NAME: 66 ALTAIR
14	AZ TO STAR: 0.000	RECORD AZIMUTH TO STAR	AZIMUTH (MILS): 3404.639	AZIMUTH (MILS): 5499.029
15	ALT TO STAR: 0.000	RECORD ALTITUDE TO STAR	ALTITUDE (MILS): +341.776	ALTITUDE (MILS): +364.289
16	NEW STAR (Y/N):	ENTER Y OR N	STAR NO-STAR NAME: 23 CANOPUS	STAR NO-STAR NAME:
17	NEW OBS TIME (Y/N):	ENTER Y OR N	AZIMUTH (MILS): 2542.766	AZIMUTH (MILS):
18	END OF MSN (Y/N):	ENTER Y OR N	ALTITUDE (MILS): +442.799	ALTITUDE (MILS):
NOTES:			STAR NO-STAR NAME: 57 ANTARES	STAR NO-STAR NAME:
			AZIMUTH (MILS): 4387.238	AZIMUTH (MILS):
			ALTITUDE (MILS): +216.997	ALTITUDE (MILS):

NOTES:
1. IN STEP 8, ENTER DAY, MONTH AND YEAR.
2. IN STEP 9, ENTER HOURS, MINUTES, AND SECONDS.
3. IN STEP 10, SEE BACK OF FORM FOR TIME ZONE LETTERS.
4. IN STEP 13, SEE BACK OF FORM FOR STAR LIST.
5. IN STEP 16, Y RESPONSE RETURNS YOU TO STEP 13.
6. IN STEP 17, Y RESPONSE RETURNS YOU TO STEP 9.

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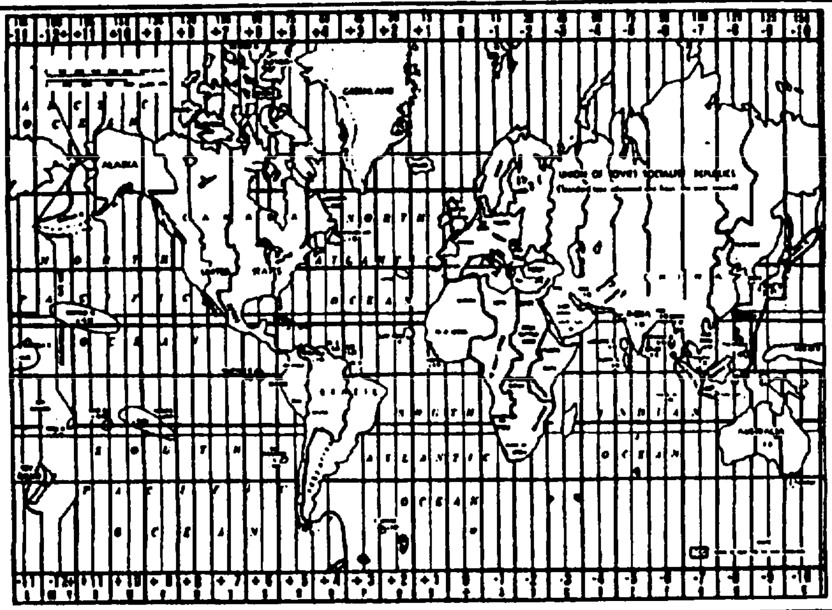
Figure 7-40. **Reverse of DA Form 7284-R**

TIME ZONE CHART



LONGITUDE OF MERIDIAN	TIME ZONE LETTER
EAST LONGITUDE	
0	Z
15	A
30	B
45	C
60	D
75	E
90	F
105	G
120	H
135	I
150	K
165	L
180	M
WEST LONGITUDE	
0	Z
-15	N
-30	O
-45	P
-60	Q
-75	R
-90	S
-105	T
-120	U
-135	V
-150	W
-165	X
-180	Y

ALPHABETICAL STAR LIST

Star	No.	
ACAMAR	12	
ACHERNAR	9	
ACRUX	42	*
ADHARA	26	
ALDEBARAN	15	*
ALHENA	24	
ALIOTH	45	
ALKAID	48	
AL NA'IR	71	
ALNILAM	20	
ALNITAK	21	
ALPHARD	35	
ALPHECCA	55	
ALPHERATZ	1	*
ALTAIR	66	*
ANKAA	4	
ANTARES	57	*
ARCTURUS	51	*
ATRIA	58	
AVIOR	32	
BELLATRIX	18	
BETA HYDRUS	3	
BETELGEUSE	22	
CANOPUS	23	
CAPELLA	17	
CAPH	2	
CASTOR	28	
DENEB	68	
DENEBOLA	39	
DIPHDA	6	
DSCHUBBA	56	
DUBHE	38	
ELNATH	19	
ELTANIN	62	
ENIF	70	
FOMALHAUT	72	
GACRUX	43	
GAMMA CASSIOPEIAE	7	
GAMMA VELORUM	31	
GIENAH	41	
HADAR	49	
HAMAL	11	
KAUS AUSTRALIS	63	
KOCHAB	54	*
MARKAB	73	
MENKAR	13	
MENKENT	50	
MERAK	37	
MISPLACIDUS	34	
MIMOSA	44	
MIRFAK	14	
MIZAR	46	
NUNKI	65	
NU	69	
PEACOCK	67	
PHECDA	40	
POLARIS	10	*
POLLUX	30	
PROCYON	29	
RASALHAGUE	61	
REGULUS	36	*
RIGEL	16	
RIGIL KENTAURUS	52	
RUCHBAH	8	
SABIK	59	
SCAULA	60	
SCHEDAR	5	
SIRIUS	25	*
SPICA	47	
SUHAIL	33	
VEGA	64	
WEZEN	27	
ZEBENELGENUBI	53	

* INDCATES THE PREFERRED STARS FOR HASTY ASTRO.

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Section V

ALTITUDE METHOD

The altitude method can be used to determine azimuth from the sun or from the stars. This method requires the solution of the astronomic (PZS) triangle (Figure 7-20) by using, as determined data, the three sides of the triangle (polar distance, colatitude, and coalititude). In the altitude method, the time is required only to determine the declination of the body. When the sun is observed, the time should be accurate within 5 minutes. For stars, only the date is required. Since time is not critical in the altitude method of observation, this method is used most frequently by artillery surveyors.

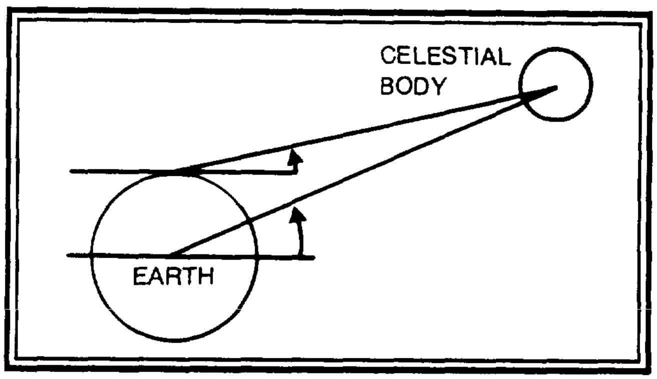
7-29. POSITIONS OF CELESTIAL BODIES

Stars for altitude observation should be in the east or west between 175 and 800 roils in altitude. When the sun or a star is observed, it should be within 530 mils of the observer's prime vertical. This is the arc on the celestial sphere that passes through points due east and west of the observer and through his zenith. The sun must not be within 2 hours of the observer's meridian. For the best results, the sun should be above 175 mils in altitude. Unless an elbow telescope or the card method paragraph 7-14) is used, the sun must be below 800 roils in altitude.

7-30. APPARENT DISPLACEMENT

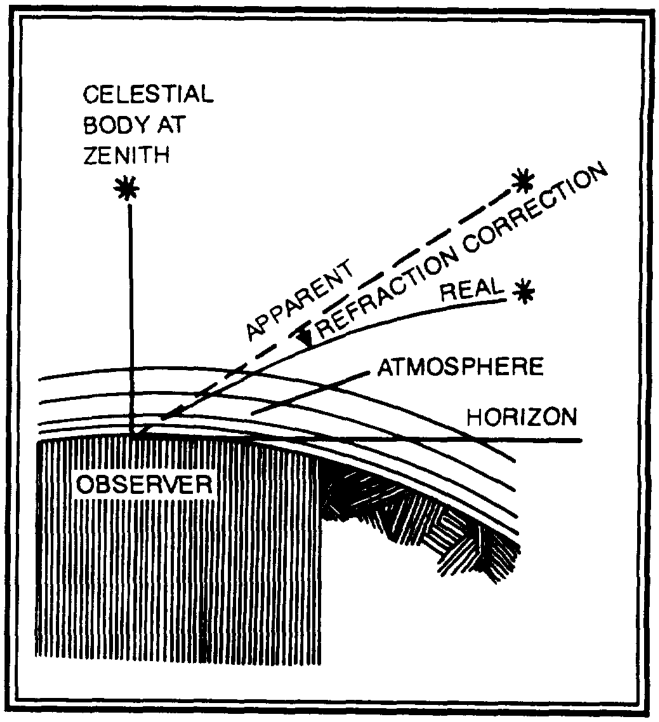
a Parallax. The word *parallax is* defined as "the difference in altitude of a celestial body as seen from the center of the earth and from a point on the surface of the earth." An observed altitude of the sun is corrected for parallax; that is, for the error introduced by the fact that the observer is on the surface of the earth and not at the center. (See Figure 7-41.) This difference is negligible on vertical angles to the stars because they are so far from earth. The constant for the parallax of the sun is considered as +7 seconds, or +0.04 mil.

Figure 7-41. **Parallax correction**



b. Refraction. Refraction (Figure 7-42) is the apparent displacement of the celestial body caused by the bending of light rays passing through layers of air of varying density. The refraction varies according to the altitude of the light source above the horizon. At a temperature of +70°, refraction of a body on the horizon is 10.26 mils; refraction of a body at the observer's zenith is 0 mils. Refraction increases with an increase in barometric pressure and a decrease in temperature. It decreases with a decrease in barometric pressure and an increase in temperature. The refraction correction is extracted from FM 6-300 (Table 1b) and is applied to observed altitudes of the sun and stars. The sign of-the refraction correction is always minus.

Figure 7-42. **Refraction correction**



7-31. ALTITUDE METHOD COMPUTATIONS

a. In solving for azimuth as in other survey problems, a standard DA form has been designed to facilitate the necessary computations. DA Form 5594-R (Computation of Astronomic Azimuth by Altitude Method, Sun (BUCS)) (Figure 7-43) and DA Form 5595-R (Computation of Astronomic Azimuth by Altitude Method, Star (BUCS)) (Figure 7-44) have been designed to solve for azimuth by the altitude method formula. (Reproducible copies of both of these forms are included at the back of this book.)

b. The top portion of the DA forms is set up basically the same as the other BUCS forms you have used. The top six blocks are for administrative information. Below the administrative data, you will find notes that refer to the operation of the BUCS in this program. Under the notes on the left side of the form, you will find specific instructions on the use of this form. To the right of the instructions, you will find the data record where all known, field, and computed data are recorded. Blocks that are marked with a bold arrow are where field data are entered. One complete observation (three sets) can be recorded and computed on each form.

c. The procedures for computing DA Form 5594-R are shown in Table 7-2.

Table 7-2. **Instructions on computing DA Form 5594-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 5. Enter the survey module, and call Program 5.
2	The display prompts ALTITUDE METHOD. The PROCEDURE column is blank. Press the END LINE key.
Note. At the completion of each step, press the END LINE key.	
3	The display prompts USE SUN (Y/N): The procedure is ENTER Y.
4	The display prompts LAT(-:S) 0.0000000. The procedure is ENTER LATITUDE OF STATION. The latitude is entered with the value of the degrees followed by a decimal and the value of the minutes and the seconds (DD.MMSS). If latitude is in the Southern Hemisphere, enter it as a negative. Record the latitude in the LATITUDE: block in the DATA RECORD section.
5	The display prompts LG(-:W) 0.0000000. The procedure is ENTER LONGITUDE OF STATION. The longitude is entered in the same manner as the latitude (DD.MMSS). If longitude is in the Western Hemisphere, enter it as a negative. Record the longitude in the LONGITUDE: block in the DATA RECORD section.
6	The display prompts ^DECLN (TBL 2/10A). Press the END LINE key. The prompt will change to (DD.MMSSS) 0.00000. The procedure is ENTER DECLINATION OF SUN (FM 6-300,TABLE 2). Extract the declination from the ephemeris, and enter it as indicated (DD.MMSSS). Record the declination in the DECLINATION: block in the DATA RECORD section.

Table 7-2. **Instructions on computing Da Form 5594-R (continued)**

STEP	INSTRUCTION
7	The display prompts DC DECLN (sec): 0000. The procedure is to ENTER DAILY CHANGE IN SECONDS OF DECLINATION. Extract the data from the ephemeris, and enter it as indicated. Record the change in the DAILY CHANGE (SECONDS): block in the DATA RECORD section.
8	The display prompts WC(-:F;.MMSS): 0.0000. The procedure is ENTER WATCH CORRECTION. Enter the difference between the watch used and the time source. A fast watch will have a correction of minus, and a slow watch will have a correction of plus. Record the correction in the WATCH CORRECTION: block in the DATA RECORD section.
9	The display prompts TZ CORR (-:E): 00. The procedure is ENTER TIME ZONE CORRECTION. Enter the hours of time zone correction. If the time zone is in the east, enter its value as a negative. Time zone correction can be obtained from the world time zone map.
10	The display prompts MN W TIME: 00.00000. The procedure is ENTER MEAN WATCH TIME. Enter the mean time of observation for set one. Enter the value as HH.MMSS. Record the mean time in the time blocks in the DATA RECORD section.
11	The display prompts REFR(TBL1,mil): 0.00. The procedure is ENTER REFRACTION(TABLE 1b). Extract the data from the ephemeris, and enter it. Record the refraction data in the ENTER AS + block in the DATA RECORD section for each set.
12	The display prompts HZ < SUN: 0.000. The procedure is ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO SUN. Enter the mean horizontal angle for set one. Record the mean horizontal angle in the HORIZONTAL ANGLE (MILS): block in the DATA RECORD section for each set.
13	The display prompts VA: 0.000. The procedure is ENTER VERTICAL ANGLE TO SUN. Enter the vertical angle to the sun for set one. Record the VA in the VERTICAL ANGLE (MILS): block in the DATA RECORD section for each set.
14	The display prompts ASTRO AZ/MK: 0.000. The procedure is RECORD THE ASTRONOMIC AZIMUTH TO AZIMUTH MARK. Record the azimuth in the ASTRONOMIC AZIMUTH (MILS): block in the DATA RECORD section for each set.
15	The display prompts ADD SETS REQD(Y/N). The procedure is ENTER Y OR N. Enter Y (yes) since this is just the first set. The program will return to step 10 when this step is answered Y. Repeat steps 10 through 15 for sets two and three. Answer N (no) to the prompt in step 15 of the third set. The program will then go to step 16.
16	The display prompts 4TH/5TH ORDER (4/5): 0. The procedure is ENTER 4 OR 5. Enter the number that corresponds to the accuracy of the survey being performed.
17	The display prompts MN ASTRO AZ: 0.000. The procedure is RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK. Record the azimuth in the MEAN ASTRONOMIC AZIMUTH (MILS): block in the DATA RECORD section. This is a **true** azimuth.
18	The display prompts GRID ZONE: 00. The procedure is ENTER GRID ZONE. Enter the grid zone in which the observer is located. It can be read from the marginal information of a map of the area. Record the grid zone in the GRID ZONE: block in the DATA RECORD section.
19	The display prompts GRID AZ/MK: 0.000. The procedure is RECORD GRID AZIMUTH TO AZIMUTH MARK. Record the azimuth in the GRID AZIMUTH (MILS): block in the DATA RECORD section.
20	The display prompts END OF MSN (Y/N): The procedure is ENTER Y OR N. If the mission is complete, enter Y (yes). The program will then prompt SURVEY PGM MENU REV1. If you enter N (no), the program returns to step 19.

Figure 7-43. **Sample DA Form 5594-R**

COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD, SUN (BUCS)

For use of this form, see FM 6-2, the proponent agency is TRADOC

COMPUTER SSG ANDERSON	NOTEBOOK REFERENCE 2-1B	DATE 10 AUG 88
CHECKER SSG PENA	AREA FT. SILL, OK	SHEET 1 OF 1 SHEETS

NOTES: 1 IF STEP 15 IS Y, PROGRAM GOES TO STEP 10
2 IF STEP 15 IS N, PROGRAM GOES TO STEP 16
3 SEE BACK OF FORM FOR REJECTION CRITERIA.
4 ENTER FIELD DATA IN BLOCKS MARKED ▶.

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE		
			AZIMUTH MARK: AZ MK	APPROXIMATE AZIMUTH TO AZIMUTH MARK (MILS) 0200
1		CALL PROGRAM 5		
2	ALTITUDE METHOD		STATION: OS	TEMPERATURE 90°F
3	USE SUN (Y/N):	ENTER Y		
4	LAT(- S): 0.0000000	ENTER LATITUDE OF STATION	LATITUDE: (+) 34° 20' 21" (N) S	
5	LG(- W): 0.0000000	ENTER LONGITUDE OF STATION	LONGITUDE: + (-) 98° 24' 18" E (W)	
6	*DECLN (TBL 2/10A) (DD.MMSSS): 0.00000	ENTER DECLINATION OF SUN (FM 6-300, TABLE 2)	DECLINATION: (+) - 15° 33' 58"	
7	DC DECLN (sec): 0000	ENTER DAILY CHANGE IN SECONDS OF DECLINATION	DAILY CHANGE (SECONDS): + 0 1061	
8	WC(- F, MMSS): 0.0000	ENTER WATCH CORRECTION	WATCH CORRECTION: (SLOW) (+) (FAST) - MINUTES 00 SECONDS 23	
9	TZ CORR (- E): 00	ENTER TIME ZONE CORRECTION IN HOURS	TIME ZONE CORRECTION: (+) 5 (W) E	

STEP	PROMPT	PROCEDURE	SET 1	SET 2	SET 3
10	MN W TIME: 00.00000	ENTER MEAN WATCH TIME	▶ HOURS 8 MINUTES 12 SECONDS 11	▶ HOURS 8 MINUTES 30 SECONDS 26	▶ HOURS 8 MINUTES 42 SECONDS 18
11	REFR(TBL1, mil): 0.00	ENTER REFRACTION (TABLE 1b)	ENTER AS + .48 MILS	ENTER AS + .43 MILS	ENTER AS + .39 MILS
12	HZ < SUN: 0.000	ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO SUN	HORIZONTAL ANGLE ▶ (MILS): 1436.2	HORIZONTAL ANGLE ▶ (MILS): 1472.6	HORIZONTAL ANGLE ▶ (MILS): 1503.0
13	VA: 0.000	ENTER VERTICAL ANGLE TO SUN	VERTICAL ANGLE (MILS): ▶ 512.8	VERTICAL ANGLE (MILS): ▶ 564.7	VERTICAL ANGLE (MILS): ▶ 606.5
14	ASTRO AZ/MK: 0.000	RECORD ASTRONOMIC AZIMUTH TO AZIMUTH MARK	ASTRONOMIC AZIMUTH (MILS): 0172.678	ASTRONOMIC AZIMUTH (MILS): 0172.687	ASTRONOMIC AZIMUTH (MILS): 0172.595
15	ADD SETS REQD(Y/N):	ENTER Y OR N			
16	4TH/5TH ORDER(4/5): 0	ENTER 4 OR (5)			
17	MN ASTRO AZ: 0.000	RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK	MEAN ASTRONOMIC AZIMUTH (MILS) 0172.654		
18	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE: 14		
19	GRID AZ/MK: 0.000	RECORD GRID AZIMUTH TO AZIMUTH MARK	GRID AZIMUTH (MILS): 0166.687		
20	END OF MSN (Y/N):	ENTER Y OR N			

SAMPLE

REMARKS

DA FORM 5594-R, DEC 86

d. The procedures for computing DA Form 5595-R are shown in Table 7-3.

Table 7-3. **Instructions on computing DA Form 5595-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 5. Enter the survey module, and call Program 5.
2	The display prompts ALTITUDE METHOD. The PROCEDURE column is blank. Press the END LINE key.
Note. At the completion of each step, press the END LINE key.	
3	The display prompts USE SUN (Y/N): The procedure is ENTER N.
4	The display prompts LAT(-:S): 0.0000000. The procedure is ENTER LATITUDE OF STATION. The latitude is entered with the value of the degrees followed by a decimal and the value of the minutes and the seconds (DD.MMSS). If latitude is in the Southern Hemisphere, enter the value as a negative. Record the latitude displayed in the LATITUDE: block in the DATA RECORD section.
5	The display prompts LG(-:W): 0.0000000. The procedure is ENTER LONGITUDE OF STATION. The longitude is entered in the same manner as the latitude (DD.MMSS). If longitude is in the Western Hemisphere, enter the value as a negative. Record the longitude displayed in the LONGITUDE: block in the DATA RECORD section.
6	The display prompts ^DECLN (TBL 2/10A). Press the END LINE key. The prompt will change to (DD.MMSSS): 0.00000. The procedure is ENTER DECLINATION OF STAR (FM 6-300, TABLE 10A). Extract the declination from the ephemeris, and enter it as indicated (DD.MMSSS). Record the declination in the DECLINATION: block of the DATA RECORD section.
7	The display prompts REFR(TBL1,mil): 0.00. The procedure is ENTER REFRACTION(TABLE 1b). Extract the data from the ephemeris, and enter the value as indicated. Record the value in the ENTER AS +: block in the DATA RECORD section.
8	The display prompts HZ < STAR: 0.000. The procedure is ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO STAR. Enter the mean horizontal angle for set one. Record the mean horizontal angle in the HORIZONTAL ANGLE (MILS): block in the DATA RECORD section.
9	The display prompts VA: 0.000. The procedure is ENTER VERTICAL ANGLE TO STAR. Enter the vertical angle to the sun for set one.
10	The display prompts STAR EAST (Y/N): The procedure is ENTER Y OR N. This step wants to know if the star being observed is in the east or west. To determine if the star is east or west, add the horizontal angle to the star to the approximate azimuth to the azimuth mark to determine the approximate azimuth to the star. East is 0 to 3,200 mils, and west is 3,200 to 6,400 mils.
11	The prompt is ASTRO AZ/MK: 0.000. The procedure is RECORD THE ASTRONOMIC AZIMUTH TO AZIMUTH MARK. Record the azimuth for set one in the ASTRONOMIC AZIMUTH (MILS): block in the DATA RECORD section.
12	The display prompts ADD SETS REQD(Y/N): The procedure is ENTER Y OR N. Enter Y (yes) since this is just the first set. The program will return to step 7 when this step is answered Y. Repeat steps 7 through 12 for sets two and three. Answer no (N) to the prompt in step 12 of the third set. The program will then go to step 13.
13	The display prompts 4TH/5TH ORDER(4/5): The procedure is ENTER 4 OR 5. Enter the number that corresponds to the accuracy of the survey being performed.
14	The display prompts MN ASTRO AZ: 0.000. The procedure is RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK. Record the azimuth in the MEAN ASTRONOMIC AZIMUTH (MILS): block in the DATA RECORD section. This is a **true** azimuth.

Table 7-3. **Instructions on computing DA Form 5595-R (continued)**

STEP	INSTRUCTION
15	The display prompts GRID ZONE: 00. The procedure is ENTER GRID ZONE. Enter the grid zone in which the observer is located. It can be read from the marginal information of a map of the area. Record the grid zone in the GRID ZONE: block in the DATA RECORD section.
16	The display prompts GRID AZ/MK: 0.000. The procedure is RECORD GRID AZIMUTH TO AZIMUTH MARK. Record the azimuth in the GRID AZIMUTH (MILS): block in the DATA RECORD section.
17	The display prompts END OF MSN (Y/N): The procedure is ENTER Y OR N. If the mission is complete, enter Y. The program then prompts SURVEY PGM MENU REV1. If you enter N, the program returns to step 16.

Figure 7-44. **Sample DA Form 5595-R**

COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD, STAR (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC

COMPUTER SSG ANDERSON	NOTEBOOK REFERENCE 2-20	DATE 21 FEB 88
CHECKER SSG PENA	AREA FT. SILL, OK	SHEET 1 OF 1 SHEETS

NOTES: 1 STEP 10 SEE BACK OF FORM TO DETERMINE IF STAR IS EAST OR WEST
2 IF STEP 12 IS Y PROGRAM GOES TO STEP 7
3 IF STEP 12 IS N PROGRAM GOES TO STEP 13
4 SEE BACK OF FORM FOR REJECTION CRITERIA
5 ENTER FIELD DATA IN BLOCKS MARKED ▶

DATA RECORD

AZIMUTH MARK: TOM	APPROXIMATE AZIMUTH TO AZIMUTH MARK (MILS): 4300
STATION: BN SCP	TEMPERATURE: 30°F
STAR NAME: REGULUS	STAR NUMBER, TABLE 9: 36
LATITUDE	34° 39' 49" N
LONGITUDE	98° 24' 18" W
DECLINATION	12° 01' 28"

INSTRUCTIONS

STEP	PROMPT		PROCEDURE	SET 1	SET 2	SET 3
1			CALL PROGRAM 5			
2	ALTITUDE METHOD					
3	USE SUN (Y/N):		ENTER N			
4	LAT(:S):	0.0000000	ENTER LATITUDE OF STATION			
5	LG(:W):	0.0000000	ENTER LONGITUDE OF STATION			
6	^DECLN (TBL 2 10A) (DD MMSSS):	0.00000	ENTER DECLINATION OF STAR (FM 6-300 TABLE 10A)			
7	REFR (TBL 1 mil):	0.00	ENTER REFRACTION (TABLE 1b)	ENTER AS - .63 MILS	ENTER AS - .63 MILS	ENTER AS - .61 MILS
8	HZ<STAR:	0.000	ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO STAR	HORIZONTAL ANGLE (MILS) 3699.8	HORIZONTAL ANGLE (MILS) 3701.8	HORIZONTAL ANGLE (MILS) 3704.2
9	VA:	0.000	ENTER VERTICAL ANGLE TO STAR	VERTICAL ANGLE (MILS) 450.3	VERTICAL ANGLE (MILS) 453.2	VERTICAL ANGLE (MILS) 456.4
10	STAR EAST (Y N):		ENTER Y OR N			
11	ASTRO AZ MK:	0.000	RECORD ASTRONOMIC AZIMUTH TO AZIMUTH MARK	ASTRONOMIC AZIMUTH (MILS) 4347.718	ASTRONOMIC AZIMUTH (MILS) 4347.792	ASTRONOMIC AZIMUTH (MILS) 4347.698
12	ADD SETS REQD(Y N):		ENTER Y OR N			
13	4TH 5TH ORDER(4 5):	0	ENTER 4 OR ⑤			
14	MN ASTRO AZ:	0.000	RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK	MEAN ASTRONOMIC AZIMUTH (MILS): 4347.736		
15	GRID ZONE:	00	ENTER GRID ZONE	GRID ZONE: 14		
16	GRID AZ MK:	0.000	RECORD GRID AZIMUTH TO AZIMUTH MARK	GRID AZIMUTH (MILS): 4341.720		
17	END OF MSN (Y N)		ENTER Y OR N			

SAMPLE

REMARKS

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7-32. FIELDWORK

The fieldwork necessary for determining azimuth by the altitude method includes measuring the horizontal and vertical angles and recording the time of the observation and the temperature. The temperature should be recorded at the beginning of the observation and again when the observation has been completed. The mean temperature is used in the computation. The watch used in the observation should be checked with radio time signals to determine the watch correction. The time signals for the Western Hemisphere are broadcast by radio station WWV at Fort Collins, Colorado, at frequencies 2.5, 5, 10, 15, 20, and 25 megahertz (MHz). Signals for the Eastern Hemisphere, broadcast by station JJY at Koganei, Japan, can be received at frequencies of 2.5, 5, 10, or 15 MHz. Each minute during the day, a tone is sounded and the exact time of the tone is announced. The voice announcement begins about 10 seconds before the time signal with the words "At the tone, the time will be (time), universal coordinated time." This announcement is followed by the sounding of the tone. The time announced is universal time. Set the minute hand of the watch to be used exactly to the time signal. Make no attempt to set the second hand. Determine the watch correction by noting the position of the second hand at the time of the tone. Then record as the watch correction the number of seconds at which the second hand was positioned before or after the 0 second mark, along with the proper sign. The procedure for time signals elsewhere may vary slightly from those given above.

7-33. EFFECT OF ERRORS

Particular attenlion should be paid to secure the best available data. Roughly, an error of 1 minute in latitude, declination, or altitude may cause a corresponding error of more than 0.5 mil in azimuth. Time is less important in a sun observation because an error of 5 minutes cannot change the azimuth more than 0.03 mil. For star observation, only the date is required.

7-34. DETERMINATION OF FINAL AZIMUTH

a. Technique for Determining Azimuth for Fifth-Order Survey. To determine azimuth for a fifth-order survey by using the T16 theodolite, observe and compute at least three sets of observations (each set, one position). Mean the azimuths, and reject any set that varies from the mean by more than 0.3 mil. At least two sets must be meaned to determine final azimuth.

b. Technique for Determining Azimuth for Fourth-Order Survey. To determine azimuth for a fourth-order survey by using the T2 theodolite, observe and compute at least three sets of observations (each set, one position). Mean the three azimuths, and reject any set that varies from the mean by more than 0.150 mil. At least two sets must be meaned to determine the final azimuth.

Section VI

ARTY ASTRO OBSERVATION METHOD (SUN)

In the arty astro method of determining azimuth, two sides of the PZS triangle (Figure 7-21), the polar distance and colatitude, and one angle are used to solve for the azimuth angle. This computation is based on the time of the observation. The problem of determining azimuth consists of taking a horizontal reading at the observer's station between the mark and sun, the azimuth of which can be computed. The simple operation of subtracting this horizontal angle from the computed azimuth of the sun gives the desired azimuth to the mark.

7-35. POSITION OF SUN

For observations by the arty astro method, the sun must not be wilhin 1 hour of the observer's meridian. For best results, the sun should be above 175 mils in ahitude. Unless an elbow telescope or the card method is used, the sun must be below 800 mils in altitude.

7-36. ARTY ASTRO (SUN/STAR) COMPUTATIONS

a. Arty astro is computed on DA Form 7285-R (Computation of Arty Astro (Sun/Star) (BUCS) (Figure 7-45). This form is basically the same as other forms used for computations with the BUCS. The administrative data are recorded on the bottom instead of on the top of the page. The left side of the form show the instructions for use of the form, and the right side shows the data record where all field work, known data, and computed data are recorded. One complete observation can be recorded and computed on this form.

b. The instructions for computing DA Form 7285-R are shown in Table 74. Program 13 uses the "electronic ephemeris," which allows the obsemation to be computed by using the internal time module of the BUCS to determine the date and time for each obsavation. However, the date and time can be entered manually. If the internal clock is used, each set has to be computed before the next reading can be made.

Table 7-4. **Instructions for computing DA Form 7285-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 13. Enter the survey module, and recall Program 13. If the internal clock is to be used, ensure that the correct date and time have been entered into the BUCS.
2	The display prompts ARTY ASTRO. The procedure is to press the END LINE key.
Note. At the completion of each step, press the END LINE key.	
3	The display prompts SPHEROID CODE: 0. The procedure is ENTER SPHEROID CODE. Enter the spheroid code for your area. The name of the spheroid can be taken from a map of the area. Match the name to one of the codes listed on the form, and enter that code. Record the name and number of the spheroid in the SPHEROID: block in the DATA RECORD section.
4	The display prompts EAST: 0.00. The procedure is ENTER EASTING. Enter the easting location of the observer. Record the displayed easting in the EAST: block in the DATA RECORD section.
5	The display prompts NORTH: 0.00. The procedure is ENTER NORTHING. Enter the northing location of the observer. Record the displayed northing in the NORTH: block in the DATA RECORD section.
6	The display prompts LATITUDE (N/S): The procedure is ENTER N OR S. If the observer is in the Northern Hemisphere, enter N; in the Southern Hemisphere, enter S.
7	The display prompts GRID ZONE: 00. The procedure is ENTER GRID ZONE. The grid zone number can be found on a map of the area. Record the grid zone in the GRID ZONE: block in the DATA RECORD section.
8	The display prompts 4TH/5TH ORDER(4/5): The procedure is ENTER 4 OR 5. Enter the appropriate number for the order of survey being performed.
9	The display prompts USE SUN (Y/N): The procedure is ENTER Y OR N.
9a	This step is used only if step 9 is answered N (no). The display prompts STAR #: The procedure is ENTER STAR NO: The star number can be extracted from the reverse of the form. (See figure 7-46.) Record the star number in the STAR NO: block in the DATA RECORD section.

Table 7-4. **Instructions for computing DA Form 7285-R**

STEP	INSTRUCTION
10	The display prompts TIME MODULE (Y/N): The procedure is ENTER Y OR N. If the time module is being used, enter Y (yes). Remember that accurate date and time must be set in the BUCS if this method is to be used.
11	The display prompts TIME ZONE LETTER: The procedure is ENTER TIME ZONE LETTER. The time zone letter is taken from the graph on the reverse of the form. (See Figure 7-46.) Enter the graph in the left column with the longitude of the observer (east or west) to the nearest degree. Locate the argument that is closest to the longitude of the observer, and read the letter in the right column of the graph. Record the letter in the TZ LTR: block in the DATA RECORD section.
12	The display prompts DAYLT SV TIME(Y/N): The procedure is ENTER Y OR N. Enter Y or N to indicate if your local time includes a correction for daylight saving time.
13	The display prompts (D)RDG AZMK: 0.000. The procedure is ENTER DIRECT RDG TO AZMK. Enter the initial circle setting of the instrument. Record the reading in the (D) RDG AZMK: block in the DATA RECORD section.
14	The display prompts PRESS END LINE AT TIP: The procedure is PRESS END LINE. This step is used only when the internal timer is being used for the date and time of observation. If date and time are to be entered manually, this step will be bypassed.
15	The display prompts OBS DATE (DD.MMYY): The procedure is RECORD AND/OR ENTER DATE. If the internal timer is being used, BUCS gives you the date and you record it in the DATE: block in the DATA RECORD section. If the date is being entered manually, record it in the space provided and enter it into the BUCS. Enter the date with the first two digits being the day of the month followed by a decimal and the next two digits being the month and the last two digits being the year (DD.MMYY). If the month is less than 10, enter the number with a zero in front (01, 02, 03).
16	The display prompts OBS TIME (HH.MMSS): The procedure is RECORD AND/OR ENTER TIME. If the internal timer is being used, the BUCS displays the time and you record it in the TIME: block in the DATA RECORD section. If time is entered manually, you record the time in the space and enter it into the BUCS. Enter the time with the first two digits being the hours followed by a decimal. The next two digits are the minutes and are followed by two digits for the seconds. If the value of the minutes is less than 10, add a zero in front of the number. If the value of the seconds is less than 10, add a zero in the same manner.
16a	The display prompts TRL/LDG/CTR(TR/L/C): The procedure is ENTER TR, L, OR C. This step asks you to describe the method of observation used. Was the observation made with pointings to the trailing edge (TR), leading edge (L), or center (C) of the celestial body.
17	The display prompts HZ RDG (D): 0.000. The procedure is ENTER (D) HZ READING. Enter the horizontal reading to the celestial body for set 1. When you enter the data in this step and press the END LINE key, the program will go back to step 16 and prompt you for the OBS TIME of set 2. Following the procedures used in steps 16, 16a, and 17, enter the data for sets two and three. If you are using the internal clock, the BUCS will prompt PRESS END LINE AT TIP. Record the horizontal reading in the HZ RDG (D): block in the DATA RECORD section.
18	The display prompts GRID AZ/MK: 0.000. The procedure is RECORD GRID AZIMUTH. The BUCS displays the desired azimuth at this point. Record it in the GRID AZ: block of the DATA RECORD section.
19	The display prompts END OF MSN (Y/N): The procedure is ENTER Y OR N. If this step is answered N, the program returns to step 18. If it is answered Y, the program will return to SURVEY PGM MENU REV1.

Figure 7-45. **Sample DA Form 7285-R**

COMPUTATION OF ARTY ASTRO (SUN/STAR) (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER: SSG ANDERSON	NOTEBOOK REFERENCE: X-3	DATE: 29 JAN 88
CHECKER: SSG PENA	AREA:	SHEET 1 OF 1 SHEETS

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	STATION:	AZ MARK:
1		CALL PROGRAM	STAR NAME: SUN	APPROX AZ TO AZMK: 0500
2	ARTY ASTRO		SPHEROID: CLARK #1 1866	
3	SPHEROID CODE: 0 1 = CLARKE 1866; 2 = INTERNATIONAL; 3 = CLARKE 1880; 4 = EVEREST; 5 = BESSEL; 6 = AUSTRALIAN; 7 = WORLD GEO SYS-72; 8 = GRS-80;	ENTER SPHEROID CODE		REMARKS: REVERSE READING ON AZMK 3201.1
4	EAST: 0.00	ENTER EASTING	EAST: 554435.93	
5	NORTH: 0.00	ENTER NORTHING	NORTH: 3835672.12	
6	LATITUDE (N/S):	ENTER (N) OR S		
7	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE: 14	NOTES:
8	4TH/5TH ORDER (4/5):	ENTER 4 OR (5)		1. IN STEP 9, Y RESPONSE RETURNS YOU TO STEP 10.
9	USE SUN (Y/N):	ENTER (Y) OR N		2. IN STEP 9, N RESPONSE RETURNS YOU TO STEP 9a.
9a	STAR #:	ENTER STAR NO	STAR NO:	3. IN STEP 10, Y RESPONSE ALLOWS ACCESS TO INTERNAL TIMER AT TIP.
10	TIME MODULE (Y/N):	ENTER Y OR (N)		4. IN STEP 10 IF RESPONSE IS N, SKIP STEP 14 AND ENTER LOCAL DATE AND TIME IN STEPS 15 AND 16.
11	TIME ZONE LETTER:	ENTER TIME ZONE LETTER	TZ LTR: S	5. STEP 16a WILL APPEAR FOR SUN OBSERVATIONS ONLY. TR = TRAILING EDGE OF SUN. L = LEADING EDGE OF SUN. C = CENTER OF SUN.
12	DAYLT SV TIME (Y/N):	ENTER Y OR N		6. SEE BACK OF FORM FOR TIME ZONE LETTER AND STAR NUMBER.
13	(D)RDG AZMK: 0.000	ENTER DIRECT RDG TO AZMK	(D) RDG AZMK: 0001.0	

STEP	PROMPT	PROCEDURE	SET NO 1	SET NO	SET NO
(14)	PRESS ENDLINE AT TIP:	PRESS END LINE			
15	OBS DATE (DD.MMYY):	RECORD AND/OR ENTER DATE	DATE: dd 29. mm 01 yy 88	DATE: dd . mm yy	DATE: dd . mm yy
16	OBS TIME (HH.MMSS):	RECORD AND/OR ENTER TIME	YEAR: hh 07. mm 43 ss 53	YEAR: hh 07. mm 44 ss 33	YEAR: hh 07. mm 45 ss 35
16a	TRL/LDG/CTR (TR/L/C):	ENTER TR, L OR (C)			
17	HZ RDG (D): 0.000	ENTER (D) HZ READING	HZ RDG (D) (MILS): 1510.1	HZ RDG (D) (MILS): 1511.8	HZ RDG (D) (MILS): 1514.4
18	GRID AZ/MK: 0.000	RECORD GRID AZIMUTH	GRID AZ (MILS): 0491.238		
19	END OF MSN (Y/N):	ENTER (Y) OR N			

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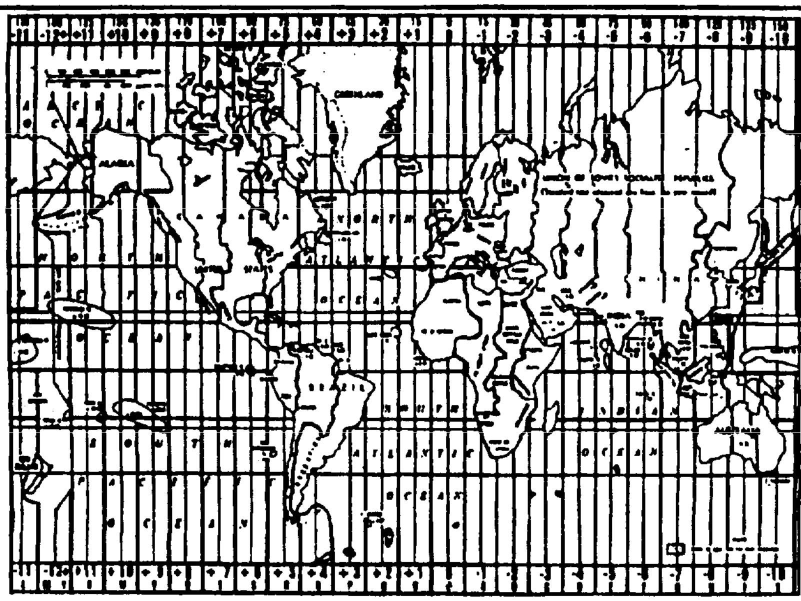
Figure 7-46. **Reverse of DA Form 7285-R**

TIME ZONE CHART



LONGITUDE OF MERIDIAN	TIME ZONE LETTER
EAST LONGITUDE	
0	Z
15	A
30	B
45	C
60	D
75	E
90	F
105	G
120	H
135	I
150	K
165	L
180	M
WEST LONGITUDE	
0	Z
-15	N
-30	O
-45	P
-60	Q
-75	R
-90	S
-105	T
-120	U
-135	V
-150	W
-165	X
-180	Y

ALPHABETICAL STAR LIST

Star	No.	
ACAMAR	12	
ACHERNAR	9	
ACRUX	42	*
ADHARA	26	
ALDEBARAN	15	*
ALHENA	24	
ALIOTH	45	
ALKAID	48	
AL NA'IR	71	
ALNILAM	20	
ALNITAK	21	
ALPHARD	35	
ALPHECCA	55	
ALPHERATZ	1	*
ALTAIR	66	*
ANKAA	4	
ANTARES	57	*
ARCTURUS	51	*
ATRIA	58	
AVIOR	32	
BELLATRIX	18	
BETA HYDRUS	3	
BETELGEUSE	22	
CANOPUS	23	
CAPELLA	17	
CAPH	2	
CASTOR	28	
DENEB	68	
DENEBOLA	39	
DIPHDA	6	
DSCHUBBA	56	
DUBHE	38	
ELNATH	19	
ELTANIN	62	
ENIF	70	
FOMALHAUT	72	
GACRUX	43	
GAMMA CASSIOPEIAE	7	
GAMMA VELORUM	31	
GIENAH	41	
HADAR	49	
HAMAL	11	
KAUS AUSTRALIS	63	
KOCHAB	54	*
MARKAB	73	
MENKAR	13	
MENKENT	50	
MERAK	37	
MIAPLACIDUS	34	
MIMOSA	44	
MIRFAK	14	
MIZAR	46	
NUNKI	65	
NU	69	
PEACOCK	67	
PHECDA	40	
POLARIS	10	*
POLLUX	30	
PROCYON	29	
RASALHAGUE	61	
REGULUS	36	*
RIGEL	16	
RIGIL KENTAURUS	52	
RUCHBAH	8	
SABIK	59	
SCAULA	60	
SCHEDAR	5	
SIRIUS	25	*
SPICA	47	
SUHAIL	33	
VEGA	64	
WEZEN	27	
ZEBENELGENUBI	53	

* INDICATES THE PREFERRED STARS FOR HASTY ASTRO.

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Section VII

ARTY ASTRO METHOD (STAR)

The arty astro method can be used with observations on Polaris or on east-west stars. Used with Polaris, this method yields the most accumte azimuths. When the arty astro method is used with east-west stars, the requirement for accurate time is a disadvantage, but the method can be used when no stars meet the position requirements for the altitude method. Computation of arty astro star is the same as the computations for arty astro sun. The only differences are steps 9 and 9a of the form. Step 9 will be amwered N (no). Step 9a asks for the star number which can be found on the reverse of the computation form.

7-37. POSITION OF STARS

The star chart is used for selecting east-west stars for arty astro observations. Polaris should be observed anytime it is visible. Best results are obtained when it is above 175 mils in altitude to minimize the effects of refraction.

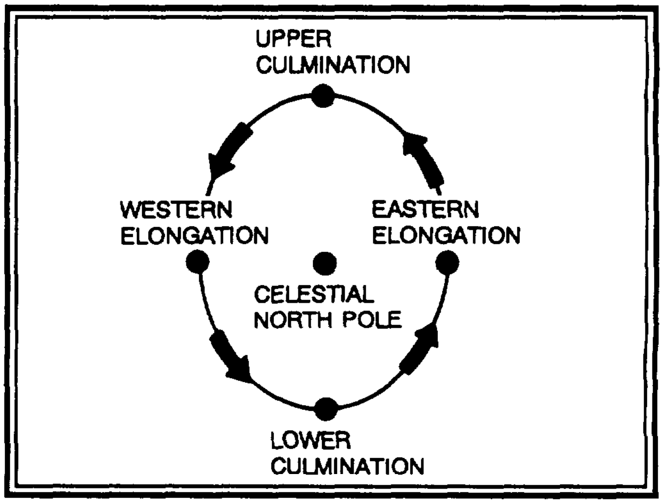
7-38. OBSERVATION AND IDENTIFICATION OF POIARIS

a Polaxis appeam to move in a small, elliptical, counterclockwise orbit about the celestial North Pole. Because Polaris stays so close to the celestial North Pole, it is visible throughout the night in most of the Northern Hemisphem. When the Polaris local hour angle is 0 or 12 hours, the star is said to be in its upper or lower culmination, respectively. (See Figure 7-47.) When the Polaris local hour angle is 6 or 18 hours, the star is said to be in its western or eastern elongation, respectively. The small orbit of Polaris results in a very slow apparent motion, so the star can be observed at any point in its orbit. The least chance of error in tracking, however, will occur when the star is in elongation.

b. To help identify Polaris, set the latitude of the observer's position as a vertical angle on the observing instrument and point the telescope north. The line of sight will be near the celestial North Pole, and since Polaris is very near the pole, the star should appear in the field of view. If the star is in elongation, its altitude will equal the obsewer's latitude. When Polaris is moving fmm eastern to weatem elongadou its altitude is greater than the latitude of the observer. When Polaxis is moving tlom weatem to eastern elongatio~ its alitude is less than the latitude of the obsewer.

c When the telescqe is diwted at Polaris, the observer will see two other stars nearby that are not visible to the naked eye. However, Polaris will be the only star visible when the cross hairs are lighted.

Figure 7-47. **Orbit of Polaris**



Section VIII

POLARIS TABULAR METHOD

The computational methods discussed in Sections V, VI, and VII are satisfactory for both fourth-order and fifth-order work. The Polaris tabular method of computation will achieve reliable fourth- and fifth-order accuracies. The Polaris tabular method uses the azimuths to Polaris that are tabulated in FM 6-300, Table 12. These azimuths are corrected by factors related to the observer's latitude and the date and time of observation.

7-39. COMPUTATION OF AZIMUTH

DA Form 5598-R (Computation of Astronomic Azimuth by Polaris Tabular Method (BUCS)) (Figure 7-48) is used to compute astronomic azimuth by the Polaris tabular method with a BUCS. (A reproducible copy of this form is included at the back of this book.)

7-40. DA FORM 5598-R

a. The top portion of DA Form 5598-R is set up basically the same as the other BUCS forms you have used. The top six blocks are for administrative informstion. Below the administrative data you will find notes that refer to the operation of the BUCS in this program. Under the notes on the left side of the form, you wilt find specific instructions on the use of this form. To the right of the instructions, you will find the data remd where all known, field, and computed data are recorded. Blocks that are marked with a bold arrow are where field data are entered. One complete obsewation can be remrded and computed on each form (three sets).

b. The instructions for computing DA Form 5598-R are shown in Table 7-5.

Table 7-5. Instructions on computing DA Form 5598-R

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 8. Enter the survey module, and call Program 8.
2	The display prompts POLARIS TAB METHOD. There is no procedure. Press the END LINE key.
Note. At the completion of each step, press the END LINE key.	
3	The display prompts LAT(-:S): 0.0000000. The procedure is ENTER LATITUDE OF STATION. Enter the value of the observer's latitude. If the observer is in the Southern Hemisphere, enter the latitude as a negative. Enter the value in the format HH.MMSS. Record the latitude in the LATITUDE: block in the DATA RECORD section.
4	The display prompts LONG(-:W): 0.0000000. The procedure is ENTER LONGITUDE OF STATION. Enter the value of the observer's longitude. If the observer is in the Western Hemisphere, enter the value as a negative. Enter the value in the format HH.MMSS. Record the longitude in the LONGITUDE: block in the DATA RECORD section.
5	The display prompts TZ CORR (-:E): 00. The procedure is ENTER TIME ZONE CORRECTION IN HOURS. Enter the correction in hours from local time to Greenwich time. This correction can be obtained from the world time zone map. If the observer is east of the Greenwich meridian, the correction is entered as a negative. Record the time zone correction, in hours, in the TIME ZONE CORRECTION BLOCK in the DATA RECORD section.
6	The display first prompts ^SIDRL TIME (TBL 2). Press the END LINE key. The display prompts (HH.MMSSS): 00.00000. The procedure is ENTER SIDEREAL TIME (FM 6-300, TABLE 2). Extract the appropriate data from FM 6-300, and enter it in the HH.MMSSS format. Record the sidereal time in the SIDEREAL TIME: block in the DATA RECORD section.

Table 7-5. **Instructions on computing DA Form 5596-R (continued)**

STEP	INSTRUCTION
7	The display prompts WC(-:F;.MMSS): 0.0000. The procedure is ENTER WATCH CORRECTION. Enter the correction from the timepiece being used and the accurate time source. If the timepiece is fast, enter the correction as a negative. Record the watch correction time in the WATCH CORRECTION: block of the DATA RECORD section.
8	The display prompts MN W TIME: 00.00000. The procedure is ENTER MEAN WATCH TIME. Enter the mean time of observation for the first set. Enter it in the format HH.MMSS. Record this time in the time blocks in hours, minutes, and seconds.
9	The display prompts HZ < STAR: 0.000. The procedure is ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO STAR. Enter the horizontal angle for set one. Record the horizontal angle in the HORIZONTAL ANGLE (MILS): block in the DATA RECORD section.
10	The display prompts (LST)HRS:_MIN:_._. The procedure is RECORD LOCAL SIDEREAL TIME. Record, in minutes and seconds, the value displayed in the time blocks in the DATA RECORD section on the form. Use these data to extract the data for steps 11, 12, and 13 from FM 6-300, Table 12.
11	The display prompts B0 (TBL 12): 00.0. The procedure is ENTER B0(+/-). Enter the value of B0 that was extracted from FM 6-300.
12	The display prompts B1 (TBL 12): 0.0. The procedure is ENTER B1(+/-). Enter the value of B1 that was extracted from FM 6-300.
13	The display prompts B2 (TBL 12): 0.0. The procedure is ENTER B2(+/-). Enter the value of B2 that was extracted from FM 6-300.
14	The display prompts ASTRO AZ/MK: 0.000. The procedure is RECORD ASTRONOMIC AZIMUTH TO AZIMUTH MARK. Record the value displayed in the ASTRONOMIC AZIMUTH (MILS): block in the DATA RECORD section of the form.
15	The display prompts ADD SETS REQD(Y/N): The procedure is ENTER Y OR N. When this step is answered Y (yes), the program returns to step 8. Answer this step Y until all three sets have been computed. After the third set is completed, answer this step N (no). When this step is answered N, the program proceeds to step 16.
16	The display prompts 4TH/5TH ORDER(4/5): 0. The procedure is ENTER 4 OR 5. Enter whether the observation is being performed to fourth- or fifth-order accuracy.
17	The display prompts MN ASTRO AZ: 0.000. The procedure is RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK. Record the data displayed in the MEAN ASTRONOMIC AZIMUTH (MILS): block in the DATA RECORD section. These data are the true azimuth to the azimuth mark.
18	The display prompts GRID ZONE: 00. The procedure is ENTER GRID ZONE. Enter the observer's grid zone. This information can be taken from a map of the area. Record the grid zone in the GRID ZONE: block in the DATA RECORD section.
19	The display prompts GRID AZ/MK: 0.000. The procedure is RECORD GRID AZIMUTH TO AZIMUTH MARK. Record the value displayed in the GRID AZIMUTH (MILS): block in the DATA RECORD section. This is the grid azimuth to the azimuth mark.
20	The display prompts END OF MSN (Y/N): The procedure is ENTER Y OR N. If this step is answered N, the program will return to step 19. If this step is answered Y, the program returns to SURVEY PGM MENU REV1.

Figure 7-48. **Sample DA Form 5598-R**

COMPUTATION OF ASTRONOMIC AZIMUTH BY POLARIS TABULAR METHOD (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC

COMPUTER SSG ANDERSON	NOTEBOOK REFERENCE 2-3	DATE 14 APR 88
CHECKER SSG PENA	AREA FT. SILL, OK	SHEET 1 OF 1 SHEETS

NOTES: 1 IF STEP 15 IS Y, PROGRAM GOES TO STEP 8
2 IF STEP 15 IS N, PROGRAM GOES TO STEP 16
3 SEE BACK OF FORM FOR REJECTION CRITERIA
4 ENTER FIELD DATA IN BLOCKS MARKED ▶

INSTRUCTIONS			DATA RECORD		
STEP	PROMPT	PROCEDURE	AZIMUTH MARK: AZ MK	APPROXIMATE AZIMUTH TO AZIMUTH MARK (MILS) 4300	
1		CALL PROGRAM 8			
2	POLARIS TAB METHOD		STATION: SCP 5		
3	LAT(-:S): 0.0000000	ENTER LATITUDE OF STATION	LATITUDE: 0 34 ° 39 ' 48 " (N) S		
4	LG(-:W): 0.0000000	ENTER LONGITUDE OF STATION	LONGITUDE: 0 98 ° 24 ' 20 " E (W)		
5	TZ CORR (:E): 00	ENTER TIME ZONE CORRECTION IN HOURS	TIME ZONE CORRECTION: 0 6 (W) E		
6	SIDRL TIME (TBL 2) (HH MMSSS): 00.00000	ENTER SIDEREAL TIME (FM 6-300, TABLE 2)	SIDEREAL TIME: HOURS 13, MINUTES 29, SECONDS 32		
7	WC(-:F:,MMSS): 0.0000	ENTER WATCH CORRECTION	WATCH CORRECTION: (SLOW) (FAST) HOURS 0, MINUTES 00, SECONDS 00		
			SET 1	SET 2	SET 3
8	MN W TIME: 00.00000	ENTER MEAN WATCH TIME	HOURS MINUTES SECONDS ▶ 20 56 42	HOURS MINUTES SECONDS ▶ 21 01 47	HOURS MINUTES SECONDS ▶ 21 10 21
9	HZ< STAR: 0.000	ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO STAR	HORIZONTAL ANGLE (MILS): ▶ 2055.6	HORIZONTAL ANGLE (MILS): ▶ 2055.5	HORIZONTAL ANGLE (MILS): ▶ 2055.6
10	(LST)HRS: __ MIN: __.__	RECORD LOCAL SIDEREAL TIME	HOURS 9, MINUTES 57.0	HOURS 10, MINUTES 02.1	HOURS 10, MINUTES 10.7
11	B (TBL 12): 00.0	ENTER B (+)	B -42.6	B -42	B -41.2
12	B (TBL 12): 0.0	ENTER B (+)	B -.1	B -.2	B -.2
13	B (TBL 12): 0.0	ENTER B (+)	B +.1	B +.1	B +.1
14	ASTRO AZ/MK: 0.000	RECORD ASTRONOMIC AZIMUTH TO AZIMUTH MARK	ASTRONOMIC AZIMUTH (MILS): 4329.054	ASTRONOMIC AZIMUTH (MILS): 4329.298	ASTRONOMIC AZIMUTH (MILS): 4329.552
15	ADD SETS REQD(Y/N):	ENTER Y OR N		REMARKS	
16	4TH/5TH ORDER(4/5): 0	ENTER 4 OR (5)			
17	MN ASTRO AZ: 0.000	RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK	MEAN ASTRONOMIC AZIMUTH (MILS): 4329.291		
18	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE: 14		
19	GRID AZ/MK: 0.000	RECORD GRID AZIMUTH TO AZIMUTH MARK	GRID AZIMUTH (MILS): 4323.281		
20	END OF MSN (Y/N):	ENTER Y OR N			

SAMPLE

DA FORM 5598-R, DEC 86

Section IX

SIMULTANEOUS OBSERVATIONS

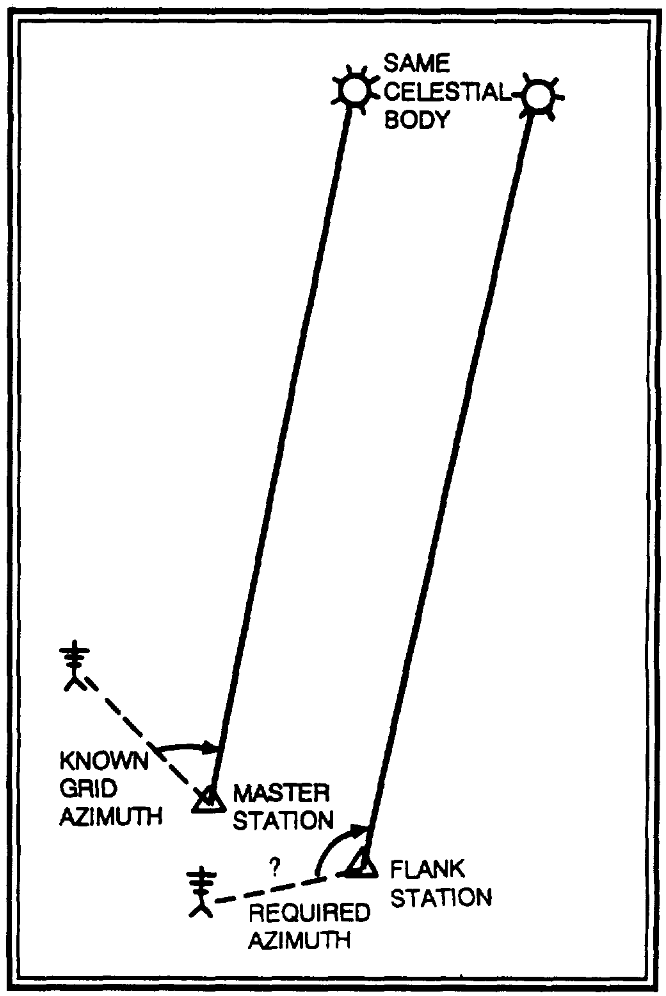
Simultaneous observations of a celestial body provide a quick method of transmitting direction over great distances without time-consuming computations. This method is ideally suited to the needs of the artillery since many units ean be placed on common directional control in a very short period of time. Because of the great distance of celestial bodies from the earth, the azimuths to a celestial body at any instant from two or more close points on the earth are approximately parallel. The difference in the azimuth is caused by the fhct that the azimuths at different points are measured with reapcet to different horizontal planes.

7-41. PROCEDURES FOR SIMULTANEOUS OBSERVATIONS

a. Flank stations are established at points where azimuth is required. A master station is established at a point from which the grid azimuth to an azimuth mark is known or has been computed. (See Figure 7-49.) (An assumed azimuth may be used.) Both the flank and master stations should be points that are easily identified on a map and provide the best possible communications.

b. An observing instrument is set up at the master station and oriented on the azimuth mark. An observing instrument is set up at eaeh flank station and oriented on a reference mark to which the azimuth is required. (See Figure 7-50.) The observing instrument at the master station must be of equal order as, or higher order than the instrument used at the flank station. A prominent celestial body is seleeted by the obsemerat the master station and identified to the observer at each flank station. On command, an assistant will key the microphone so the observer can transmit information at the same time he observes a celestial body. A headset; loudspeaker, orotherdevice must be provided for the observer at each flank station so he ean hear instructions from the obsewer at the master station. When all stations are ready to obseme, the master station obsemer announces **READY, START TRACKING** (countdown), **TIP.** Each flank station observer, when observing a star, places the vertical cross hair of his instrument on the star and keeps it there by using the horizontal recording motion tangent screw. When observing the sun, he centers the sun inside the solar circle. He keeps it centered by using the tangent screws. The master station observer announces **TIP** at the instant the star is at the intersection of the cross hairs or when the sun is centered in the solar circle. The observer at the master station records the readings on the horizontal and vertical scales. Each flank station observer records the reading on the horizontal scales. All observers then plunge their telescopes and repeat the tracking procedure.

Figure 7-49. **Simuitaneous observations**



c. At the master station, the measured horizontal angle is added to the known azimuth to the mark to determine the azimuth to the sun. The grid coordinates of the master station, the vertical angle to the sun, and the grid azimuth of the sun are transmitted to each flank station. The flank station operator plots on his map a line representing the azimuth from the master station to the celestial body. From the flank station, a line is drawn perpendicular to the line representing the azimuth from the master station to the celestiat body. (See Figure 7-50.) The flank station observer then determines the correction to be applied to the azimuth from the master station to the celestial body. When this correction is applied (added or subtracted), the result is the azimuth from the flank station to the celestial body, The correction is determined by using the correction nomograph in Figure 7-51 (or Table 13 of FM 6-300).

Figure 7-50. **Relative locations of stations for simultaneous observations**

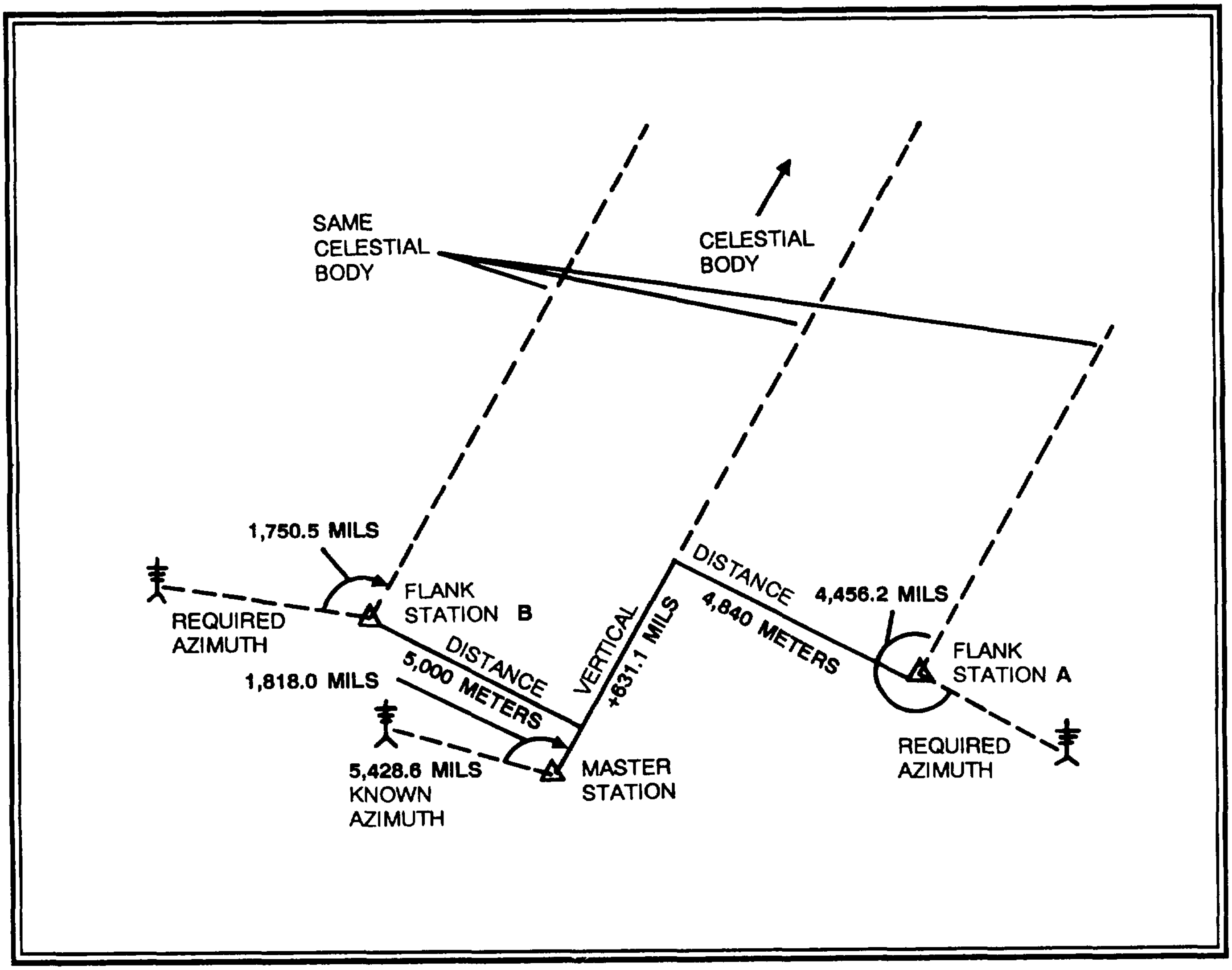
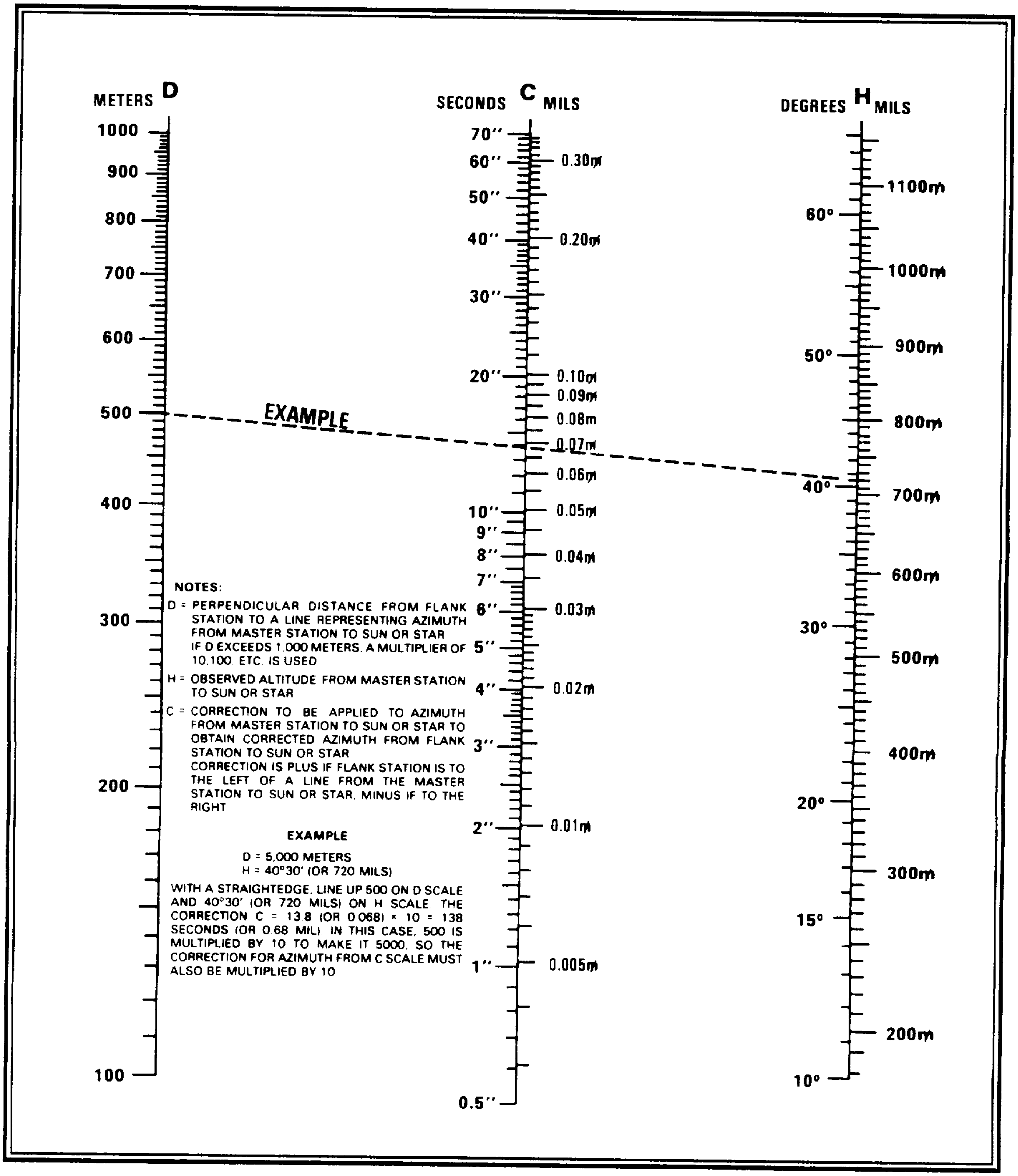


Figure 7-51. **Correction nomograph**



d. The nomograph consists of three columns. The left column is graduated in meters from 100 to 1,000. It represents the value of the length of the line (D) from the flank station to the plotted line that represents the azimuth to the sun from the master station. The center column is graduated in seconds and roils from 0.5" to 70" and from 0.003 mil to 0.34 mil and is the correction (C). The right column is graduated in degrees and roils from 10" to 65° and from 180 roils to 1,150 mils. It represents the vertical angle to the celestial body at the master station (H). Before C can be determind, the values of D and H must be known and used as arguments in the nomograph. When the distance exceeds 1,000 meters, it must be divided by 10, 100, or 1,000 to obtain a value between 100 and 1,000. In such cases, the chart value of C must be multiplied by the same value by which the distance was divided. The value H must be between 180 and 1,150 mils. If the flank station is to the left of the line from the master station to the celestial body, the sign of the correction is plus; if the flank station is to the right the sign of the correction is minus.

e. When the azimuth to the sun from the flank station has been determined, the measured horizontal angle is subtracted. The result is the azimuth to the azimuth mark at the flank station.

EXAMPLE

Mean data from observations are as follows:

Master station:

Horizontal angle	1,818.0 mils	
Vertical angle	+631.1 mils	
Flank stations	A	B
Horizontal angle	4,456.1 mils	1,750.5 mils
Perpendicular distance	4,840 meters	5,000 meters

The grid azimuth to the mark at the master station is 5,428.6 mils. The relative locations of stations are as shown in Figure 7-50. The flank station observer enters the nomograph (Figure 7-51) by using the value of the mean vertical angle and the perpendicular distance from the flank station to the master station azimuth to the sun. The correction obtained from the nomograph (expressed to the nearest 0.01 mil) is applied to the grid azimuth from the master station to the celestial body. This is the grid azimuth from the flank stations to the celestial body. The sign of the correction is minus when the flank station is to the right and plus when the flank station is to the left of the master station when facing the celestial body.

Azimuth to master station azimuth mark	5,428.6 mils
Horizontal angle at master station	+1,818.0 mils
Sum	7,246.6 mils
	-6,400.0 mils
Azimuth to body	0846.6 mils
Flank station A	
Perpendicular distance 4,840 meters	
Azimuth to body	0846.6 mils
Correction from nomograph (station on right)	-0.6 mil
Azimuth to body at flank station	0846.0 mils
	+6,400.0 mils
	7,246.0 mils
Horizontal angle to body at flank station	-4,456.2 mils
Azimuth to flank station A azimuth mark	2,789.8 mils
Flank station B	
Perpendicular distance 5,000 meters	
Azimuth to body	0846.6 mils
Correction from nomograph (station on left)	+0.6 mils
Azimuth to body at flank station	0847.2 mils
	+6,400.0 mils
	7,247.2 mils
Horizontal angle to body at flank station	-1,750.5 mils
Azimuth to flank station B azimuth mark	5,496.7 mils

7-42. ACCURACY OF SIMULTANEOUS OBSERVATIONS

a. Simultaneous observations are comparable in accuracy to an astro observation with a theodolite or aiming circle. The accuracy cannot exceed that of the instrument used. Requirements for the various accuracies are discussed below.

(1) Requirements for fourth-order azimuth (±0.150 mil) are as follows:

- A known azimuth of fourth-order or better and a T2 theodolite at the master station.
- A T2 theodolite at the flank station.

(2) Requirements for fifth-order azimuth (+0.3 mil) areas follows:

- An azimuth of fifth-order or better and a T16 or T2 theodolite at the master station.
- T16 at the flank station.

(3) Requirements for 1:500 azimuth (±0.5 mil) are as follows:

- An azimuth of fifth-order or better and a T16 theodolite at the master station.
- An aiming circle at the flank station.

(4) Specifications arc the same as for an astro observation (Appendix B).

(5) Station displacement (cumature) corrections must be applied (paragraphs 7-41c and d).

b. When a T16 theodolite is used at a flank station and a T2 theodolite is used at the master station and the conditions of a above are met, the maximum accuracy that can be realized will be fifth-order azimuth or ±0.3 mil. If the master station instrument is a T16 theodolite and the flank station instrument is an aiming circle, the maximum accuracy to be expected is ±0.5 mil.

> **Note.** Simultaneous observations will yield the same accuracy as astro azimuths taken with the instructions used to a maximum D value of approximately 26,000 meters. Obseservations may be conducted over much longer distances if a 1-roll or 2-roll accuracy is acceptable.

7-43. HASTY ASTRO OBSERVATION

a. This method enables battalion surveyoxs and firing battery personnel to compute a grid azimuth and a check angle from observations of the sun or a selected survey star. The accuracy of the computation depends on which instrument is used to perform the observations (M2A2 aiming circle ±2.0 mils or T16 theodolite ±0.3 mils).

b. The fieldwork for this method is the same as the fieldwork for a flank station simultaneous observation. The hasty astro program is the master station for the observation. A T2 does not have a nonrecording motion; therefore, it will not be used in conjunction with this method.

c. Follow the field procedures below when using a T16 and the hasty astro program. Check angles must compare within 0.3 mil.(Figure 7-52 shows a hasty astro field sketch.)

(1) Emplace the T16 over the orienting station.

(2) Place 0000.0 mils on the horizontal scale. Lock the scale with the horizontal clamp.

(3) Track the celestial body (with scale lccked), and announce **TRACKING** when the instrument is oriented on the sun or selected survey star. Announce **TIP** when the center of the reticle is exactly aligned on the sun or star.

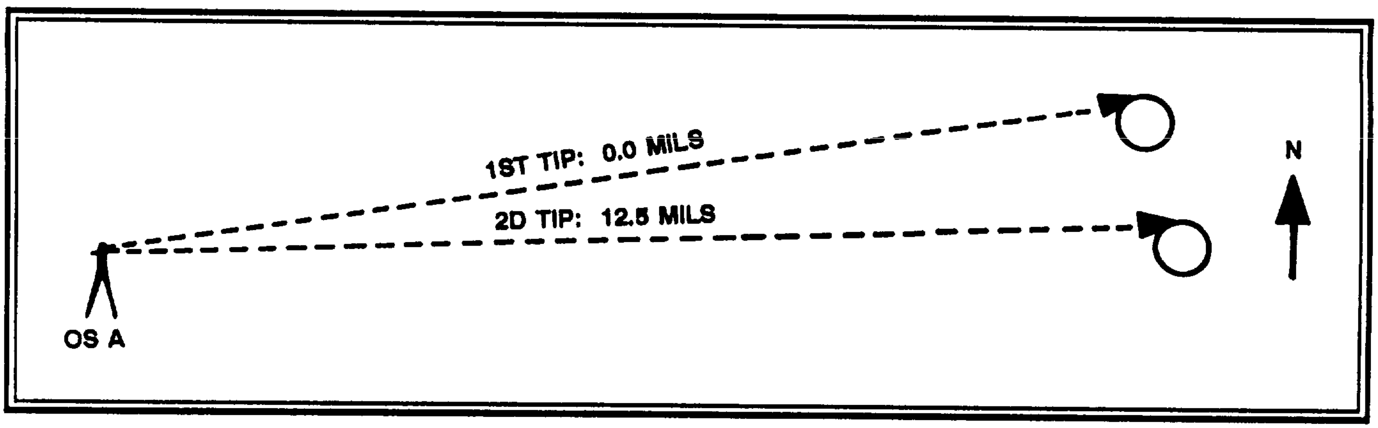
(4) At the announcement of **TIP** when using the internal timer, press the END LINE key on the BUCS. If the internal timer is not being used, manually enter the date and time of tip into the BUCS.

(5) When the grid azimuth to the celestial body at the time of tip is displayed, record this as the azimuth to the EOL.

(6) Depress the telescope, and emplace the EOL.

(7) Unlock the scales, and repeat steps 3 and 4. The BUCS will display the check angle. timpme the check angle from the BUCS to the check angle on the instrument. If the difference is ±2.0mils for the aiming circle and ±0.3 mil for the T16 theodolite, the azimuth to the EOL is good; if not, check all data and/or reobserve.

Figure 7-52. **Hasty astro field sketch**



d. Azimuth from the hasty astro method is computed with BUCS by using DA Form 72WR (Computation of Hasty Astro (BUG)) (Figures 7-53 and 7-54) and Program 6. (A reproducible copy of this form is included at the back of this book.) This program uses the electronic ephemeris, which eliminates the need to extract ephemeris data from FM 6300. This program provides the option of using the internal timer to determine the date and time of tip for each observation or to input the date and the time manually. The ability to manually input the date and time of observation allows surveyors to perform fieldwork without the BUCS at the site of observation.

e. The instructions for computing DA Form 721WR are shown in Table 7-6.

Table 7-6. **Instructions to compute DA Form 7286-R**

STEP	INSTRUCTION
1	There is no prompt in the PROMPT column of the form. The procedure in the PROCEDURE column is CALL PROGRAM 11. Enter the survey module, and call Program 11.
2	The display prompts HASTY ASTRO. There is no procedure. Press the END LINE key.
Note. At the completion of each step, press the END LINE key.	
3	The display prompts SPHEROID CODE: 0. The procedure is ENTER SPHEROID CODE. Enter the spheroid code for your area. Record the spheroid name and number in the SPHEROID block in the DATA RECORD section. **Note.** For WGS-84, use GRS-80.
4	The display prompts EAST: 0.00. The procedure is ENTER EASTING. Enter the UTM easting of the observer's station. Record the easting in the EAST: block of the DATA RECORD section.
5	The display prompts NORTH: 0.00. The procedure is ENTER NORTHING. Enter the UTM northing of the observer's station. Record the northing in the NORTH: block of the DATA RECORD section.
6	The display prompts LATITUDE (N/S): The procedure is ENTER N OR S. Enter N (north) or S (south).
7	The display prompts GRID ZONE: 00. The procedure is ENTER GRID ZONE. Enter the grid zone number. Record the grid zone number in the GRID ZONE: block in the DATA RECORD section.
8	The display prompts USE SUN (Y/N): The procedure is ENTER Y OR N. Select the appropriate response. Press Y (yes), if using the sun; press N (no), if using a survey star. If answer is N, perform step 8a.
8a	The display prompts STAR #: 00. The procedure is ENTER STAR NO. Record the star number in the STAR NO: block in the DATA RECORD section.
9	The display prompts TIME MODULE (Y/N): The procedure is ENTER Y OR N. Select the appropriate response. Press Y if you have set the internal timer to the current local date and local time. Press N if you plan to manually enter the local date and local time for each observation.
10	The display prompts TIME ZONE LETTER: The procedure is ENTER TIME ZONE LETTER. Enter the time zone letter extracted from the back of the form. Record the time zone letter in the TZ LTR: block of the DATA RECORD section.

Table 7-6. **Instructions to compute DA Form 7286-R (continued)**

STEP	INSTRUCTION
	Note. The ABORT, TOP OF FILE, and BACKUP functions are disabled at this step.
11	The display prompts DAYLT SV TIME (Y/N): The procedure is ENTER Y OR N. Enter Y or N to indicate if local time includes a daylight saving time correction.
12	The display prompts PRESS END LINE AT TIP when the time module is being used. If the prompt appears, press the END LINE key when the instrument operator announces **TIP**. The date and time of tip are entered manually in steps 13 and 14.
13	The display prompts OBS DATE (DD.MMYY): The procedure is RECORD OR ENTER LOCAL DATE. Enter the local date of observation in a day, month, and year format. If the time module is used, record in the DATE: block of the DATA RECORD section the date and time as displayed.
14	The display prompts OBS TIME (HH.MMSS): The procedure is RECORD OR ENTER LOCAL TIME. Enter the local time of observation for the first tip in an hour, minute, and second format. If the time module is used, record in the TIME: block on the same line as step 14 the time as displayed.
14a	The display prompts TRL/LDG/CTR (TR/L/C): The procedure is ENTER TR, L, OR C. This prompt requests information on what part of the sun was observed. If the trailing edge of the sun was observed, press TR. If the leading edge of the sun was observed, press L. If the center of the sun was observed, press C. Observations on the center of the sun provide the most accurate solution for azimuth, and it is the preferred method of observation when weather conditions permit.
15	The display prompts GRID AZ: 0.000. The procedure is RECORD GRID AZIMUTH. Record the displayed grid azimuth in the GRID AZ (MILS): block in the DATA RECORD section.
16	The display prompts PRESS END LINE AT TIP when the time module is being used. If the answer to step 9 was N, this display prompt will not appear. If the prompt appears, press the END LINE key when the instrument operator announces **TIP**. The time of tip is entered manually in step 17.
17	The display prompts OBS TIME (HH.MMSS): The procedure is RECORD OR ENTER LOCAL TIME. Enter the local time of observation for the second tip in an hour, minute, and second format. If the time module is used, record the local time in the TIME: block on the same line as step 17.
17a	The display prompts TRL/LDG/CTR (TR/L/C): The procedure is ENTER TR, L, OR C. Enter the response for the method used.
18	The display prompts CK ANGLE: 0.000.0. The procedure is RECORD CHECK ANGLE. Record the check angle in the CK ANGLE (MILS): block in the DATA RECORD section. Compare the BUCS check angle with the measured check angle on the instrument. The allowable differences are ±2.0 mils for the aiming circle and ±0.3 mil for the T16 theodolite. If the check angles are within tolerance, the grid azimuth from the first tip is a good azimuth. If the check angles are not within tolerance, then the instrument operator should perform a new set of observations. A field check with a compass should be made to ensure that no gross errors occurred in the fieldwork or computations.
19	The display prompts ANOTHER OBS (Y/N): The procedure is ENTER Y OR N. Select the appropriate response Y or N. If the response is Y, the next display prompt is TIME MODULE (Y/N): Perform steps 9 through 18 with two new observations that will provide a new grid azimuth and a new check angle. If the response is N, the prompt END OF MSN (Y/N): appears.
20	The display prompts END OF MSN (Y/N): This is the last point at which data can be recalled. Select the appropriate response—Y or N.

Figure 7-53. **Sample DA Form 7286-R**

COMPUTATION OF HASTY ASTRO (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER: SSG ANDERSON	NOTEBOOK REFERENCE: X-1	DATE: 28 AUG 88
CHECKER: SSG PENA	AREA: SYDNEY	SHEET 1 OF 1 SHEETS

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE		
1		CALL PROGRAM	STATION: OSA	APPROX AZ TO AZMK (MILS): 3600
3	SPHEROID CODE: 0 1 = CLARKE 1866; 2 = INTERNATIONAL; 3 = CLARKE 1880; 4 = EVEREST; 5 = BESSEL; 6 = AUSTRALIAN; 7 = WORLD GEO SYS-72; 8 = GRS-80:	ENTER SPHEROID CODE	SPHEROID: AUSTRALIAN	REMARKS:
4	EAST: 0.00	ENTER EASTING	EAST: 396700.00	
5	NORTH: 0.00	ENTER NORTHING	NORTH: 7566800.00	
6	LATITUDE (N/S):	ENTER N OR (S)		
7	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE: 55	
8	USE SUN (Y/N):	ENTER Y OR (N)		
8a	STAR #: 00	ENTER STAR NO	STAR NO: 42	
9	TIME MODULE (Y/N):	ENTER (Y) OR N		
10	TIME ZONE LETTER:	ENTER TIME ZONE LETTER	TZ LTR: K	NOTES:
11	DAYLT SV TIME (Y/N):	ENTER (Y) OR N		
(12)	PRESS ENDLINE AT TIP	PRESS END LINE		
13	OBS DATE (DD.MMYY):	RECORD OR ENTER LOCAL DATE	DATE: dd 28. mm 08 yy 88	
14	OBS TIME (HH.MMSS):	RECORD OR ENTER LOCAL TIME	TIME: hh 22. mm 15 ss 15	
14a	TRL/LDG/CTR (TR/L/C):	ENTER TR, L, OR C		
15	GRID AZ: 0.000	RECORD GRID AZIMUTH	GRID AZ (MILS): 3667.431	
(16)	PRESS ENDLINE AT TIP	PRESS END LINE		
17	OBS TIME (HH.MMSS)	RECORD OR ENTER LOCAL TIME	TIME: hh 22. mm 19 ss 30	
17a	TRL/LDG/CTR (TR/L/C):	ENTER TR, L, OR C		
18	CK ANGLE: 0.000	RECORD CHECK ANGLE	CK ANGLE (MILS): 6396.42	
19	ANOTHER OBS (Y/N):	ENTER Y OR (N)		
20	END OF MSN (Y/N):	ENTER (Y) OR N		

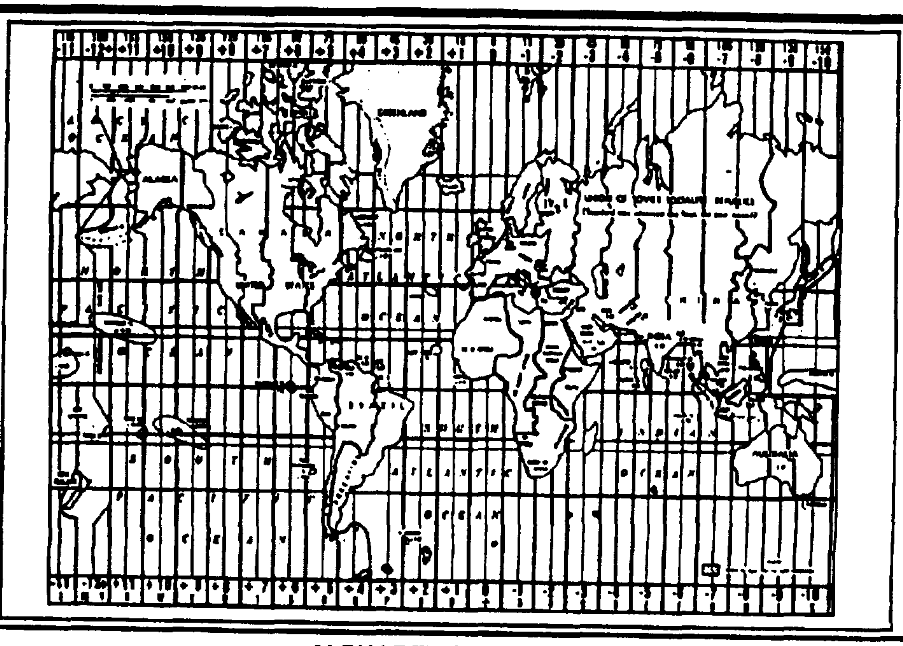
NOTES:

1. IN STEP 8, Y RESPONSE RETURNS YOU TO STEP 9.
2. IN STEP 8, N RESPONSE RETURNS YOU TO STEP 8a.
3. IN STEP 9, Y RESPONSE WILL ALLOW ACCESS TO INTERNAL TIMER AT TIP.
4. IN STEP 9 IF RESPONSE IS N, SKIP STEPS 12 AND 16. ENTER LOCAL DATE IN STEP 13 AND LOCAL TIME IN STEPS 14 AND 17.
5. STEPS 14a AND 17a WILL APPEAR FOR SUN OBSERVATIONS ONLY.
   TR = TRAILING EDGE OF SUN.
   L = LEADING EDGE OF SUN.
   C = CENTER OF SUN.
6. SEE BACK OF FORM FOR TIME ZONE LETTER AND STAR NUMBER.
7. CHECK ANGLE COMPARISON:
   M2 (AC): ± 2.0 MILS
   T16: ± 0.3 MIL

DA FORM 7286-R, SEP 93

Figure 7-54. **Reverse of DA Form 7286-R**

T I M E Z O N E C H A R T



LONGITUDE OF MERIDIAN	TIME ZONE LETTER
EAST LONGITUDE	
0	Z
15	A
30	B
45	C
60	D
75	E
90	F
105	G
120	H
135	I
150	K
165	L
180	M
WEST LONGITUDE	
0	Z
-15	N
-30	O
-45	P
-60	Q
-75	R
-90	S
-105	T
-120	U
-135	V
-150	W
-165	X
-180	Y

ALPHABETICAL STAR LIST

Star	No.	
ACAMAR	12	
ACHERNAR	9	
ACRUX	42	*
ADHARA	26	
ALDEBARAN	15	*
ALHENA	24	
ALIOTH	45	
ALKAID	48	
AL NA'IR	71	
ALNILAM	20	
ALNITAK	21	
ALPHARD	35	
ALPHECCA	55	
ALPHERATZ	1	*
ALTAIR	66	*
ANKAA	4	
ANTARES	57	*
ARCTURUS	51	*
ATRIA	58	
AVIOR	32	
BELLATRIX	18	
BETA HYDRUS	3	
BETELGEUSE	22	
CANOPUS	23	
CAPELLA	17	
CAPH	2	
CASTOR	26	
DENEB	68	
DENEBOLA	39	
DIPHDA	6	
DSCHUBBA	56	
DUBHE	38	
ELNATH	19	
ELTANIN	62	
ENIF	70	
FOMALHAUT	72	
GACRUX	43	
GAMMA CASSIOPEIAE	7	
GAMMA VELORUM	31	
GIENAH	41	
HADAR	49	
HAMAL	11	
KAUS AUSTRALIS	63	
KOCHAB	54	*
MARKAB	73	
MENKAR	13	
MENKENT	50	
MERAK	37	
MISPLACIDUS	34	
MIMOSA	44	
MIRFAK	14	
MIZAR	46	
NUNKI	65	
NU	69	
PEACOCK	67	
PHECDA	40	
POLARIS	10	*
POLLUX	30	
PROCYON	29	
RASALHAGUE	61	
REGULUS	36	*
RIGEL	16	
RIGIL KENTAURUS	52	
RUCHBAH	8	
SABIK	59	
SCAULA	60	
SCHEDAR	5	
SIRIUS	25	*
SPICA	47	
SUHAIL	33	
VEGA	64	
WEZEN	27	
ZEBENELGENUBI	53	

* INDOCATES THE PREFERRED STARS FOR HASTY ASTRO.

PAGE 2, DA FORM 7286-R, SEP 93

Section X

SELECTION OF METHODS OF OBSERVATION

The method selected for observation depends upon the observer's location, celestial bodies available, and the accuracy required. During daylight hours, only the sun is available. The observer's location will dictate if the altitude method or the arty astro method must be used. At night, the determining factors will be the availability and locations of the stars.

7-44. FIFTH-ORDER AZIMUTHS

a. Generally, speed of computation is the most important consideration in choosing a method for fifth-order astro azimuth determination. The techniques covered in Sections V, VI, VII, and VIII are all satisfactory for fifth-order azimuth determination.

b. At night, in the Northern Hemisphere, Polaris should always be used if it is observable, because it is easy to identify and easy to track. When observing Polaris, use either the arty astro method or the Polaris tabular method. If Polaris is not visible but an east-west star is, either the altitude method or the arty astro method can be used. If the star has a high star rate and accurate time is available, use the arty astro method. If the star has a low rate, the altitude method generally is preferable because it requires less accurate time than does the arty astro method. If time is not critical and only east-west stars are observable, observe a star in the east and one in the west.

c. In the daytime, use the sun-altitude method if the sun is in the proper position, since accurate time is not so important as it is with the arty astro method. If the sun is not in the proper position to use the altitude method, use the arty astro method.

7-45. FOURTH-ORDER AZIMUTHS

a. Generally, the prime consideration in choosing a method of fourth-order azimuth determination is accuracy. Theoretically, the arty astro method is more accurate than the altitude method, but this accuracy depends in turn on the availability of accurate time.

b. The beat source of fourth-order accuracy is the Polaris arty astro method. (Polaris is never observed by the altitude method.) Polaris is easily identified and tracked, and when the arty astro method is used with Polaris, accurate time is not so critical as it is when used with an east-west body. The Polaris tabular method will yield reliable fourth-order azimuths. When Polaris cannot be seen, observe an east-west star with the arty astro method if accurate time is available. If time is unreliable, use the altitude method of observation.

c. In the daytime, use the arty astro method with the sun if accurate time is available; if not, use the altitude method.

7-46. CHOICE OF CELESTIAL BODY

During daylight hours, the sun is the only celestial body that can be readily observed. At night, Polaris is one of the most easily identified stars in the Northern Hemisphere. It is ideal for observation because of its slow movement. However, Polaris cannot be seen in many parts of the Northern Hemisphere because of local weather conditions, and it cannot be used in areas close to the equator and in the Southern Hemisphere. Therefore, it is inadvisable to depend solely on this star for night observations. Methods of identification and approximate locations of the stars on the celestial sphere in relation to the observer's position are presented in Section IV. All artillery surveyors must be familiar with the more common stars and their relative positions in the sky.

7-47. CHOICE OF METHOD

The primary considerations in selecting a method of determining azimuth are as follows:

- The time availabIe to the observer.
- The instruments available for the observer's use.
- The observer's knowledge of the correct time.
- The observer's experience in astro observations.

The secondary consideration is the degree of accuracy desired. Refer to Table 7-7 for a comparison of azimuth determination methods.

Table 7-7. **Comparison of methods for determining azimuth**

	METHODS		
	ALTITUDE	ARTY ASTRO	POLARIS TABULAR
Observable bodies	Sun or east-west star	Sun, any star	Polaris
Latitude accuracy	1 second	Not required	1 second
Longitude accuracy	1 second[1]	Not required	1 second
UTM easting	Not required	Within 150 meters	Not required
UTM northing	Not required	Within 150 meters	Not required
Temperature and vertical angle	Required	Not required	Not required
Horizontal angle	Required	Required	Required
Time accuracy	Sun: nearest 5 minutes	Sun or star: nearest 1 second	Fifth order: 1 minute
	Star: nearest day	Polaris: 10 seconds	Fourth order: 1 minute
Altitude of sun or star	Sun or star must be within 530 mils of the prime vertical and preferably between 175 and 800 mils in altitude.	Sun or star should be between 175 and 800 mils in altitude.	Not applicable
Location of sun or star	Sun or star must not be within 2 hours of observer's meridian.	Sun and noncircumpolar stars must not be within 1 hour of the observer's meridian.	Not applicable
Degree of accuracy	Fourth order	Fourth order	Fourth order
	Fifth order	Fifth order	Fifth order

[1]Required only for computation of grid convergence.

7-48. SOLUTION OF THE PZS TRIANGLE TO ESTABLISH AZIMUTH (SOUTHERN HEMISPHERE)

The Army must be prepared to undertake field operations at any location on the earth. Hence, the artillery surveyor must be able to function effectively at any and all locations, to include those in the Southern Hemisphere.

a. Locations within the Southern Hemisphere present new problems to an observer accustomed to working the PZS triangle in the Northern Hemisphere. The coaltitude colatitude, and local hour angle are computed in the same manner as in the Northern Hemisphere. However, other techniques must be used in determining the polar distance and true azimuth.

b. The polar distance is determined by algebraically adding the declination of the celestial body to 90° (1,600 mils) with due regard for the algebraic sign of the declination. In the Southern Hemisphere, the true azimuth to the celestial body is determined by adding the azimuth angle to or subtracting it from 3,200 mils. If the celestial body is west of the observer, the azimuth angle is added to 3,200 mils; if the body is east of the observer, the azimuth angle is subtracted from 3,200 mils. (See Figure 7-55.)

EXAMPLE

Find the polar distance value for an observation made on the star Fomalhaut (Number 72) at 21 hours, 1 December 1993.

Declination of the star Fomalhaut at time and date of observation is -527.20 mils (FM 6-300, Table 10b). Arc from the celestial equator to the celestial South Pole is 1,600 mils, a positive value.

Length of arc (equator to pole)	+1,600.00 mils
Declination of star	- 527.20 mils
Polar distance	+1,072.80 mils

Star West of Observer

Azimuth to star (Northern Hemisphere)= 6,400 mils minus azimuth angle

Azimuth to star (Southern Hemisphere)= 3,200 mils plus azimuth angle

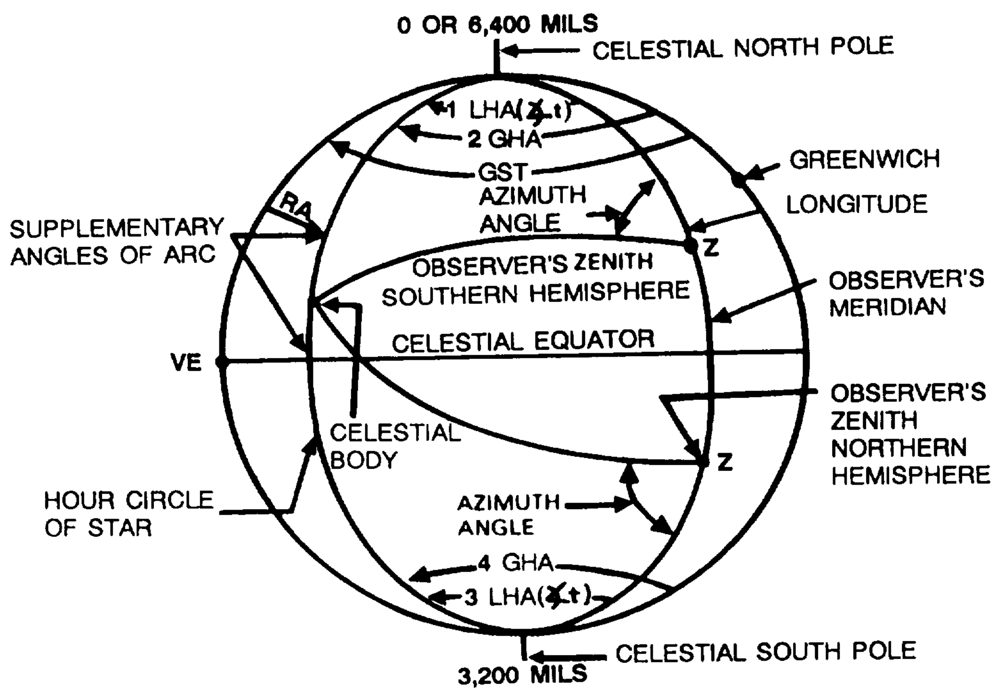
Star East of Observer

Azimuth to star (Northern Hemisphere) = azimuth angle

Azimuth to star (Southern Hemisphere)= 3,200 mils minus azimuth angle

Note. In Figure 7-55. Angle 1 at celestial North Pole is the same as Angle 3 at the celestial South Pole. Angle 2 at the celestrial North Pole is the same as Angle 4 of the celestial South Pole.

Figure 7-55. **Comparison of the PZS triangle in the Northern and Southern Hemisphere**



Note. Log functions of supplementary angles are the same.

CHAPTER 8
GYROSCOPIC AZIMUTH

This chapter discusses the skills needed to operate the azimuth gyro (SIAGL [Lear]). It also discusses the conversion of the azimuth determined by gyroscope (true azimuth) to grid azimuth.

Section I
SIAGL (LEAR)

This section is a guide for survey personnel to develop the skills needed to operate the azimuth gyro. The azimuth gyro available for use is the SIAGL (Lear). The SIAGL is a portable gyrocompass used to determine a true north direction at any selected station, latitude permitting. The SIAGL can determine direction without lengthy computations or existing control in almost any weather condition. Accuracy of the SIAGL is comparable to that of astro observation. All persons involved in FA survey operations must understand the functions of this instrument and be able to determine a direction with it.

8-1. PRINCIPLE OF OPERATION

A gyroscope acts as a north-indicating device. When leveled, the gyroscope detects the earth's rotation and orients itself to north. Once the gyroscope locks in on north, the true azimuth to any point can be determined by reading the horizontal scales. Since the effects of the earth's rotation vary from place to place, the gyroscope will be less accurate at points farther north or south of the equator.

8-2. COMPONENTS AND ACCURACY

a. The SIAGL can determine true north with high accuracy without the help of celestial or landmark sightings. The SIAGL consists of the following:

- Gyroscopic reference unit (GRU) with an integral theodolite and tripod assembly.
- Electronic control unit (ECU).
- Transit case, which houses the reference unit.
- Alternating current-direct current (AC-DC) converter.
- Auxiliary equipment.

The complete SIAGL, minus the wind screen, is contained in a transport case. The instrument can determine and indicate true north within about 20 minutes after power is applied.

b. The accuracy of the SIAGL depends on the latitude of the location. The accuracy at a specific location can be computed by the formula:

$$\text{Accuracy} = \frac{0.150 \text{ mil}}{\text{cosine of latitude}}$$

Table 8-1 lists the accuracies that can be expected at various latitudes from 0° to 75°.

Table 8-1. **Azimuth observation accuracy table**

LATITUDE	ACCURACY (MILS)	LATITUDE	ACCURACY (MILS)	LATITUDE	ACCURACY (MILS)
0°	0.150	30°	0.173	55°	0.262
5°	0.151	35°	0.183	60°	0.300
10°	0.152	40°	0.196	65°	0.355
15°	0.155	45°	0.212	70°	0.439
20°	0.160	50°	0.233	75°	0.580
25°	0.166				

c. The real value of the SIAGL is to establish initial directional control for cannon battalion surveys.

d. The LATITUDE select switch on the ECU maintains instrument operating time at different latitudes of operation. The switch is adjusted with a screwdriver and has eight positions. Adjust the LATITUDE switch to correspond to the closest latitude of operation. Table 8-2 lists the switch positions and their corresponding latitudes.

Table 8-2. **ECU LATITUDE select switch position**

SWITCH POSITION	LATITUDE OF OPERATION
0	0° TO 15°
25	15° TO 30°
40	30° TO 45°
50	45° TO 55°
60	55° TO 63°
65	63° TO 67°
70	67° TO 73°
75	73° TO 75°

e. The TEST METER on the ECU provides a visual check of the operational status of the instrument in both testing and operating modes. Satisfactory operation of the circuits associated with TEST SELECT switch positions is indicated when the meter pointer moves to the green area (right of center). The meter and the TEST SELECT switch are used with the PRESS TO TEST switch, which must be pressed to obtain meter readings during self-test operations. When the gyrocompass activates, the meter pointer indicates the relationship of the pendulum and follow-up assembly.

f. For the specific functions of other GRU controls (Figure 8-1) and ECU controls (Figure 8-2), refer to TM 5-6675-250-10.

8-3. INITIAL SETUP PROCEDURES

The following steps are performed when unloading and unpacking the equipment.

a. Remove the GRU from the transit case as discussed below.

(1) Press the pressure relief valve.

(2) Unfasten the latches securing the upper and lower sections of the case together. Remove the upper section.

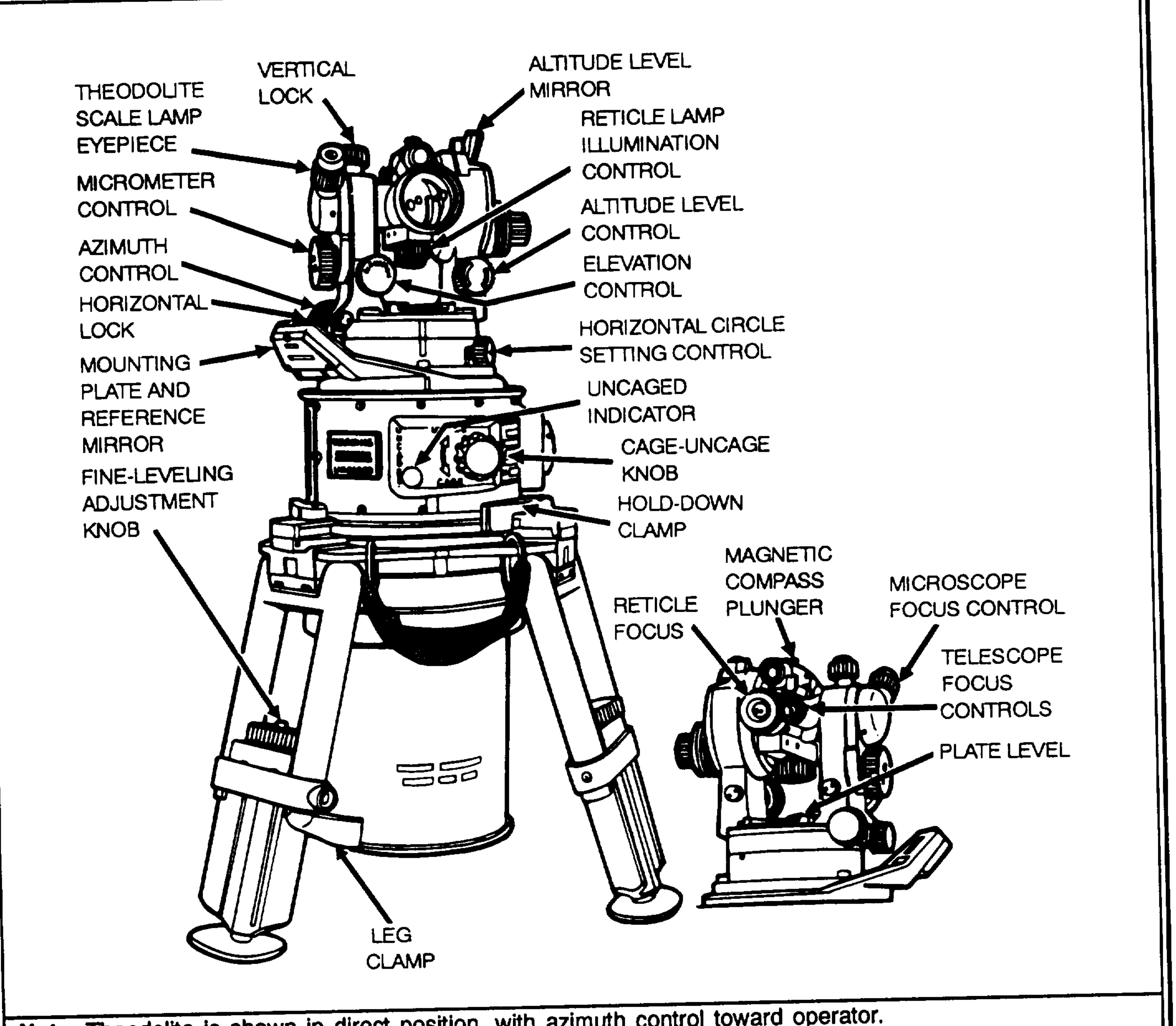
(3) Unfasten the clamps securing the GRU in the case. Remove the unit from the case.

(4) Inspect equipment for damage and for loose or missing parts.

> **CAUTION**
> Avoid unnecessary exposure of the equipment to dust, soil, or other abrasive materials.

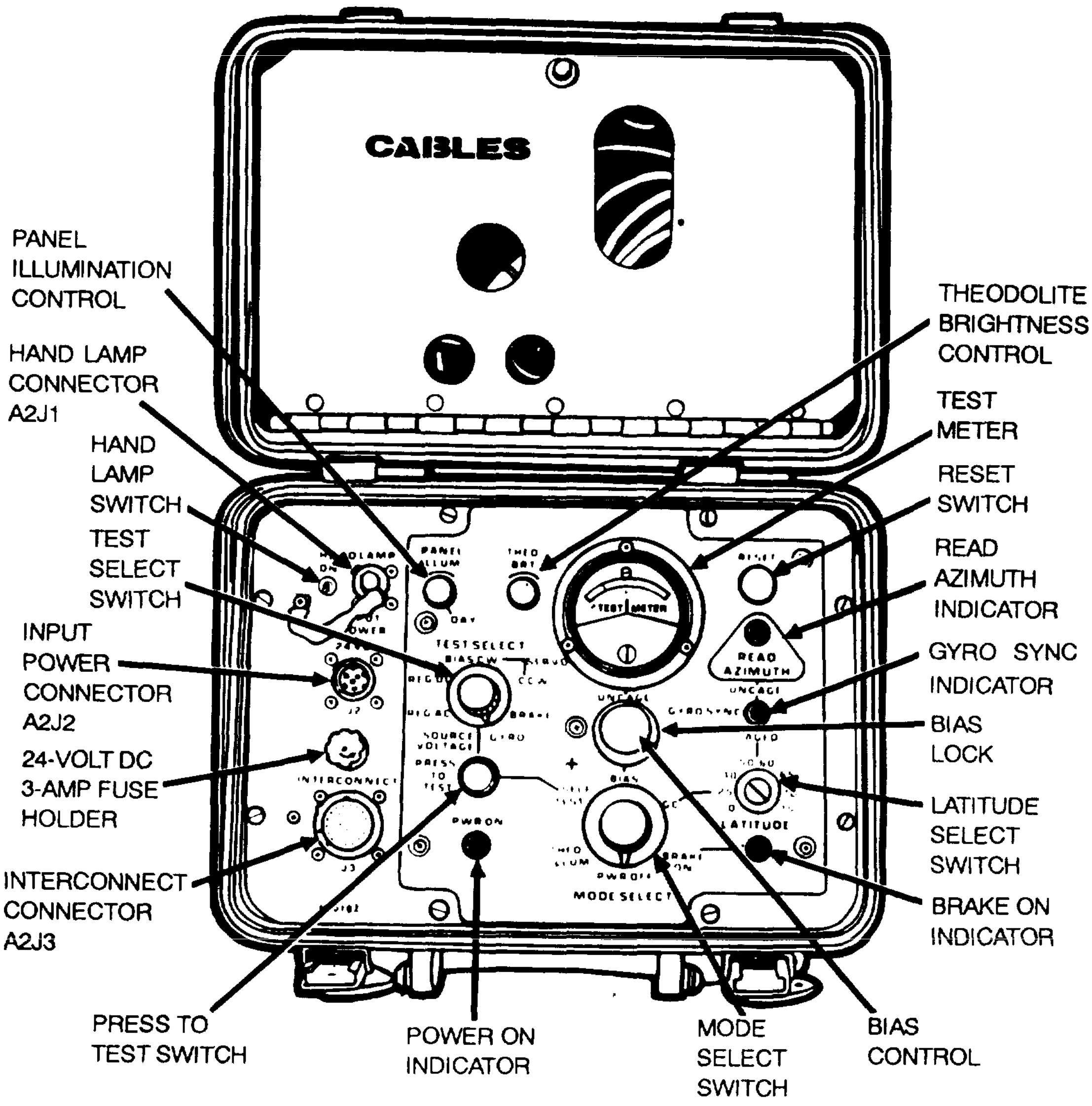
b. Loosen the clamps on each leg of the tripod, and extend each leg to within 1/2 inch of full extension. Tighten the leg clamps. Extend the spades 1/4 to 3/8 inch by rotating the leveling screws.

Figure 8-1. **Gyroscopic reference unit**



Note. Theodolite is shown in direct position, with azimuth control toward operator.

Figure 8-2. **Electronic control unit controls**



8-4. FINAL SETUP PROCEDURES

With the equipment unpacked and the tripod extended (Figure 8-3), complete setup procedures as discussed below.

a. Course-level the instrument by releasing one of the tripod leg clamps. Adjust the leg to obtain a level indication on the tripod circular level. Repeat the procedure for each of the other two tripod legs.

b. To center the unit over a fixed reference point, extend the plumb pointer located on the bottom of the GRU housing. Place the reference unit on the ground so the pointer is near the fixed point. Press the leg spades into the ground. Check the plumb pointer from two positions 1,600 mils apart.

CAUTION
When ground wind speeds are more than 20 miles per hour, use of the wind shelter is mandatoryto obtain azimuth accuracies listed in Table 8-1.

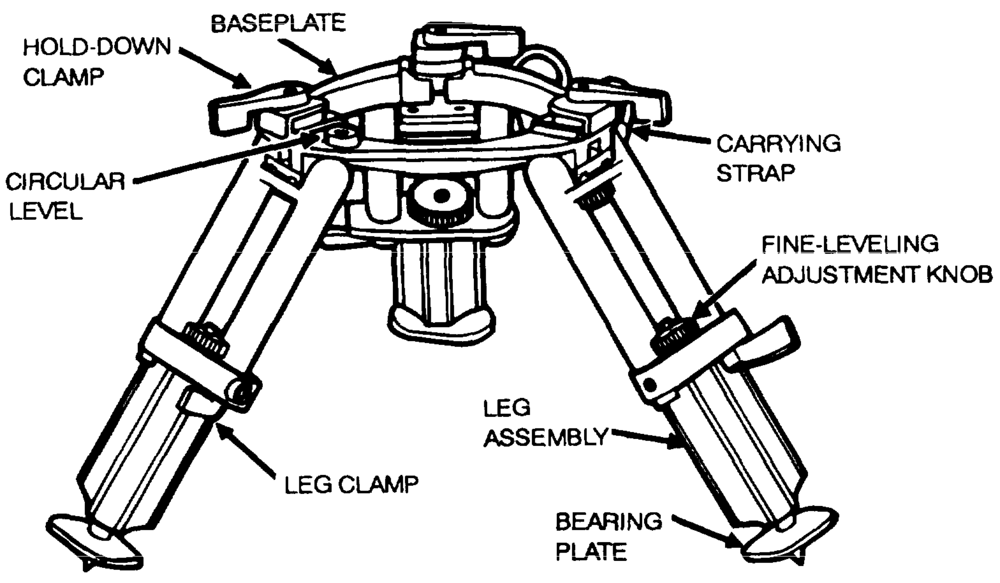
c. Release the horizontal lock on the theodolite. Rotate the alidade to position the objective end of the telescope over the NORTH mark on the reference unit; tighten the horizontal lock. The telescope must be level (white index marks lined up) for the compass to operate properly. Release the three hold-down clamps. Depress the plunger on the magnetic compass. Rotate the GRU in the tripod until the two compass needle images are in coincidence. Check to ensure the plumb pointer is still over the fixed reference point. Adjust the plumb as necessary, tighten the hold-down clamps, and recheck the compass.

d. Connect the interconnect cable between the ECU and the GRU. Connect the power cable between the INPUT POWER connector on the ECU and a 24-volt DC power source. Auxiliary cables and the AC-DC converter are stored in the transport ease for use as needed. The AC-DC converter allows operation from a 115-volt, 60- or 400-Hz power source. Remove the converter from the transport ease by unfastening the screw assembly. Cap and chain assemblies protect the two receptacles on the converter. One receptacle connects the converter to the power source. The second receptacle connects the converter to the control unit.

CAUTION
Observe the cable markings and connectors. The cables may be connected backward if not aligned properly.

e. For fine leveling, rotate the theodolite alidade so the long axis of the plate level is in the same plane as any two of the tripod legs. Adjust the fine level control to place the bubble in the center of the level vial. Rotate the alidade 1,600 mils, and adjust the remaining leg. Continue the process until the alidade can be rotated 6,400 mils without displacing the bubble more than one division.

Figure 8-3. **Tripod assembly**



8-5. HORIZONTAL CIRCLE ALIGNMENT PROCEDURE

Align the theodolite horizontal circle to the reference mirror as discussed below.

a. Place the MODE SELECT switch to THEO ILLUM.

b. Adjust the reticle focus to get a sharp, clear image of the reticle through the telescope eyepiece.

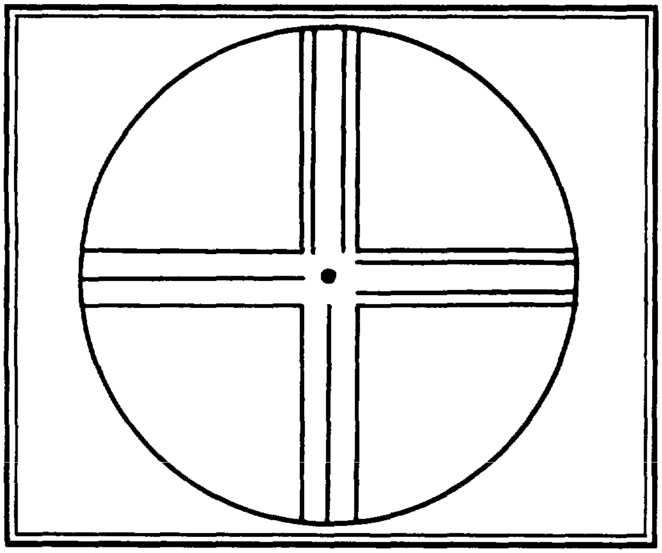
c. Turn the telescope focus counterclockwise until it stops; then turn it clockwise two turns.

d. Rotate the telescope to place the mirror azimuth (rounded to the nearest 5 mils) on the horizontal scales.

e. Depress the telescope until the vertical scales read about 2,400 mils. The green cross or a portion thereof will be visible in the telescope.

f. Adjust the focus to obtain a sharp, clear image, and center the green cross in the reticle. (See Figure 8-4.)

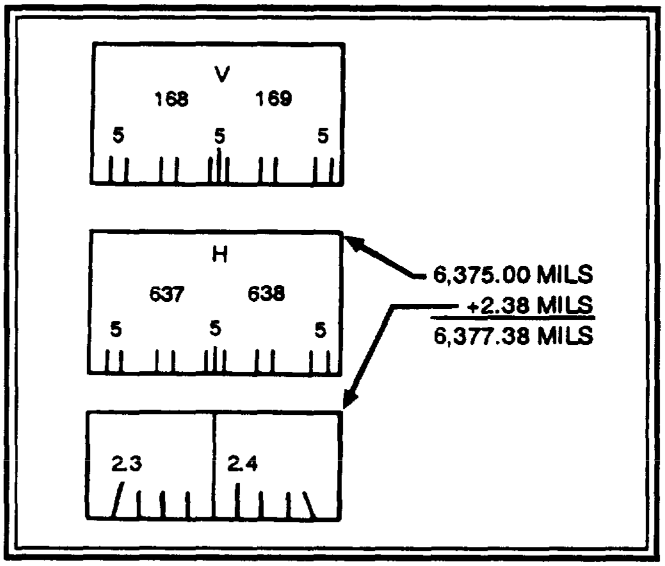
Figure 8-4. **Correct alignment of telescope reticle with cross**



g. Adjust the microscope focus control and the THEO BRT control until the scales appear in clear focus.

h. Adjust the micrometer control to position the fixed index mark (Figure 8-5) of the horizontal (H) scale to the exact center of the nearest double line.

Figure 8-5. **Horizontal scale reading**



i. If the vernier scale does not appear under the fixed index, adjust the micrometer control to position the fixed index mark of the horizontal scale to the center of the nearest double line.

j. Record the H-scale reading (Figure 8-5) as discussed below.

(1) If the fixed index is over a three-digit number, record the number and add a 0 as the fourth digit.

(2) If the fixed index is over a number 5, record the preceding three-digit number and add a 5 as the fourth digit.

k. Record the vernier scale reading.

l. Obtain the direct horizontal reading by adding the recorded readings of the horizontal and vernier scales. (See Figure 8-5.)

m. Obtain reverse readings as discussed below.

(1) Release the horizontal and vertical locks on the telescope, and plunge the telescope.

(2) Subtract 3,200 mils from the mirror azimuth. Place the first four digits of the answer on the horizontal scales.

(3) Depress the telescope until the vertical scales read about 4,000 mils.

(4) Repeat steps in h through 1 above to obtain the reverse mirror reading.

n. Obtain the mean mirror reading as discussed below.

(1) Apply 3,200 mils to the reverse reading.

(2) Add the direct and reverse readings.

(3) Divide the sum obtained in (2) above by two to obtain the mean mirror reading.

o. If the mirror reading determined in n above is within 0.04 mil of the value displayed on the mirror azimuth plate just below the reference mirror window, make no adjustment. If the error is greater than 0.04 mil, use the adjustment procedures below.

(1) Subtract the last four digits of the reverse reading from the last four digits of the direct reading. (Disregard the first two digits.)

(2) Divide this value by two to determine the collimation error.

(3) Algebraically add the collimation error to the value on the mirror azimuth plate.

(4) With the telescope in the direct position, center the image (green cross) accurately in the reticle pattern as in a through f above. Using the micrometer, set the value determined in (3) above on the horizontal and vernier scales. Using the horizontal circle adjusting tool, center the index between the nearest double line. See Figure 8-1 for location of the horizontal circle setting control.

(5) Take an additional direct and reverse reading. Compare these with the mirror azimuth plate, and repeat adjustment until the desired reading is obtained.

8-6. SELF-TEST

Place the telescope in the direct position. Perform the self-test as discussed below.

a. With the MODE SELECT switch set to SELF TEST and the PWR ON indicator lit, place the TEST SELECT switch to SOURCE VOLTAGE.

b. Press the PRESS TO TEST switch. Verify that the TEST METER pointer falls between 22 and 33 volts DC on the meter scale.

Note. You must press the PRESS TO TEST switch for each of the test positions.

c. Place the TEST SELECT switch to REG AC. Verify that the TEST METER pointer is in the green band of the meter scale.

d. Repeat step c with the TEST SELECT switch in the REG DC and BIAS positions.

e. Place the TEST SELECT switch to the SERVO CW position. When looking down on the reference unit, verify that the theodolite rotates in a clockwise direction and the TEST METER pointer is in the green band of the meter scale.

f. Place the TEST SELECT switch to the SERVO CCW position. When looking down on the reference unit, verify that the theodolite rotates in a counterclockwise direction and that the TEST METER pointer is in the green band of the meter scale.

g. Place the TEST SELECT switch to either SERVO CW or SERVO CCW until the yellow index mark is in the center of the yellow servo operating band.

h. Place the TEST SELECT switch to BRAKE. Verify that the BRAKE ON indicator lights and the TEST METER pointer is in the green band.

i. Place the TEST SELECT switch to GYRO. Verify that the TEST METER pointer centers in the yellow area of the test meter scale (0).

8-7. OPERATION OF THE INSTRUMENTS

Note. For daytime operation, the PANEL ILLUM control must be in the DAY position and the theodolite illumination must be at least two-thirds full illumination.

a. Place the ECU MODE SELECT switch to BIAS (audible click).

b. Rotate the CAGE-UNCAGE knob on the GRU clockwise until the UNCAGED indicator lights (audible click). If the GRU will not uncage, check the fine level of the instrument.

c. Observe the TEST METER pointer swing left and right at an approximate rate of one reversal every 5 seconds. When the pointer comes to a stop, verify that it is at 0. If necessary, unlock the outer ring on the BIAS control by turning it counterclockwise, and turn the inner control knob in the appropriate direction to move the needle to 0. When the pointer is at 0, turn the outer ring clockwise to lock the BIAS control in position.

d. Rotate the CAGE-UNCAGE knob on the GRU counterclockwise until the UNCAGED indicator goes out (audible click).

e. Place the MODE SELECT switch to GC (gyrocompass). Verify that the GYRO SYNC indicator lights within 2 minutes.

f. Rotate the CAGE-UNCAGE knob clockwise until the UNCAGED indicator lights.

CAUTION

During the initial wait for the READ AZIMUTH light, ensure the yellow index mark does not approach either end of the yellow servo operating band. Failure to keep the index mark near the center of the operating band will cause extensive damage to the instrument. If the yellow index mark does approach either end of the servo operating band, place the CAGE-UNCAGE knob in the CAGE position. Rotate the GRU in the tripod 60° in the direction that the index mark was moving. Relevel and rebias the instrument, then proceed with the gyrocompass operation.

g. Verify the READ AZIMUTH indicator on the ECU lights about 15 minutes after uncaging the gyro.

h. After the READ AZIMUTH indicator light illuminate, take a direct and reverse reading on the azimuth mark with the theodolite and record the readings. This constitutes one set of readings. With the telescope in the direct position, press the RESET button. The READ AZIMUTH indicator light will illuminate in about 45 seconds. Take a second set of readings to the azimuth mark. The mean of each set must agree within 0.3 mil for fifth-order accuracy. If time permits, take another set of readings to check the mean of the first two sets.

i. Stop the gyroscope by the procedures outlined in paragraphs 8-9a(2) and (3).

j. Place the MODE SELECT switch to BIAS. Rotate the CAGE-UNCAGE knob on the GRU clockwise until the UNCAGED indicator light illuminates. Recheck BIAS to ensure that the TEST METER pointer is within the shaded (yellow) band of the meter.

k. If the difference between the two meaned azimuths is greater than 0.3 mil or if the TEST METER pointer is not within the shaded (yellow) band, disregard the two sets of readings. Retake both sets, starting with c above.

8-8. READING THE THEODOLITE

a. Adjust the reticle focus to obtain a sharp, clear image of the reticle seen through the telescope eyepiece.

b. Release the horizontal and vertical locks on the theodolite.

c. Align the telescope on the target, and tighten the horizontal and vertical locks.

d. Adjust the telescope focus until the target appears in clear focus.

e. Adjust the azimuth and elevation controls to center the target image accurately in the reticle pattern.

f. Adjust the microscope focus control and the optical scales THEO ILLUM control on the ECU panel until the H-scale image appears in clear focus.

g. Adjust the micrometer to position the fixed index mark of the H-scale to the center of the nearest double line.

h. If the vernier scale does not appear under the fixed index, adjust the micrometer to position the fixed index mark of the H-scale to the center of the nearest double line.

i. Record the H-scale reading (Figure 8-5) as discussed below.

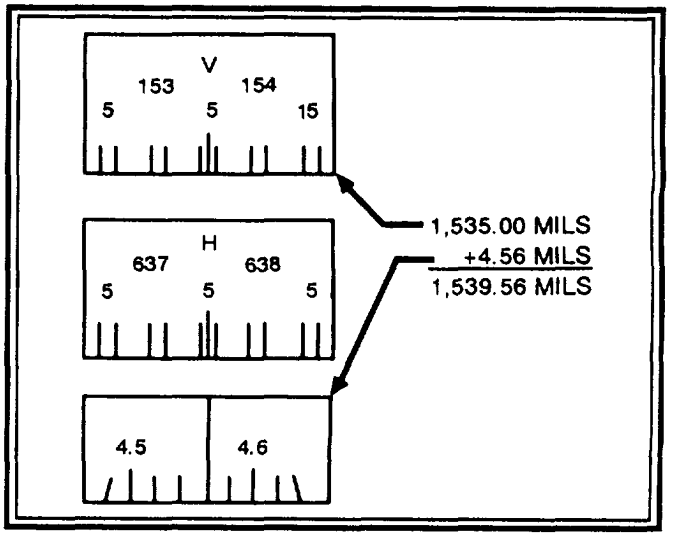
(1) If the fixed index is over the three-digit number, record the number and add a O.

(2) If the fixed index is over a number 5, record the preceding three-digit number and add a 5.

j. Obtain the direct azimuth indication by adding the recorded readings of the horizontal and vernier scales.

k. Read the vertical scales (Figure 8-6) in the same manner as the horizontal scales.

Figure 8-6. **Vertical scale reading**



l. Mathematically average the last four digits of the direct and reverse readings to determine true azimuth (recorded as shown in Figure 4-15).

m. Convert the true azimuth to grid azimuth by using the BUCS. (Refer to Chapter 8, Section II.

8-9. MARCH-ORDERING EQUIPMENT

a. Take down the instrument as discussed be!ow.

(1) Rotate the CAGE-UNCAGE knob counterclockwise until the UNCAGED indicator light is out.

(2) Place the MODE SELECT switch to BRAKE ON. Verify that the BRAKE ON indicator lights and goes out at the completion of the braking sequence (in about 90 seconds).

(3) Place the MODE SELECT switch to PWR OFF.

(4) Verify that the yellow index mark is in the center of the yellow operating band. If it is not, place the MODE SELECT switch to SELF TEST. Place the TEST SELECT switch to BIAS CW or CCW to center the index mark. Then place the TEST SELECT switch to BRAKE, and return the MODE SELECT switch to PWR OFF.

Note. Center the Index mark in the yellow operating band to be sure the GRU will fit in the transit case.

(5) Dismantle the equipment in reverse order of setup for removal from service or transport to a new work site.

b. Secure the transit case by fastening the upper and lower sections of the case together. Place the transit case in the transport case, and fasten the strap latches.

c. When using vehicle transportation, securely tie the transport case down before moving.

8-10. MAINTENANCE

The SIAGL will operate in all climatic categories. However, because of known design limitations of theodolites, use of the procedures below will permit successful operation.

a. Avoid subjecting the instrument to extreme sudden changes in temperature.

b. Allow the instrument to stabilize at the operating temperature.

c. Select operating sites that can shield or protect the instrument from the full effects of the extreme environment. Make use of available tents or other shelters.

d. At the end of a mission, return the instrument to its transport case. Do not allow the instrument to be exposed in conditions where it cannot be used.

e. Remove moisture and fogging of the optics by storing the instrument in a warm, dry place. (Locally fabricated "hot boxes" and a desiccant can be used.)

f. Adhere to the standard operation, transportation, maintenance, and storage procedures prescribed for the various climatic regions.

g. During operations in winds exceeding 20 miles per hour, use a wind shelter.

h. Ensure that the equipment is clean and dry before storage.

Section II

CONVERSION OF GYROSCOPIC AZIMUTH TO GRID AZIMUTH

The azimuth determined by gyroscope is a true azimuth. For use in artillery survey, this azimuth must be converted to grid azimuth. The difference between true azimuth and grid azimuth (Figure 8-7) is called grid convergence.

Figure 8-7. **Relation of true azimuth to grid azimuth**

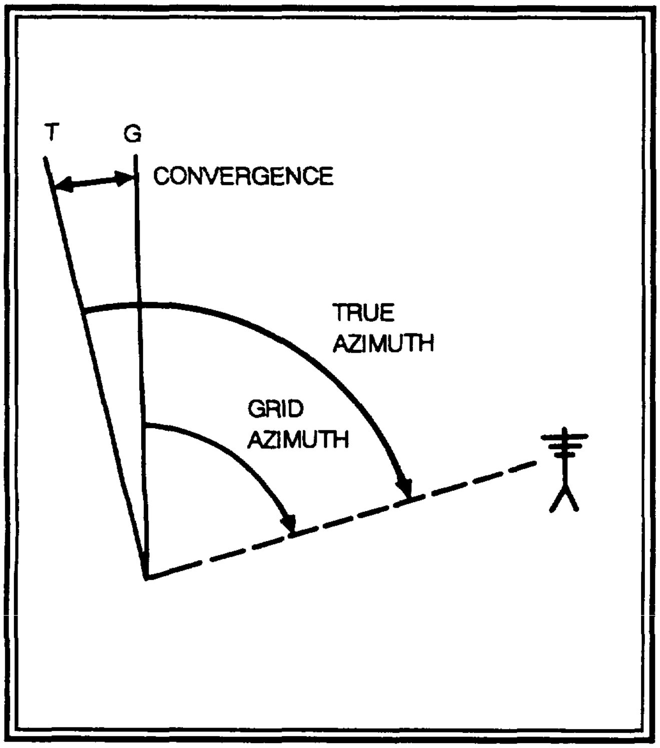
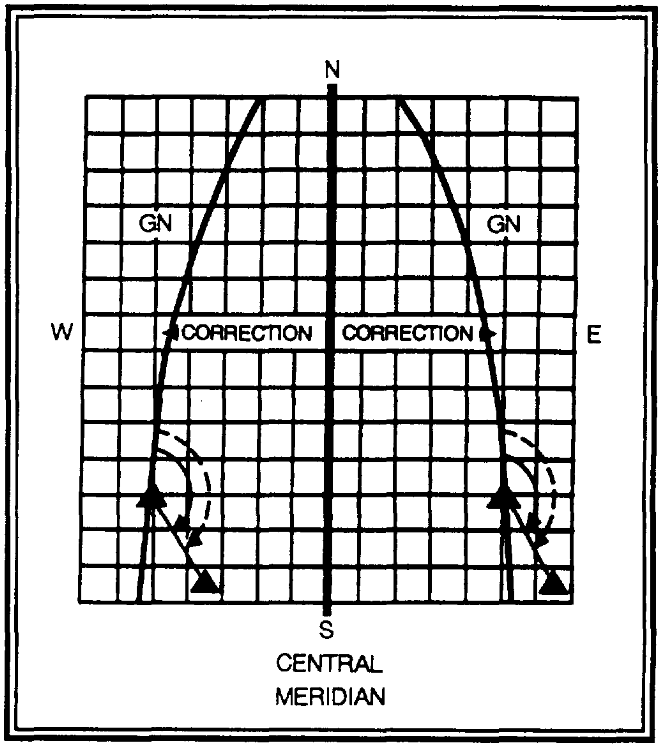


Figure 8-8. **Convergence**



8-11. DETERMINATION OF CONVERGENCE

a. The sign of grid convergence correction is plus when the observer's station is west of the central meridian and minus when the station is east of the central meridian. (See Figure 8-8.) Grid azimuth is determined by algebraically adding the true azimuth and the value of grid convergence. If the azimuth is determined in the Southern Hemisphere, the signs of convergence are opposite the corrections for the Northern Hemisphere.

b. Convergence is a function of both latitude and longitude. Its value is computed on DA Form 5599-R (Computation—Convergence of True Azimuth to Grid Azimuth (BUCS)) (Figure 8-9) by using the geographic coordinates and the grid zone of the observer. (A reproducible copy of this form is included at the back of this book.) This form is basically the same as the other forms that you have used. The top six blocks are for administrative information. Below the administrative data, you will find notes that refer to the operation of the BUCS in this program. Under the notes on the left side of the form, you will find specific instructions on the use of this form. To the right of the instructions, you will find the data record where all known, field, and computed data are recorded. Blocks that are marked with a bold arrow are where field data are entered. Four separate computations for convergence can be computed on one form. (See Table 8-3 for instructions on computing DA Form 5599-R.)

Table 8-3. **Instructions for computing DA Form 5599-R**

STEP	INSTRUCTION
1	There is no prompt. The procedure in the PROCEDURE column is CALL PROGRAM 9. Enter the survey module, and call Program 9.
2	The display prompts GRID CONVERGENCE. There is no procedure. Press the END LINE key
3	The display prompts LAT(-:S) 0.0000000. The procedure is ENTER LATITUDE OF STATION. Enter the value of the latitude. If the latitude is in the Southern Hemisphere, enter it as a negative. Enter the value in the format DD.MMSS. Record the latitude In the LATITUDE block in the top DATA RECORD section.
4	The display prompts LG(-:W) 0.0000000. The procedure is ENTER LONGITUDE OF STATON. Enter the value of the longitude. If the observer is in the Western Hemisphere, enter the value as a negative. Enter the value in the format DD.MMSS. Record the longitude in the LONGITUDE: block in the top DATA RECORD section.
5	The display prompts TRUE AZ: 0.000. The procedure is ENTER TRUE AZIMUTH. Enter the azimuth that is to be converted to a grid azimuth. Record the azimuth in the TRUE AZIMUTH (MILS): block in the top DATA RECORD section.
6	The display prompts GRID ZONE: 00. The procedure is ENTER GRID ZONE NUMBER. Enter the grid zone. This information can be taken from a map of the area. Record the grid zone In the GRID ZONE: block in the top DATA RECORD section
7	The display prompts CONVG: 0.000. The procedure is RECORD CONVERGENCE. This is the difference between true and grid azimuth for the location. Record It in the CONVERGENCE (MILS): block in the top DATA RECORD section.
8	The display prompts GRID AZ: 0.000. The procedure is RECORD GRID AZIMUTH. This is the value of the true azimuth with the amount of the grid convergence applied. Record it In the GRID AZIMUTH (MILS): block in the top DATA RECORD section.
9	The display prompts ANOTHER CVG (Y/N): The procedure is ENTER Y OR N. If this step is answered Y (yes), the program returns to step 2. If this step is answered N (no), the program goes on to step 10.
10	The display prompts END OF MSN (Y/N). The procedure is ENTER Y OR N. If this step is answered N, the program returns to step 9. If this step is answered Y, the program will return to SURVEY PGM MENU REV1.

Figure 8-9. **Sample DA Form 5599-R**

COMPUTATION—CONVERGENCE OF TRUE AZIMUTH TO GRID AZIMUTH (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
SSG ANDERSON	4-12	24 JUN 91
CHECKER: SSG PENA	AREA: FT. SILL, OK	SHEET 1 OF 1 SHEETS

NOTES: 1. IF STEP 9 IS Y PROGRAM GOES TO STEP 2.
2. IF STEP 9 IS N PROGRAM GOES TO STEP 10.
3. FOUR CONVERGENCE PROBLEMS CAN BE RECORDED PER FORM.
4. ENTER FIELD DATA IN BLOCKS MARKED ▶.

STEP	PROMPT	PROCEDURE	DATA RECORD	DATA RECORD
			AZIMUTH MARK: DAN	AZIMUTH MARK: MB-4
			STATION: POTATO	STATION: DAVID
1		CALL PROGRAM 9		
2	GRID CONVERGENCE			
3	LAT(-:S): 0.0000000	ENTER LATITUDE OF STATION	LATITUDE: 34° 40' 42" N	LATITUDE: 34° 39' 43" N
4	LGI :W): 0.0000000	ENTER LONGITUDE OF STATION	LONGITUDE: 98° 17' 26" W	LONGITUDE: 98° 25' 16" W
5	TRUE AZ: 0.000	ENTER TRUE AZIMUTH	▶ TRUE AZIMUTH (MILS): 1742.603	▶ TRUE AZIMUTH (MILS): 6380.171
6	GRID ZONE: 00	ENTER GRID ZONE NUMBER	GRID ZONE: 14	GRID ZONE: 14
7	CONVG: 0.000	RECORD CONVERGENCE	CONVERGENCE (MILS): -7.176	CONVERGENCE (MILS): -5.853
8	GRID AZ: 0.000	RECORD GRID AZIMUTH	GRID AZIMUTH (MILS): 1735.427	GRID AZIMUTH (MILS): 6374.318
9	ANOTHER CVG (Y/N):	ENTER Y OR N		
10	END OF MSN (Y/N):	ENTER Y OR N		

REMARKS:

SAMPLE

DATA RECORD

AZIMUTH MARK:	AZIMUTH MARK:
STATION:	STATION:
LATITUDE: ° ' " N S	LATITUDE: ° ' " N S
LONGITUDE: ° ' " E W	LONGITUDE: ° ' " E W
▶ TRUE AZIMUTH (MILS):	▶ TRUE AZIMUTH (MILS):
GRID ZONE:	GRID ZONE:
CONVERGENCE (MILS):	CONVERGENCE (MILS):
GRID AZIMUTH (MILS):	GRID AZIMUTH (MILS):

DA FORM 5599-R, DEC 86

8-12. DETERMINATION OF CONVERGENCE WITH NOMOGRAPH

a. Table 6a of FM 6-300 is a grid convergence nomograph. This nomograph permits a graphic determination of grid convergence in mils. The arguments for entering the nomograph are the casting coordinate rounded to the nearest 100 meters and the northing coordinate rounded to the nearest 10,000 meters.

b. The convergence is extracted from the right column of the nomograph as discussed below.

(1) With a straightedge, align the value of the casting coordinate on the left column of the nomograph with the value of the northing coordinate on the center (slanted) column.

(2) Read the amount of the convergence in roils from the right column.

(3) Apply the grid convergence to the true, or astronomic, azimuth to determine the UTM grid azimuth.

c. Grid azimuths determined with the nomograph are satisfactory for cannon battery orienting lines obtained by astro observation or gyroscopic means. The nomograph should not be used to determine convergence when directional control is initiated at a battalion SCP for fifth-order survey.

*Section III

North-Seeking Gyroscope

The north-seeking gyroscope (NSG) is a portable gyro compass that determines both true and grid azimuth with an accuracy of ±0.2 mil probable error (PE). (See Figure 8-10 on page 8-14.) The FA surveyor can use the NSG to determine an azimuth, whenever required, that is within artillery orientation specifications. The NSG does not require any precise orientation or computations. Detailed information on the operation and maintenance of the NSG and additional equipment can be found in TM 5-6675-333-10 (TO 33D7-9-53-1).

8-13. PRINCIPLE OF OPERATION

The NSG is a precise survey instrument that finds the direction of geodetic north and determines azimuths relative to geodetic north (true north) or grid north. Trained personnel can determine a grid azimuth (after setup) in about 4 minutes. During the setup, there is a requirement to enter UTM coordinates accurate to the nearest 200 meters casting and 1,000 meters northing.

8-14. COMPONENTS

The NSG is housed in three watertight transport cases. Upon receipt of equipment, inspect each component, including the transport cases, for completeness and damage in accordance with (IAW) TM 5-6675-333-10. The instrument can be transported by vehicle, hand carried by using the carrying handles, or backpacked by using the shoulder straps located in each case.

a. SKK3-1 Gyro Compass. The gyro compass is a single box unit that is designed to fit into the gyro tripod. The heart of the gyro compass is a gyro motor suspended on a thin metal tape. Internally the gyro makes two coarse measurements and one (or two) fine measurements near north to determine an azimuth. The keyboard is attached to the gyro compass, and it is the operator's link to the gyrocompass. It has alphanumerical screens for data entry and display of azimuth and system status. The theodolite horizontal scale can be aligned with respect to the gyro mirror that is viewed through the autocollimation attachment. Power is applied to the NSG via the back of the gyro compass.

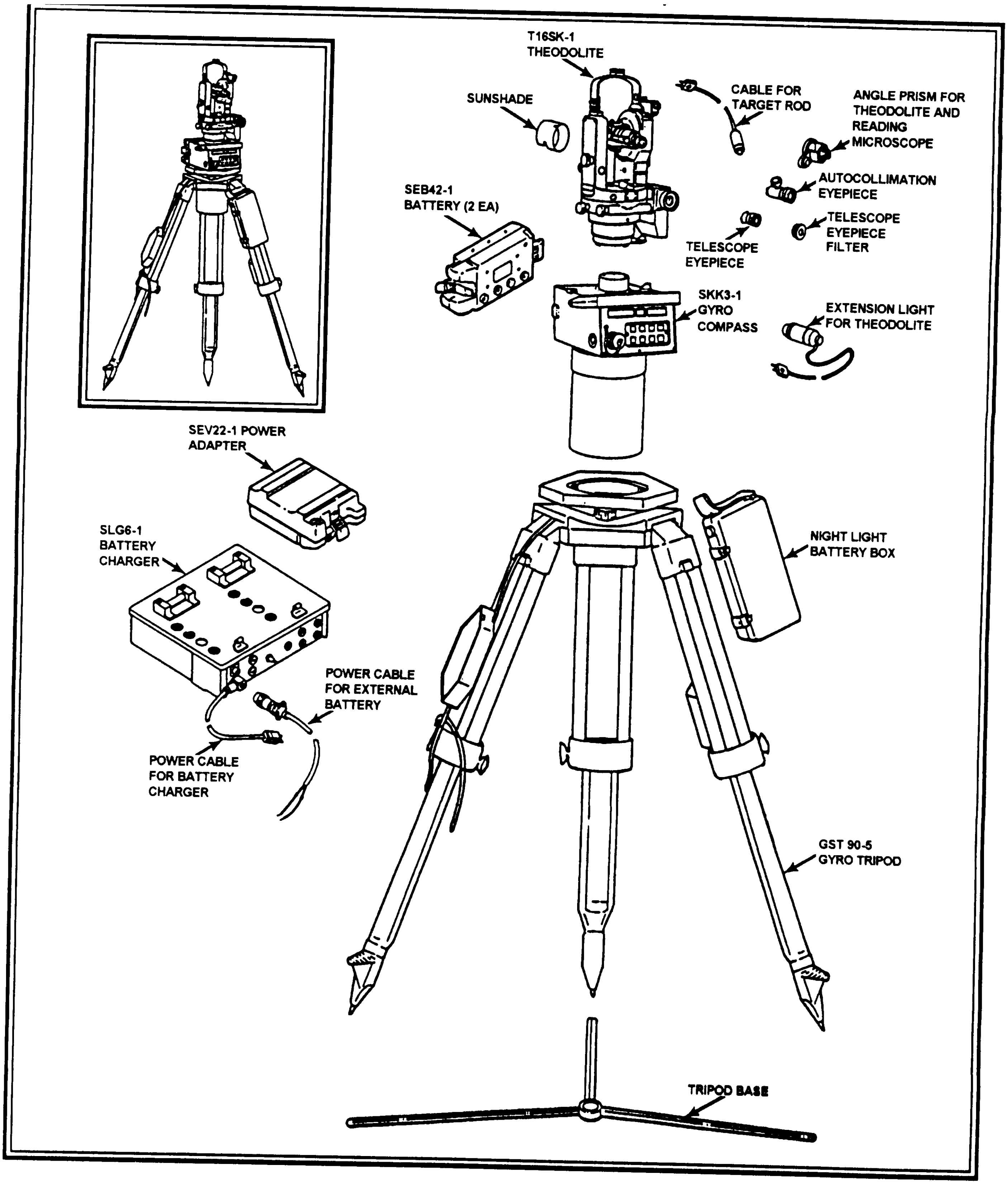
b. Power Supply.

(1) The **SEB42-1 battery** is a rechargeable 24-volt NICAD cell battery that is capable of about 35 measurements at 68° F. Use of lighting accessories will decrease battery life. The battery clamps to the rear of the gyro compass and is protected from discharging by a fuse.

(2) The **SLG6-1 battery charger** is capable of charging two SEB42- 1 batteries at the same time, using either AC or DC. Depending on cell voltage and temperature, the charger automatically provides the appropriate current. The charger will accept 10 to 33 v DC or 115 to 230 v AC. At temperatures between 41°F to 122°F, it takes less than 7 hours to completely charge a dead battery, whereas at 14° F, it may take up to 14 hours.

(3) The **SEV22-1 power adapter** enables the gyro compass to be powered directly from vehicle power (9 v to 33 v). The adapter is protected with a fuse and is connected to the rear of the gyro compass as is the battery.

Figure 8-10. **North-seeking gyroscope**



c. T16SK-1 Theodolite. The theodolite is a modified version of the current T16-84 (upright image). One distinction is the autocollimation box attached to the side, This is used to align the theodolite with the gyro. The scales are read the same as the T 16-84 scales. The T16SK- 1 comes with accessories such as electric lighting for night operations, target rod (barber pole with tricolor lights), eyepiece filter (sun filter), sun shade, adjustment tools, and rain and dust cover. For a complete list of accessories, see TM 5-6675-333-10.

Note. The telescope must be in the reverse position when determining azimuth. The laser range finder studs will face up when in the reverse position. When no range finder studs are present, the microscope (reading scale) will be on the left side of the telescope when facing the keyboard.

d. GST90-5 Gyro Tripod. The gyro tripod has three leveling screws, a circular level, a clamping screw, and a tilting dish capable of lateral movement of 1 inch for simple positioning of the north-seeking gyroscope. For transport, there is a protective cover for the tilting dish.

8-15. INITIAL SETUP PROCEDURES

The NSG can be set up over an established point (point already in the ground), or a point can be established after setup. Because of the size and the lack of an easy method for plumbing the tripod, it maybe easier and faster to establish the point under the plumb bob after first setting up and leveling the NSG. If the point is already established, care must be taken to ensure the instrument is plumbed directly over the point. Setup procedures are in TM 5-6675-333-10.

Note. In a windy environment, setup the NSG as low to the ground as possible. The tripod legs should be extended only enough to allow or leveling procedures.

8-16. SURVEY APPLICATIONS

a. System Settings. When the gyro is turned on, the system will default to the factory settings of **Grid** (azimuth), **NE** (UTM coordinates), and **1U** (standard measurement mode, which includes **self-calibration).** To change the azimuth setting, press the MODE key to select **GEO** (true north) and then press the STEP key. There are two other major settings: local parameters and measurement modes.

(1) Local parameter. The local parameter most commonly used will be NE (UTM coordinates). If the user wants to enter location in geographic coordinates, he selects **LC** (latitude and meridian correction) from the Control Menu.

(2) *Measurement mode.* The measurement mode most commonly used will be 1U. The advantage in using the 1U mode is that the operator does not have to decide whether or not to calibrate and does not have to know the zero-calibration procedure.

b. Entering Data. The keyboard is a **right fill** enter (input) type of keyboard. This means that when data are entered, the last number in a string of numbers is entered first. The decimal point on the keyboard applies only to azimuths.

c. **Entering UTM Coordinates.** Only four digits are entered when entering UTM casting and northing during the setup. When entering the easting coordinate of 546321.5 (accurate to the nearest 200 meters), the user enters 5463 (546,300 meters) by first entering 3, then 6, then 4, and finally 5. When entering the northing coordinate of 3819765.7 (accurate to the nearest 1,000 meters), enter 3820 (3,820,000 meters) by first entering 0, then 2, then 8, and then 3.

Note. When surveying within 1,000,000 meters north of the equator, the user enters three digits northing and four digits casting.

8-17. DETERMINATION OF E-2 ADDITIVE CONSTANT

The E-2 additive constant is a setting that can be input into the gyro computer to compensate for wear and tear on the instrument. When the equipment is new, the factory setting is 0 mils. Over time, the connections that fit the theodolite to the gyro can become worn. This can be caused by rough use of the equipment or just general wear and tear. For this reason, the gyro and theodolite must remain as a set, If for some reason a different theodolite or gyro is used together, a new E-2 additive constant for the pair should be determined. This procedure is performed under the following conditions:

- Upon initial receipt of equipment.
- When azimuth is suspect.
- After rough handling.
- Annually.
- Upon return from maintenance.

Note. The E-2 constant should be done more often, at least semiannually, if the gyro gets a lot of use.

a. Accuracy. To determine the E-2 additive constant, you need at least one survey line with an azimuth known to fourth-order or higher specifications. Ideally, the length of the survey line should be at least 1,000 meters.

> **CAUTION**
> PADS does not meet the requirements to establish an azimuth line for this procedure. Determining the E-2 additive constant is a very critical procedure. This will affect all future azimuths. This procedure should be performed under the direct supervision of the survey chief.

b. Procedure for Determining E-2 Additive Constant.

(1) Set up the instrument at one end of the survey line.

(2) Adjust horizontal collimation error to zero. This should be done whenever the NSG is being used. Any collimation error will affect the accuracy of the azimuth that is determined.

(3) Determine gyro compass azimuth, and orient the theodolite.

(4) Sight in on the other end of the survey line, and read the horizontal scales.

(5) Calculate the azimuth correction. This is the additive constant (E-2). If the measured azimuth is more than the known azimuth, the correction is a negative value. If the measured azimuth is less than the known azimuth, the correction is a positive value. (See the example below.)

EXAMPLE

Known azimuth	4800.0	1600.0
Measured azimuth	4800.2	1599.6
Azimuth error	0.2	0.4
Azimuth correction	-0.2	+0.4

(6) Repeat the steps in paragraphs (2) through (5) five more times (for a total of six corrections).

(7) Algebraically apply the mean (E-2new) additive constant to the present correction (E-2old). (See the example below.)

EXAMPLE

Known Azimuth	Measure Azimuth	Azimuth Corrections	
			E-2new -0.1
			E-2old +0.4
			+0.3
3200.0	3200.2	= -0.2	
	3200.2	= -0.2 (-.4)	
	3199.9	= +0.1 (-.3)	
	3200.0	= 0.0 (-.3)	
	3200.2	= -0.2 (-.5)	
	3200.1	= -0.1 (-.6)	

Mean = -0.6/6= E-2new (-.1)

c. Procedure for Entering the E-2 Additive Constant.

(1) Press the MODE key until CONTROL appears in the status display; then press the STEP key.

(2) Use the cursor and +/- key to enter the code (59382).

(3) Press the STEP key to read the previously stored additive constant.

(4) Compute new additive constant; then algebraically apply it to the old additive constant as shown above.

(5) Use the cursor and +/- key to enter E-2new, and press the STEP key to store it.

(6) Record date, old E-2 additive constant, new E-2 additive constant, and horizontal collimation error (if any) on a label attached to the gyro and protected by some sort of waterproof material.

> **Note.** If the azimuth correction appears excessive, the accuracy of the azimuth line must be verified. Another option would be to use another verified azimuth line.

8-18. MAINTENANCE

Refer to TM 5-6675-333-10 for preventive maintenance schedule and troubleshooting table.

CHAPTER 9

POSITION AND AZIMUTH DETERMINING SYSTEM

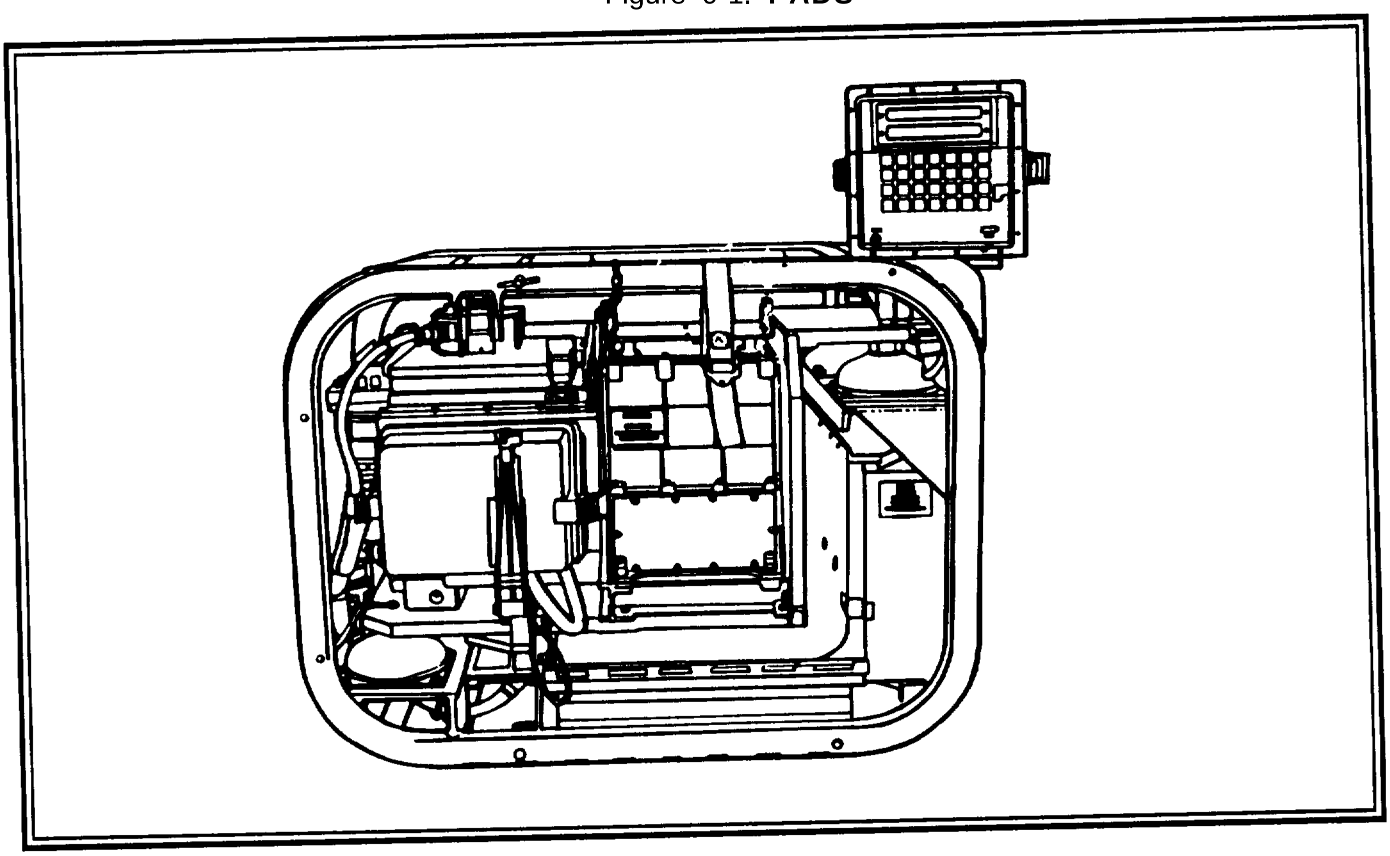
The PADS is a self-contained inertial surveying system. It can be used to rapidly and accurately determine position, azimuth, and elevation (PAE) in either ground or airborne survey operations. It is a precise and sensitive piece of equipment and should be handled with the same care as any other precise survey instrument. Detailed information on the PADS installation, operation, maintenance, and additional equipment is given in TM 5-6675-308-12.

9-1. SYSTEM USES AND CONFIGURATIONS

a. System Uses. PADS is used to conduct FA surveys critical to the fire control function. PADS provides a common grid for weapon and TA systems. It can determine position, elevation, and grid or true azimuth for each point surveyed.

b. Configurations. The system (Figure 9-1) can be installed in and operated from an M151 -series vehicle, a HMMWV, a commercial utility cargo vehicle (CUCV), and the small-unit support vehicle (SUSV). These vehicles must have alternators of 60 amperes or greater. PADS can also be operated from a UH-1 helicopter and an OH-58 light observation helicopter. Mounted in the M151-series or HMMWV, the PADS can also be transported or operated in a CH-47 cargo helicopter. PADS can be transferred to UH-60 (Blackhawk) helicopter. (The UH-60 needs a power converter to convert the helicopter's AC power to DC power.)

Figure 9-1. **PADS**

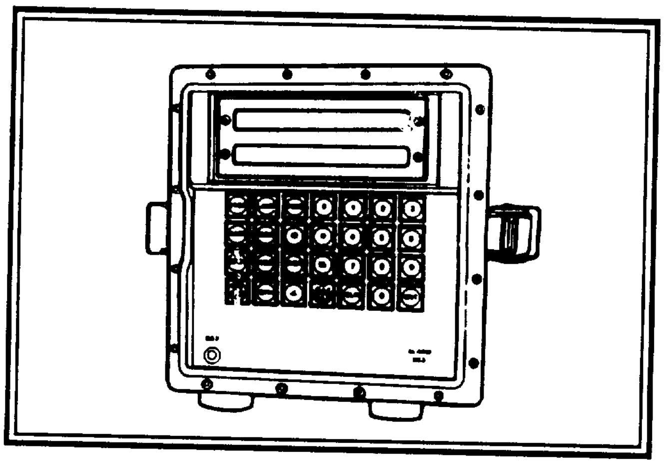


9-2. PADS COMPONENTS

a. PADS primary pallet contains the basic electronic modules for the PADS. These are the control and display unit (CDU), power supply (PS), inertial measurement unit (IMU), and computer.

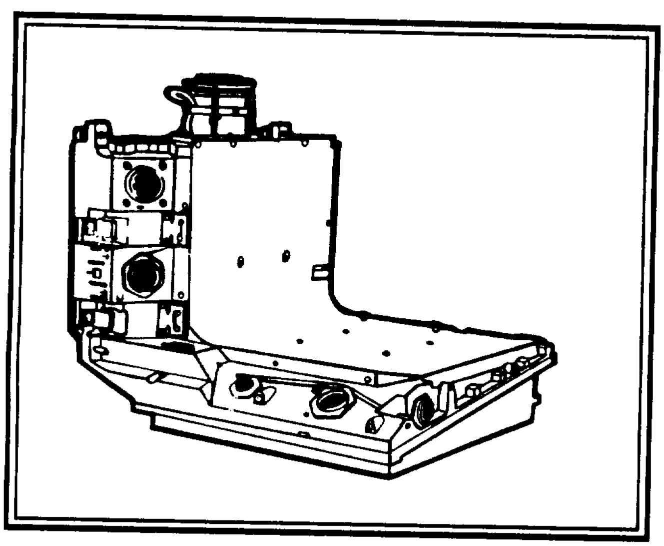
(1) The CDU (Figure 9-2) has a keyboard and an alphanumeric display for data entry and display of survey data and system commands. The CDU is the input-output device for the system.

Figure 9-2. **Control and display unit**



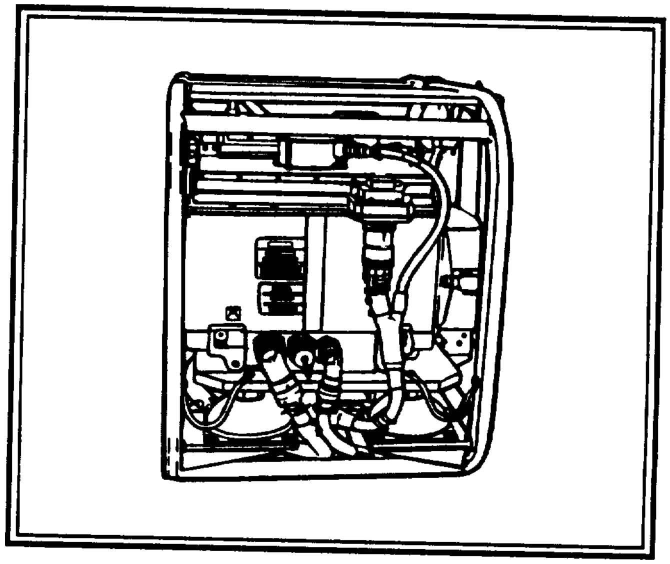
(2) The PS (Figure 9-3) receives unregulated power from the transporting vehicle or PADS batteries. It provides controlled and regulated power to the IMU, computer, and CDU.

Figure 9-3. **Power supply**



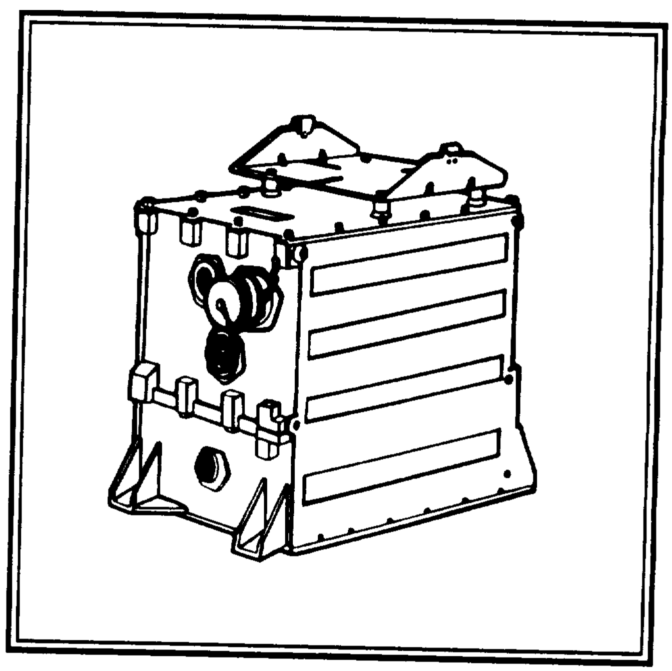
(3) The IMU (Figure 9-4) contains the gyroscopes, accelerometer sensors, and associated electronics needed to maintain the survey coordinate frame. It will measure distance traveled to each coordinate axis.

Figure 9-4. **Inertial measurement unit**



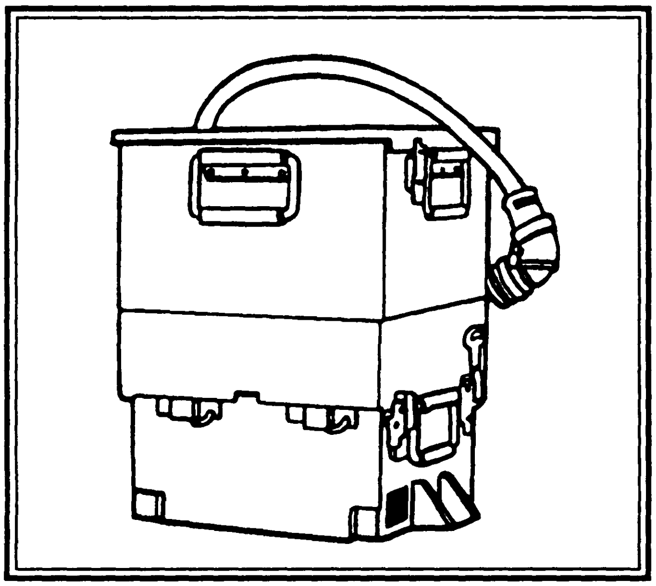
(4) The computer (Figure 9-5) Processes IMU data, computes survey data, and provides system control functions. The computer accepts data from and sends data to the CDU.

Figure 9-5. **PADS computer**



b. The secondary pallet is the battery box. The battery box (Figure 9-6) contains two 12-volt batteries. They are used to continue operations while the PADS is transferred from ground vehicle to helicopter or from helicopter to ground vehicle. It supplies additional power requirements for initialization and provides a backup power supply in case the vehicle power fails. It also houses cables, tools, and small hardware items.

Figure 9-6. **Battery box**



9-3. PADS OPERATION

PADS operation requires a two-man party, an assistant PADS operator (driver-radio operator), and a PADS operator (PADS party chief). Both must be qualified in FA survey.

a. Preparation for Operation. A PADS mission begins on receipt of a warning order with before-operation checks and services, followed by initialization. (See TM 5-6675 -308-12.) After arrival at the initialization point (which must be within 100 meters horizontal and 10 meters vertical accuracy), activate the system by switching circuit breakers 1 and 2 on and pressing the ON-OFF button. Enter the spheroid, grid zone number, casting and northing coordinates, and elevation. The PADS then automatically aligns itself. Initialization takes from 30 to 45 minutes, depending on ambient temperature. After the PADS has completed initialization modes 0 through 8 and the CDU shows a flashing GO light, the system is ready to be updated. Drive to the SCP, and maneuver the PADS over the SCP by using the plumb bob suspended from the plumb bob arm for alignment. Enter the correct grid coordinates and height of the SCP. PADS is then ready to perform the survey mission. The SCP may not be accessible to the PADS by using the plumb bob. In this case, update the system by using a theodolite. The procedures for updating the PADS by using a theodolite are discussed in TM 5-6675-308-12, Chapter 3.

b. Zero-Velocity Corrections. Zero-velocity (Z-VEL) corrections must be performed en route to points to be surveyed and during the survey mission. The Z-VEL correction allows the PADS to correct itself to its present location. Ten minutes is the maximum Z-VEL time allowed. This is associated with battalion fifth-order survey requirements. If more accurate survey control is necessary, a 5-minute Z-VEL correction (associated with div arty or TAB fourth-order requirements) must be performed. PADS is automatically set for a 10-minute Z-VEL time. To change this time, consult TM 5-6675-308-12. The desired Z-VEL time is entered into the computer after initialization. To perform a Z-VEL correction, the vehicle must be at a complete stop and the STOP button on the CDU must be pressed. In aircraft operations, the aircraft must be stationary on the ground, but it can continue at flight idle. The PADS requests a Z-VEL correction be performed by alternately flashing the GO and STOP indicators and sounding the DS3 ALARM. This audible alarm will sound 30 seconds before the required Z-VEL correction.

c. Survey Operations. On arrival at the position to be surveyed, maneuver the vehicle with PADS over the point to be established. The PADS operator must know what data the user requires. He must decide which marking procedure (plumb bob or theodolite) will be used. If an orienting line is required in the mission, a two-position azimuth mark-must be performed. The two-position azimuth mark using the plumb bob requires that the two points beat least 100 meters apart and intervisible, The PADS automatically computes the grid azimuth from the second marked position back to the first marked position. The coordinates that the PADS computes are unadjusted. This unadjusted data may be given to the users with the understanding that the adjusted data will be given upon completion of the mission. The procedures for performing a two-position azimuth mark and adjusting data are also discussed in TM 5-6675-308-12, Chapter 3. Because of terrain or unit SOP, two-position azimuth marks may not be the preferred method. In this case, the second method, marking position, azimuth, and elevation by using the theodolite, would be used, since there is no distance requirement.

Note. Do not use PADS coordinates of two stations to compute the azimuth between those stations. The error incorporated within the computed azimuth could cause artillery rounds to miss the target. This could result in the rounds impacting on friendly units. Only use azimuths from a two-position mark or a theodolite mark.

d. Shutdown Procedures. On completion of the survey mission, the PADS must be shut down. The PADS can be operated for an **unlimited** amount of time, but you must perform an update every 7 hours of operation. If the PADS is shut down and you are required to do an additional mission after shutdown, you must wait 2 minutes, then reinitialize. After initialization is complete, update over a known SCP. Before shutdown, close out the survey over a known SCP by updating the system and recalling the adjusted data. The first step in the shutdown procedure is to conduct a PADS battery test. This test checks the PADS battery operation under load. After the battery test, turn off the system. (Detailed shutdown procedures are listed in TM 5-6675-308-12, Table 3-2.)

9-4. PADS MISSION CLOSURE

a. Field artillery surveyors are accustomed to describing survey accuracies in terms of survey specifications for fourth-order (1:3,000) and fifth-order (1:1,000) surveys. These specifications are described in Appendix B and serve as rejection criteria for conventional survey techniques. PADS operations are similar to a conventional traverse. The computer determines the position of a point by using input from the accelerometers (compared to measuring the distance with a tape or distance-measuring equipment). Conventional traverse errors usually increase during the survey because of systematic errors in the measurement of angles and distances. PADS errors also generally increase as the PADS proceeds along the survey route. However, absolute rejection criteria cannot be applied to PADS position data. This is because the error will vary with mission length, duration, system characteristics, Z-VEL correction periods, and other factors. In units that require fourth-order conventional specifications, the PADS uses 5-minute Z-VEL corrections. In units that require fifth-order conventional specifications, it uses 10-minute Z-VEL corrections. Acceptability of a conventional survey is determined by comparing the radial error of closure with a maximum allowable error in position and similar criteria for azimuth. PADS performance is checked by using an update rejection procedure.

b. A PADS survey should be started on fourth-order or higher conventional survey control or on a PADS SCP established by using 5-minute Z-VEL corrections. It should be closed on a second SCP of an equal or higher order survey. If a second known SCP does not exist, a PADS survey must be closed on the starting point. If PADS accepts the data, then the survey is good, if not, refer to TM 5-6675-308-12, Table 3-3.

★9-5. UPDATING THE PADS

Entering accurate position and/or elevation data into the PADS is called updating. Updates should be performed over fourth-order or higher conventional survey control. If known control is not available, update over a PADS SCP established by using 5-minute Z-VEL corrections, or when no known PADS SCPs are available, update by using the precise lightweight GPS receiver (PLGR). (Refer to TM 5-6675-308-12, Change 3, page 3-36.12). The PADS must be updated after initialization before it can provide accurate survey data. The first update after initialization is called the initial update. The survey mission starts with the initial update. The PADS must also be updated at the end of a survey mission. This closing update should be on a second known SCP. lf a second known SCP does not exist, a PADS survey can be closed on the starting point, or when no known SCPs are available, by using the PLGR. As in conventional survey, if a survey is closed on the starting point (or GPS), there is no check on the starting control. Care should be taken to verify these data by using all available means (another GPS, maps, and so on). The PADS will either accept or reject the update. If it accepts the update, the PADS automatically adjusts all data recorded since the previous update. The adjusted data replace the unadjusted data stored in the system computer memory. The adjusted data must be provided to all users.

> **Note.** Position and/or elevation updates can be performed independently.

a. Update Procedures With Plumb Bob or Theodolite. Procedures used to update position and/or elevation with the plumb bob or theodolite are listed in TM 5-6675-308-12, Table 3-2, steps 3, 4, 5, and 6.

b. Update Acceptance. After the operator has entered the known trig list positions and/or elevation data of the SCP into the PADS, the system automatically tests the difference between the update coordinates (trig list data) and the PADS position coordinates. If the difference (error) is within the built-in calibration tolerance parameters, the update is accepted and the CDU displays ID* PAE U-U. This display tells the PADS operator that the PADS has met the specified accuracy needed for that update and all surveyed stations established back to the previous update. When the update has been accepted by the PADS, the survey is considered a closed survey within the prescribed accuracy.

c. **Update Rejection.** If the difference (error) is outside the built-in calibration tolerance parameters, the PADS recues for the update data by displaying a flashing E on the CDU, followed by the data the operator entered. The flashing E indicates a possible update rejection in position. The operator then checks the probable reason for the update rejection and takes the appropriate corrective action as outlined in TM 5-6675-308-12, Table 3-3.

9-6. PADS SURVEY PLANNING

Because of the speed and accuracy of the system, extensive planning and a map reconnaissance must be performed. The mode of travel, route, weather, terrain, and tactical situation must be considered. Because of time and distance limitations, SCPs nearest the area of the PADS mission must be used for starting control. For detailed information on PADS planning and use of the PADS in FA units, refer to Chapters 14 and 15.

9-7. PADS USE IN SPECIAL SITUATIONS

The following are special situations in which the PADS can be used. No additional personnel or equipment is required.

★ **a. Establish a Declination Station.** When the PADS is used to establish a declination station, the criteria for the predetermined site is the same as that described in paragraph 14-5d. The preferred procedure, time and tactical situation permitting, is to travel directly from an update point and determine the mean of two azimuths for each azimuth line (as a check) by following normal PADS procedures for determining an azimuth. The azimuths should agree within 0.4 mil. To close out the declination station survey, update as soon as possible and record adjusted data. Record and include measured vertical angles with the declination station data. (The vertical angle is not used with PADS but will be used at the declination station to determine a vertical angle correction when the aiming circle is declinated.)

★ **b. Using the PADS With Assumed Data.** The PADS can be operated in areas where known survey control or GPS data are not available. In such cases, the PADS operator must know the spheroid and UTM grid zone and must use all existing support elements (S2, SPCE) to determine the data needed to initialize the system. The initialization data used should be as accurate as possible. When conducting a PADS operation under these conditions, the PADS operator will update the system over the initialization point (assumed point) and all control will be extended from this point to ensure all elements are on a common grid. To close out this type of survey, the PADS must be updated over the initialization-initial update point (assumed SCP). This procedure should be used only in special missions where known survey control is not available.

c. PADS Operation at Night. The PADS can be operated at night under blackout conditions as long as the CDU keyboard can be read with the lamps dimmed or with a flashlight with strict light control. Only the CDU status indicators and data display can be dimmed. The keyboard is either fully illuminated or dark. If autoreflection is to be performed, the theodolite front sight can be painted white with typewriter correction fluid or can be illuminated with the hand lamp. The end of the azimuth line must be illuminated. Under blackout conditions, the two-position mark method is preferred in establishing an azimuth line. The only illumination required for this method is to aid in marking the station. For tactical reasons, the PADS team must be thoroughly familiar with all indicators and controls and the CDU keyboard.

d. PADS Decontamination. While in a survey mission, the PADS can continue to operate in a nuclear, biological, chemical (NBC) environment with partial decontamination, To partially decontaminate the system, the PADS operator should use the M13 decontamination kit. The CDU, plumb bob arm, porro prism cover, circuit breaker covers, flashlight, and battery box latches should be decontaminated. When the survey mission is complete and the unit has established a decontamination point, the entire system can be decontaminated with soapy water. When the entire system is to be decontaminated, extreme caution must be used to prevent exposing the system to high-pressure water. The PADS operator also must ensure that the circuit breaker covers are closed and that any unconnected cable connector is capped or taped.

*CHAPTER 10
FORWARD ENTRY DEVICE METEOROLOGICAL/SURVEY

The FED MSR is a digital communications device that allows the artillery surveyer to process command and control information and to perform the full range of calculations that are currently performed by the BUCS (Survey REV 1 and DDCT modules). The FED MSR also gives the surveyor limited forward observer capabilities and graphics that will allow the user to display tactical symbols and other graphical information.

Section I
OVERVIEW

When properly prepared for operation, the FED MSR is configured to allow surveyors to choose the survey option desired. The surveyor can perform limited forward observer functions and can manipulate and display maneuver and fire support information.

10-1. SYSTEM CONFIGURATION

a. The basic device for the FED MSR is the simplified hand-held terminal unit (SHTU). (See Figure 10-1.) The quantity authorized to survey elements is the same as the current authorization for the BUCS (Table 12-1, page 12-1).

b. The FED MSR is issued with a printer (printer, automatic data processing), Cables are included for connection to a communications device, printer, and external power source.

c. The FED MSR is powered with an internal battery (BA 5800/U lithium) or external 24 v DC (vehicle) power source. The average life of the BA 5800/U battery is 18 hours.

d. The FED MSR has a continuous memory capability. This allows for the retention of data base information while the device is turned off.

e. The screen of the SHTU is a dot matrix liquid crystal display. It is capable of displaying 25 lines of information. The device has a screen saver that blanks the screen after 30 seconds of nonuse.

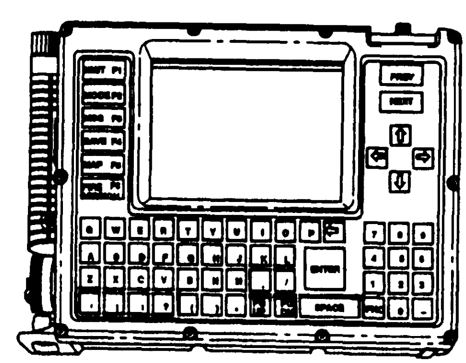
f. The device has an audible alarm. It alerts the oeprator when a message has been received or an error has been made.

g. The alphanumeric keyboard is arranged like a standard computer keyboard with additional special function keys. TM 11-7025-300-10, Chapter 1, explains use of the function keys.

Note. See TM 11-7025-300-10 for warning and safety statements concerning use of the BA 5800/U lithium battery. See TM 11-7025-311-12&P for caution and warning statements concerning connection of the printer.

h. The SHTU will accept forward observer command and control (FOCC) application software and MSR software. The memory capabilities of the SHTU does not allow for loading more than one application. THE MSR is the software the surveyor should use. If FOCC software is loaded, it will need to be erased and MSR software installed. See TM 11-7025-300-10, Chapter 2, for detailed upload-download procedures.

Figure 10-1. **FED MSR (SHTU)**



> **Note.** If upload-download procedures fail using MSR.TLF as the file name, rename the ADA_HEAP file (see Figure 10-2). Then retry according to the upload-download procedures in the TM. The renaming of this file will be necessary if the FED MSR was **turned off** before exiting the software. To avoid the renaming procedure, **always** exit to OPNL SERVICES before turning off the FED MSR.

10-2. PREPARATION FOR OPERATION

Before placing the FED MSR into operation as a communications device, system operational parameters need to be established. These parameters are entered through the FED STATUS selection (option J) from the MODE MENU. The FED STATUS selection provides the operator with the means to enter information concerning the following:

- Local address and observer number of your device.
- Type of communications device being used.
- Current date and time.
- Current FED location.
- Map modification data.
- Auto target and survey point numbering.

a. Local address and observer number information can be found in the current signal operation instructions (S0I). To ensure communications with other elements, member data (address, observer number, and device type) must be entered. Member data can be entered by selecting MEMBER DATA (option F) from the MODE MENU. See TM 11-7025-300-10, Chapter 2, for detailed information on entering member data. Local SOPs will dictate the elements that will be entered into the member data table.

b. The FED MSR allows the operator to enter authentication data required for automatic authentication of messages. The authentication table provides for the entry of four groups of authentication codes. Each authentication group can be assigned a specific destination address. More than one authentication group can be assigned to one destination address. Authentication codes are contained in current SOIs. A two-letter **key code** is used to verify the use of the authentication tables. The two-letter key code has to be entered and verified each time a message is sent by using the authentication tables. The authentication tables can be used in the secure or nonsecure mode. Local SOPs will dictate the use of the authentication tables.

10-3. SURVEY OPTIONS

The SURVEY OPTIONS MENU of the FED MSR gives the user access to the Survey Control Point File and survey order functions of the device.

a. The MSR will maintain three survey orders (Received Survey Order, Working Survey Order, and Issued Survey Order) in memory at any time. Survey orders can be maintained in either full five-paragraph form or the abbreviated two-paragraph form (fragmentary order [FRAGO]). The issued and received survey orders can be updated and/or edited by copying them to the Working Copy file.

b. The Survey Control Point File maintains information on as many as 360 survey positions. The amount of SCP information maintained in the data base depends on the echelon at which the MSR was initialized. The file can be used to store and transmit firing element information and SCP data. The Survey Control Point File does not differentiate between an SCP and a surveyed position. The Survey Control Point File can be searched by using parameters identified by the operator and SCP information transmitted to other members. Members can also search the Survey Control Point File of other members by transmitting search criteria. If survey position information is entered into the file by using geographic coordinates (latitude and longitude), the device will automatically convert the geographic coordinates to UTM coordinates and enter the data in the easting and northing fields of the survey point message.

Figure 10-2. **Renaming the ADA_HEAP file**

From the MODE MENU:

Enter OPNL SERVICES by pressing [N].
Respond to the WARNING message by pressing [Y].
View the MAIN MENU.
Press [6] (EXIT TO DOS).
Type [D][:]; then press [ENTER].
Type [R][E][N][A][M][E] [SPACE] [*][.] [D][T][B] [SPACE] [*][.][D][T][A] .
Press [ENTER].
Type [D][I][R] ; then press [ENTER] key. Ensure file ADA_HEAP DTA is present.
Type [E][X][I][T] ; then press [ENTER] to return to the MAIN MENU.

10-4. FORWARD OBSERVER OPERATIONS

Forward observer messages are found under the MESSAGE TYPE (option I) selection from the MAIN MENU. Forward observer messages can also be accessed from the LOCAL MISSION FILE. These messages permit the operator to direct engagement of enemy targets by indirect fire and to transmit and/or receive battlefield information messages. Detailed information on the use and capabilities of these messages can be found in TM 11-7025-300-10, Chapter 3.

10-5. GRAPHICS CAPABILITIES

The graphics of the FED MSR allow the operator to manipulate and display maneuver and fire support information stored in the data base. The user identifies the map area that will be displayed by entering minimum and maximum easting and northing values in the MAP MODIFICATION DATA under the FED STATUS selection from the MODE MENU. Information entered into the Unit List, Equipment List, Geometry List, and Point/Installation List files will be displayed on the graphics map. Information listed in the Member Data File and Survey Control Point File will also appear on the graphics map. The graphics map uses icons to display and identify information on the graphics map. The icons represent military symbols that can be found in FM 101-5-1. The graphics map displays information based on the map level that is present on the graphics map. There are four different map levels available in the FED MSR. Each map level displays a different set of icons. Some icons will be visible at more than one map level. The icons that appear at each of the map levels are listed in TM 11-7025-300-10, Appendix C. The graphics map will display an area ranging from 1,000 meters to 99,999 meters, with a default setting of 8,000 meters. TM 11-7025-300-10 provides detailed information on the use of the graphics map.

Section II

SURVEY CALCULATIONS WITH THE FED MSR

The survey calculations function of the FED MSR allows the operator to perform various types of survey calculations without performing any setup procedures as described in Section I. The type of survey calculation desired is selected from the SURVEY CALCULATIONS MENU (Figure 10-3). The FED MSR will maintain up to three completed calculations in its data base for each type of calculation. Completed calculations are automatically saved in the data base. Records remain in the data base until the operator either deletes or writes over the record. The device will allow the operator to establish a new calculations record or to view and/or edit an existing one.

Figure 10-3. **SURVEY CALCULATIONS MENU**

SURVEY CALCULATIONS MENU

A = AZIMUTH/DISTANCE
B = TRAVERSE
C = TRIANGULATION
D = RESECTION
E = ALTITUDE METHOD (SUN)
F = ALTITUDE METHOD (STAR)
G = HASTY ASTRO (SUN)
H = HASTY ASTRO (STAR)
I = STAR ID
J = POLARIS TABULAR METHOD
K = GRID CONVERGENCE
L = TRIG TRAVERSE
M = SUBTENSE
N = INTERSECTION
O = ARTY ASTRO (SUN)
P = ARTY ASTRO (STAR)

(PRESS KEY CORRESPONDING TO THE DESIRED OPTION, <PREV>=RETURN)

00:00:00

10-6. SURVEY CALCULATIONS

a. FED MSR Forms. The FED MSR calculation forms were designed to be similar to the BUCS forms to simplify their use. There are five major parts to the forms:

- Administrative data.
- Instructions.
- Required fields.
- Data record.
- Remarks.

Some of the forms have additional information on the back. The use of the different parts of the FED MSR forms and the procedures for computing them are discussed below. (Detailed instructions for the use of the FED MSR are in TM 11-7025-300-10.)

(1) Administrative data. At the top of the form, right below the form title, there are six blocks. These blocks are used to record administrative data. When conducting survey operations, all required information must be entered. This will ensure that proper records of survey operations can be maintained.

(2) Instructions. Below the administrative data blocks are the instructions for the use of the form, to include the following:

- How to call up the required computation.
- How to determine what field data are required.
- How to display the *window of legal entries.*
- How to calculate the data.

(3) Required fields. On the left side of the form, under the instructions, are the required fields blocks. These blocks show which fields appear in the computation. This part of the form also shows where to record computed data.

(4) Data record. To the right of the required fields blocks are the data record blocks. These blocks show where to enter field data (blocks marked with a filled-in arrow). They are used for recording station names and computed data.

(5) Remarks. This block is located under the required fields blocks and is provided to record any remarks that are pertinent to the survey being computed. There are no particular remarks that are required; however, any information that could affect the survey should be included.

b. Selecting a Calculation. Once a calculation has been called up from the SURVEY CALCULATION MENU by pressing the key that corresponds to the desired calculation, the summary list for that particular calculation will appear.

(1) To select an empty file (one without a name or main points), whether it be A, B, or C, select the empty file by pressing the corresponding letter. For example, if A and B are full, then select C.

(2) To delete a file if they are all full, the operator can select one of the full files by pressing the corresponding letter. When the calculation screen appears, delete only the one file by pressing the X key.

(3) To delete the entire list, press the X key at the Summary List screen. All files for that particular calculation will be permanently deleted.

c. Entering Data. Once a calculation has been selected and the applicable DA form has been filled in, the next steps are to enter field data and record the computed data. When the calculation is initially called up, the first required field will be highlighted in black.

(1) When entering data into **any** of the calculation programs, all fields that are followed by a question mark (?) must have an entry. If any question marks remain when the user tries to perform the calculation, the program will error and return to the step containing the question mark.

(2) The FED MSR will not accept data into the computation unless the window of legal entries is displayed on the screen. The ENTER key acts as a toggle for displaying the window of legal entries, which shows the range of values that can be entered in any field. TM 11-7025-300-10, Section 5, and Appendix B list the legal values for all required entries. The window must be displayed before trying to enter or edit data in a specific field.

(3) Entry of data is in a fixed format that requires the operator to complete all available characters for all fields. This requirement uses preceding and ending zeros for values that do not include the full range of characters provided. for example, when entering northing data, there are eight required digits to the left of the decimal; therefore, you must enter a zero (unless near the equator) before entering the normal seven-digit northing. When naming stations, you would have to fill in the remaining ?s with spaces if the name is not as long as the required field.

(4) When a field is completely filled in, the next field will automatically be highlighted and the window will still be displayed. You can also toggle between fields by using the up and down arrows to check your data or to edit data already entered. The ENTER key must be pressed before the C key for calculating is pressed so that the window of legal entries is removed. If this is not done, the FED MSR will not respond.

d. Editing Calculations. When the need to edit a calculation arises (for example, rerunning a survey or converting to common control), you can edit the calculation while still in the calculation or by recalling it.

(1) To edit the calculation from the solution screen, press the S key to show input data. The first screen of entered data will appear. To move through the calculation within the pages, use the PG UP or PG DN keys and the up and down arrow keys.

(2) To edit the data, do the following in order of listing:

- Move the cursor until the required field is highlighted.
- Press the ENTER key to display the window of legal entries.
- Replace previously entered data with the new data.

When all required fields have been edited, press the C key to calculate. The display will move to the next page. Continue to edit data until you reach the solution screen.

(3) To edit a calculation after you have left it, you must recall the calculation from the Summary List. Once you recall the calculation, the solution screen will appear. You then follow the same procedures as when you were originally in the calculation.

e. Special Operations. When computing with the FED MSR, there are several options available when in a calculation. At the bottom of the screen, there is a list of options with the key to press to activate the option.

(1) One such option is ACCESS SCP FILE (A key). This function is used when the SCP file contains the data for the known control being used in a particular calculation. For example, when computing a resection and one or more of the known points (left, center, right) are in the SCP files, you can retrieve the data and input them into your calculation by pressing the A key. Once in the Survey Control Point File, you can select from the list or perform a search to find known points to use for your calculation.

(2) Another option when computing a survey is the PREV return function. When you press the PREV key from within a calculation, you will return to the Summary List. When you press the PREV key from the Summary List, you will return to the SURVEY CALCULATIONS MENU and you can restart operations.

(3) As previously mentioned, you can use the X delete function to delete the calculation if you need a blank record. However, the data will be lost.

10-7. AZIMUTH AND DISTANCE CALCULATION FILE

a. The Azimuth and Distance Calculation File is designed to compute the grid azimuth and distance between two stations. The user must input the known UTM coordinates of both stations, or select points from the Survey Control Point File to be imported into the Azimuth and Distance Calculation File. (See TM 11-7025-300-10, page 5-37, for step-by-step procedures.)

b. DA Form 7356-R (Computation of Azimuth and Distance From Coordinates (FED MSR)) (Figure 10-4) is used to record the data determined. The instructions for computing the data for this program are shown on the front of the form.

10-8. TRAVERSE CALCULATION FILE

a. The Traverse Calculation File is designed to compute the grid azimuth, coordinates, and height of up to 40 main scheme traverse stations and 10 offset points from the known data of the starting station and the field data of the traverse. The program allows for entry of either slope or horizontal distance. If slope distance is entered, the program does a conversion to horizontal distance. The program allows the user to access the Survey Control Point File to import information for the starting point. The program computes closing data to include the following:

- Azimuth correction.
- Height correction.
- Total traverse length.
- Radial error.
- Accuracy ratio.

Traverse adjustment is computed by pressing the T key at the CLOSURE SOLUTION screen. A list of traverse points can be displayed by pressing the P key from the CLOSURE SOLUTION screen of a completed traverse. The list of traverse points displays adjusted data if the survey was adjusted. If the survey was not adjusted, unadjusted data are displayed. (See TM 11-7025-300-10, page 5-40, for step-by-step procedures.)

b. DA Form 7357-R (Computation of Coordinates and Height From Azimuth, Distance, and Vertical Angle (FED MSR)) (Figure 10-5) is used to record the data determined. The instructions for computing the data for this program are shown on the front of the form. Closure and adjustment data are recorded on the reverse of DA Form 7357-R (Figure 10-6).

10-9. TRIANGULATION CALCULATION FILE

a. The Triangulation Calculation File computes coordinates, height, azimuth, and distance by triangulation. The program will compute a single triangle or a chain up to 40 triangles. The program allows access to the Survey Control Point File for importing data for the starting point. When entering the name of the starting station, the user identifies the starting point as B or C. This step is where the program determines the side to be computed for the first triangle of a chain. For the first triangle, the user must also identify the side to be computed for the **next** triangle of the chain (prompt **NEXT TRI BASE BA/CA).** As the computation continues, this step is repeated (enter the side to be computed for **next** triangle). When entering data for the last triangle in a chain or a single triangle, enter either BA or CA (the side to be computed for the last triangle was entered in the previous triangle) at the prompt NEXT TRI BASE BA/CA. The program will not compute a triangle without an entry in this field. (See TM 11-7025-300-10, page 5-45, for step-by-step procedures.)

Figure 10-4. **Sample DA Form 7356-R**

COMPUTATION OF AZIMUTH AND DISTANCE FROM COORDINATES (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SSG HERNDON	NOTEBOOK REFERENCE:	DATE: 8 JAN 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select AZIMUTH/DISTANCE (option A) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the AZIMUTH/DISTANCE SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶. 3. Four computations can be recorded on this form. 4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OCC STA: ?	NAME OCC STA: KATHY	NAME OCC STA:
ENTER EASTING: ?	▶ EASTING: 554428.24	▶ EASTING:
ENTER NORTHING: ?	▶ NORTHING: 3835721.94	▶ NORTHING:
ENTER NAME AZMK: ?	NAME AZMK: OCS WT	NAME AZMK:
ENTER EASTING: ?	▶ EASTING: 553398.40	▶ EASTING:
ENTER NORTHING: ?	▶ NORTHING: 3835130.22	▶ NORTHING:
RECORD AZ OCC STA TO AZMK: ?	AZ (MILS): 4268.790	AZ (MILS):
RECORD DIST OCC STA TO AZMK: ?	DIST (METERS): 1187.730	DIST (METERS):

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OCC STA: ?	NAME OCC STA:	NAME OCC STA:
ENTER EASTING: ?	▶ EASTING:	▶ EASTING:
ENTER NORTHING: ?	▶ NORTHING:	▶ NORTHING:
ENTER NAME AZMK: ?	NAME AZMK:	NAME AZMK:
ENTER EASTING: ?	▶ EASTING:	▶ EASTING:
ENTER NORTHING: ?	▶ NORTHING:	▶ NORTHING:
RECORD AZ OCC STA TO AZMK: ?	AZ (MILS):	AZ (MILS):
RECORD DIST OCC STA TO AZMK: ?	DIST (METERS):	DIST (METERS):

REMARKS:

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Figure 10-5. **Sample DA Form 7357-R**

COMPUTATION OF COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE, AND VERTICAL ANGLE (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SSG HERNDON	NOTEBOOK REFERENCE:	DATE: 3 FEB 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select TRAVERSE (option B) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶.
3. Select the desired record from the TRAVERSE SUMMARY LIST.	3. Step MAIN/OFFSET is not required for first leg.
4. Observe the required fields, and enter the desired data.	4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME REAR STA: ?	NAME REAR STA: AZ MK	NAME REAR STA: TS-1
ENTER NAME OCC STA: ?	NAME OCC STA: SCP 1 NUMBER: 1	NAME OCC STA: TS-2 NUMBER: 3
ENTER EAST OCC STA: ?	EASTING: 546380.2	EASTING: 546834.05
ENTER NORTH OCC STA: ?	NORTHING: 3818253.4	NORTHING: 3818174.12
ENTER HEIGHT OCC STA: ?	HEIGHT: 465.6	HEIGHT: 469.0
ENTER AZIMUTH TO REAR: ?	AZ TO REAR (MILS): 4085.6	AZ TO REAR (MILS): 5725.1
REQUIRED FIELDS	**DATA RECORD**	
ENTER NAME FWD STA: ?	NAME FWD STA: TS-1	NAME FWD STA: SCP 2
MAIN/OFFSET: ? (SEE NOTE 3)	(MAIN) ~~(OFFSET)~~	(MAIN) ~~(OFFSET)~~
ENTER HORZ ANGLE TO FWD STA: ?	▶ HORZ ANGLE (MILS): 3623.2	▶ HORZ ANGLE (MILS): 5412.4
ENTER VERT ANGLE TO FWD STA: ?	▶ VERT ANGLE (MILS): ± +16.8	▶ VERT ANGLE (MILS): ± -10.3
RECIPROCAL VERT ANGLE (Y/N)	~~(RECIPROCAL)~~ (NONRECIPROCAL)	~~(RECIPROCAL)~~ (NONRECIPROCAL)
HORZ OR SLOPE DIST: ?	▶ DISTANCE: (HORZ) ~~(SLOPE)~~ 332.47	▶ DISTANCE: (HORZ) ~~(SLOPE)~~ 347.18
REQUIRED FIELDS	**DATA RECORD**	
RECORD NAME REAR STA: ?	NAME REAR STA: SCP	NAME REAR STA: TS-2
RECORD NAME OCC STA: ?	NAME OCC STA: TS-1 NUMBER: 2	NAME OCC STA: SCP 2 NUMBER: 4
RECORD EAST OCC STA: ?	EASTING: 546699.06	EASTING: 546487.65
RECORD NORTH OCC STA: ?	NORTHING: 3818347.12	NORTHING: 3818152.84
RECORD HEIGHT OCC STA: ?	HEIGHT: 471.1	HEIGHT: 465.5
RECORD AZIMUTH TO REAR: ?	AZ TO REAR (MILS): 4508.8	AZ TO REAR (MILS): 1537.5
REQUIRED FIELDS	**DATA RECORD**	
ENTER NAME FWD STA: ?	NAME FWD STA: TS-2	NAME FWD STA:
MAIN/OFFSET: ? (SEE NOTE 3)	(MAIN) ~~(OFFSET)~~	(MAIN) (OFFSET)
ENTER HORZ ANGLE TO FWD STA: ?	▶ HORZ ANGLE (MILS): 4416.3	▶ HORZ ANGLE (MILS):
ENTER VERT ANGLE TO FWD STA: ?	▶ VERT ANGLE (MILS): ± -9.6	▶ VERT ANGLE (MILS): ±
RECIPROCAL VERT ANGLE (Y/N)	~~(RECIPROCAL)~~ (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
HORZ OR SLOPE DIST: ?	▶ DISTANCE: (HORZ) ~~(SLOPE)~~ 219.52	▶ DISTANCE: (HORZ) (SLOPE)

REMARKS:

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Figure 10-6. **Sample DA Form 7357-R (reverse)**

CLOSURE/ADJUSTMENT

INSTRUCTIONS	NOTES
	1. Observe closure screen by pressing the T key. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate. 3. Press the T key when in the completed closure screen to view adjusted traverse data.

REQUIRED FIELDS	DATA RECORD	
	CLOSURE DATA	ADJUSTED DATA
ENTER CLOSING ANGLE: ?	CLOSING ANGLE (MILS): 1545.5	STATION NAME:
ENTER AZIMUTH FWD STA: ?	KNOWN AZ FORWARD (MILS): 3082.9	EASTING:
ENTER HEIGHT CLOSING STA: ?	KNOWN HEIGHT (METERS): 465.8	NORTHING:
ENTER EAST CLOSING STA:	KNOWN EASTING: 546487.6	HEIGHT (METERS):
ENTER NORTH CLOSING STA: ?	KNOWN NORTHING: 3818152.7	ADJUSTED AZ TO REAR (MILS):
ENTER 4TH/5TH ORDER: ?	4 OR (5)	
PRESS ENTER THEN C KEY TO CALCULATE		

REQUIRED FIELDS	DATA RECORD	
RECORD CMPT AZ FWD:	CMPT AZ FORWARD (MILS): 3083.0	STATION NAME:
RECORD TOTAL AZ CORRECTION:	TOTAL AZ CORRECTION (MILS): -0000.1	EASTING:
RECORD TOTAL HEIGHT CORRECTION:	TOTAL HEIGHT CORRECTION (METERS): .3	NORTHING:
RECORD TOTAL TRAVERSE LENGTH:	TOTAL TRAVERSE LENGTH (METERS): 899.17	HEIGHT (METERS):
RECORD RADIAL ERROR:	RADIAL ERROR (METERS): .14	ADJUSTED AZ TO REAR (MILS):
RECORD ACCURACY RATIO:	ACCURACY RATIO: 1/6248(1/6200)	

ADJUSTED DATA

REQUIRED FIELDS	DATA RECORD	
RECORD STATION NAME:	STATION NAME:	STATION NAME:
RECORD STATION EASTING:	EASTING:	EASTING:
RECORD STATION NORTHING:	NORTHING:	NORTHING:
RECORD STATION HEIGHT:	HEIGHT (METERS):	HEIGHT (METERS):
RECORD AZ TO REAR:	ADJUSTED AZ TO REAR (MILS):	ADJUSTED AZ TO REAR (MILS):

REMARKS:

(BACK) DA FORM 7357-R, SEP 96

b. DA Form 7358-R (Computation of Plane Triangle Coordinates and Height From One Side, Three Angles, and Vertical Angle (FED MSR)) (Figures 10-7 and 10-8) is used to record the data determined. The instructions for computing the data for this program are shown on the front of the form. Closure and adjustment data are recorded on the reverse of DA Form 7358-R (Figure 10-9).

10-10. RESECTION CALCULATION FILE

a. The Resection Calculation File computes the coordinates and height of one or more stations from the UTM coordinates of three known stations and the azimuth from the occupied station to the center station. The program allows the user access to the Survey Control Point File for importing data of the three known points. (See TM 11-7025-300-10, page 5-51, for step-by-step procedures.)

b. DA Form 7359-R (Computation of Coordinates and Height by Three-Point Resection (FED MSR)) (Figure 10-10) is used to record the data determined. The instructions for computing the data for this program are shown on the front of the form.

10-11. COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD (SUN AND STAR)

a. Altitude Method (Sun) Calculation File. This program computes a grid azimuth to an azimuth mark from three sets of observations of the sun. The program provides the user with a mean astronomic and grid azimuth. The program compares each of the azimuths to the mean to determine if the observation meets required accuracies. If one of the sets does not meet the rejection criteria, an audible alarm sounds and the status line will display: OBSERVATION SET _ REJECTED. If two of the sets fail to meet the rejection criteria, the audible alarm will sound and the status line will display: TWO OR MORE OBSERVATION SETS REJECTED. RERUN OBSERVATIONS. The audible alarm can be silenced and the status line cleared by pressing the NEXT (F8) key. The user can access the Survey Control Point File to import location data for the observing station only if the latitude and longitude are entered in the Survey Control Point File. If the geographic location is not entered in the Survey Control Point File, the program will display NO APPLICABLE SURVEY POINTS AVAILABLE FOR ACCESS. (See TM 11-7025-300-10, page5-55, for step-by-step procedures.)

> **Note.** The last prompt in the initiation screen is DAYLT SAVING TIME (Y/N). It does not matter what is entered at the DAYLT SAVING TIME (Y/N) prompt; the calculation does not use this information. The user must enter the time zone correction, to include daylight savings time, at the TIME ZONE CORRECTION prompt for the calculation to **correctly compute the azimuth.**

b. Altitude Method (Star) Calculation File. This program computes a grid azimuth to an azimuth mark from three sets of observations of a selected star. The user must enter the number of the star being used at the STAR NO/NAME prompt. (A list of star names and numbers are located on the back of the form.) The program determines accuracy and mean azimuth in the same manner as the Altitude Method (Sun) Calculation File program. Access to the Survey Control Point File and rejected data are controlled in the same manner as the Altitude Method (Sun) Calculation File. (See TM 11-7025-300-10, page 5-58, for step-by-step procedures.)

> **Notes.**
> **1.** Altitude Method (Sun and Star) Calculation Files computations will be recorded on DA Form 7360-R (Figures 10-11 and 10-12). (A list of stars is on the back of the form [Figure 10-13]).
> **2.** Both Altitude Method Calculation Files require the entry of OBS DATE, OBS TIME, DAYLT SAVINGS TIME, and TIME ZONE CORRECTION. This information is used to determine if the sun or selected star is in position to meet the prime vertical requirements (Chapter 7, paragraph 7-11e). If the prime vertical requirements are not met, the status line will display SUN/STAR NOT WITHIN 530 MILS OF PRIME VERTICAL. The status line will also display a warning (VERTICAL ANGLE TO SUN/STAR NOT BETWEEN 175 AND 800 MILS) when the vertical angle does not fall between 175 and 800 mils. The programs will perform the calculation and provide a solution even if either or both of these conditions exist.

10-12. HASTY ASTRO CALCULATION FILE (SUN AND STAR)

a. Hasty Astro (Sun) Calculation File. This program computes a grid azimuth and check angle from observations of the sun. The program uses an internal electronic ephemeris, which eliminates the need to extract data from FM 6-300. The program also provides the option to use the internal clock (see arty astro method) of the device to determine the date and time of tip. Date and time can also be entered manually. The ability to manually input date and time of observation allows the computation to be performed at a site remote from where the fieldwork is performed. The Survey Control Point File can be accessed from the program. This allows data for the position of the observation to be imported directly into the computation (the latitude and longitude must be included in the Survey Control Point File). (See TM 11-7025-300-10, page 5-62, for step-by-step procedures.)

b. Hasty Astro (Star) Calculation File. This program computes a grid azimuth and check angle from observations of survey stars. The user must enter the number of the star being used at the STAR NO/NAME prompt. The program has the same capabilities as the Hasty Astro (Sun) program. (See TM 11-7250-300-10, page 5-65, for step-by-step procedures.)

> **Note.** DA Form 7361-R (Computation of Astronomic Azimuth by the Hasty Astro Method (FED MSR)) (Figure 10-14) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form. A list of star names and numbers is located on the back of the form (Figure 10-15).

Figure 10-7. **Sample DA Form 7358-R**

COMPUTATION OF PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES, AND VERTICAL ANGLE (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SSG HERNDON	NOTEBOOK REFERENCE:	DATE: 8 JAN 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 2 SHEETS

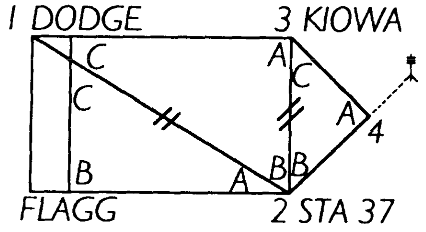
INSTRUCTIONS

1. Select SURVEY CALC (option B) from the MODE MENU.
2. Select TRIANGULATION (option C) from the SURVEY CALCULATIONS MENU.
3. Select the desired record from the TRIANGULATION SUMMARY LIST.
4. Observe the required fields, and enter the desired data.

NOTES

1. Press ENTER to display the window of legal entries.
2. Enter field data in blocks marked ▶.
3. Two triangles can be recorded on this form.
4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

SKETCH: (DRAW SKETCH, AND LABEL STATIONS BY NAME AND NUMBER.)



NOTES

1. Draw a diagram of the triangle scheme, and label starting base, required side(s), interior angles, and stations by name.
2. Number the stations in the order that the stations are computed. The starting station is Number 1.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME REAR STA: ?	NAME REAR STA: FLAGG	NAME REAR STA: DODGE
ENTER NAME START POINT/ B OR C: ?	NAME OCC STA (B OR Ⓒ): DODGE NUMBER: 1	NAME OCC STA (Ⓑ OR C): STA 37 NUMBER: 2
ENTER/RECORD EAST START POINT: ?	EASTING: 560201.37	EASTING: 557661.09
ENTER/RECORD NORTH START POINT: ?	NORTHING: 3839261.96	NORTHING: 3840686.81
ENTER/RECORD HEIGHT START POINT: ?	HEIGHT: 399.9	HEIGHT: 367.3
ENTER/RECORD AZ START POINT TO REAR: ?	AZ OF BASE (MILS): 6102.513	AZ OF BASE (MILS): 2120.680
ENTER/RECORD BASE DISTANCE: ?	BASE DISTANCE (METERS): 2690.754	BASE DISTANCE (METERS): 2912.597
GRID OR HORZ BASE: ?	(GRID) ~~(HORIZONTAL)~~	(GRID) ~~(HORIZONTAL)~~

REQUIRED FIELDS	DATA RECORD	
ENTER NAME FWD STA: ?	NAME FWD STA: STA 37	NAME FWD STA: KIOWA
ENTER INTERIOR ANGLE POINT A: ?	▶ ANGLE A (MILS): 1109.5	▶ ANGLE A (MILS): 1113.1
ENTER INTERIOR ANGLE POINT B: ?	▶ ANGLE B (MILS): 1308.6	▶ ANGLE B (MILS): 0756.8
ENTER INTERIOR ANGLE POINT C: ?	▶ ANGLE C (MILS): 0781.8	▶ ANGLE C (MILS): 1330.0
ENTER VERTICAL ANGLE TO FWD STA: ?	▶ VERTICAL ANGLE (MILS): ± -11.4	▶ VERTICAL ANGLE (MILS): ± +.2
RECIP VERT ANGLE (Y/N): ?	(RECIPROCAL) ~~(NONRECIPROCAL)~~	(RECIPROCAL) ~~(NONRECIPROCAL)~~
NEXT TRI BASE BA/CA: ?	(BA) (CA) — BA circled	(BA) (CA) — CA circled

REMARKS: CLOSURE .100   CLOSURE .100

DA FORM 7358-R, SEP 96

Figure 10-8. **Sample DA Form 7358-R (page 2)**

COMPUTATION OF PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES, AND VERTICAL ANGLE (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SSG HERNDON	NOTEBOOK REFERENCE:	DATE: 8 JAN 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 2 OF 2 SHEETS

INSTRUCTIONS

1. Select SURVEY CALC (option B) from the MODE MENU.
2. Select TRIANGULATION (option C) from the SURVEY CALCULATIONS MENU.
3. Select the desired record from the TRIANGULATION SUMMARY LIST.
4. Observe the required fields, and enter the desired data.

NOTES

1. Press ENTER to display the window of legal entries.
2. Enter field data in blocks marked ▶.
3. Two triangles can be recorded on this form.
4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

SKETCH: (DRAW SKETCH, AND LABEL STATIONS BY NAME AND NUMBER.)

SEE PAGE ONE.

NOTES

1. Draw a diagram of the triangle scheme, and label starting base, required side(s), interior angles, and stations by name.
2. Number the stations in the order that the stations are computed. The starting station is Number 1.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME REAR STA: ?	NAME REAR STA: STA 37	NAME REAR STA: KIOWA
ENTER NAME START POINT/ B OR C: ?	NAME OCC STA (B OR (C)): KIOWA NUMBER: 3	NAME OCC STA (B OR C): AGA-2 NUMBER: 4
ENTER/RECORD EAST START POINT: ?	EASTING: 558646.69	EASTING: 555235.15
ENTER/RECORD NORTH START POINT: ?	NORTHING: 3837678.46	NORTHING: 3840349.92
ENTER/RECORD HEIGHT START POINT: ?	HEIGHT: 367.9	HEIGHT: 360.7
ENTER/RECORD AZ START POINT TO REAR: ?	AZ OF BASE (MILS): 6077.513	AZ OF BASE (MILS): 2276.680
ENTER/RECORD BASE DISTANCE: ?	BASE DISTANCE (METERS): 3165.688	BASE DISTANCE (METERS): 4333.049
GRID OR HORZ BASE: ?	(GRID) (HORIZONTAL)	(GRID) (HORIZONTAL)

REQUIRED FIELDS	DATA RECORD	
ENTER NAME FWD STA: ?	NAME FWD STA: AGA-2	NAME FWD STA:
ENTER INTERIOR ANGLE POINT A: ?	▶ ANGLE A (MILS): 0817.2	▶ ANGLE A (MILS):
ENTER INTERIOR ANGLE POINT B: ?	▶ ANGLE B (MILS): 1781.9	▶ ANGLE B (MILS):
ENTER INTERIOR ANGLE POINT C: ?	▶ ANGLE C (MILS): 0600.8	▶ ANGLE C (MILS):
ENTER VERTICAL ANGLE TO FWD STA: ?	▶ VERTICAL ANGLE (MILS): ± -1.7	▶ VERTICAL ANGLE (MILS): ±
RECIP VERT ANGLE (Y/N): ?	(RECIPROCAL) ~~(NONRECIPROCAL)~~	(RECIPROCAL) (NONRECIPROCAL)
NEXT TRI BASE BA/CA: ?	(BA) (CA)	(BA) (CA)

REMARKS:

DA FORM 7358-R, SEP 96

Figure 10-9. **Sample DA Form 7358-R (reverse)**

CLOSURE ON KNOWN POINT OR CHECK BASE

INSTRUCTIONS	NOTES
	1. Observe closure screen by pressing the T key. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate. 3. Enter K for known point or C for check base.

REQUIRED FIELDS (Known Point)	DATA RECORD	
ENTER CLOSING ANGLE: ?	CLOSING ANGLE (MILS): ▶ 1412.6	
ENTER AZ CLOSING STA TO AZMK: ?	KNOWN AZ FORWARD (MILS): 3689.299	
ENTER HEIGHT CLOSING STA: ?	KNOWN HEIGHT (METERS): 360.6	
ENTER EAST CLOSING STA: ?	KNOWN EASTING: 555235.61	
ENTER NORTH CLOSING STA: ?	KNOWN NORTHING: 3840349.94	
PRESS ENTER THEN C KEY TO CALCULATE		

REQUIRED FIELDS	DATA RECORD	
RECORD CMPTD AZ TO AZMK:	CMPTD AZ TO AZMK: 3689.280	
RECORD TOTAL AZ ERROR:	TOTAL AZ ERROR (MILS): -.019	
RECORD TOTAL HEIGHT ERROR:	TOTAL HEIGHT ERROR (METERS): .1	
RECORD TOTAL DISTANCE OF SCHEME:	TOTAL DISTANCE OF SCHEME: 10411.334	
RECORD RADIAL ERROR:	RADIAL ERROR (METERS): .463	
RECORD ACCURACY RATIO:	ACCURACY RATIO: 1/22400 (CHECK SPECIFICATIONS)	

REQUIRED FIELDS (Check Base)	DATA RECORD	
ENTER MEASURED AZIMUTH OF CHECK BASE: ?	MEASURED AZIMUTH (MILS): ▶	
ENTER MEASURED BASE DISTANCE: ?	MEASURED BASE (METERS): ▶	
RECORD AZIMUTH ERROR:	AZ ERROR (MILS):	
RECORD COMPARATIVE ACCURACY:	COMPARATIVE RATIO: (CHECK SPECIFICATIONS)	

REMARKS:

(BACK) DA FORM 7358-R, SEP 96

Figure 10-10. **Sample DA Form 7359-R**

COMPUTATION OF COORDINATES AND HEIGHT BY THREE-POINT RESECTION (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SSG HERNDON	NOTEBOOK REFERENCE:	DATE: 8 JAN 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select RESECTION (option D) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶.
3. Select the desired record from the RESECTION SUMMARY LIST.	3. Two resection computations can be recorded on this form.
4. Observe the required fields, and enter the desired data.	4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
	5. Sums between 2845-3555 provide NO VALID SOLUTION.

REQUIRED FIELDS	DATA RECORD	
ENTER EAST LEFT STA: ?	EASTING OF LEFT: 553076.95	EASTING OF LEFT: 552996.62
ENTER NORTH LEFT STA: ?	NORTHING OF LEFT: 3839844.23	NORTHING OF LEFT: 3838175.16
ENTER EAST CENTER STA: ?	EASTING OF CENTER: 548900.78	EASTING OF CENTER: 548900.78
ENTER NORTH CENTER STA: ?	NORTHING OF CENTER: 3839712.56	NORTHING OF CENTER: 3839712.56
ENTER HEIGHT CENTER STA: ?	HEIGHT OF CENTER: 483.4	HEIGHT OF CENTER: 483.4
ENTER EAST RIGHT STA: ?	EASTING OF RIGHT: 550199.77	EASTING OF RIGHT: 550199.77
ENTER NORTH RIGHT STA: ?	NORTHING OF RIGHT: 3841880.82	NORTHING OF RIGHT: 3841880.82

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OCC STA: ?	NAME OCC STA: VICTOR	NAME OCC STA: VICTOR
ENTER HORZ ANGLE LEFT TO CENTER: ?	▶ HORZ ANGLE P1 (MILS): 1836.6	▶ HORZ ANGLE P1 (MILS): 1477.4
ENTER HORZ ANGLE CENTER TO RIGHT: ?	▶ HORZ ANGLE P2 (MILS): 0785.0	▶ HORZ ANGLE P2 (MILS): 0785.0
ENTER VERT ANGLE OCC STA TO CENTER: ?	▶ VERT ANGLE FROM P TO CENTER: ⊕ 28.8	▶ VERT ANGLE FROM P TO CENTER: ⊕ 28.8
ENTER TARGET HEIGHT AT CENTER: ?	HEIGHT OF TARGET (METERS): 3.0	HEIGHT OF TARGET (METERS): 3.0
ENTER INSTRUMENT HEIGHT AT OCC STA: ?	HEIGHT OF INSTRUMENT (METERS): 1.5	HEIGHT OF INSTRUMENT (METERS): 1.5

REQUIRED FIELDS	DATA RECORD	
SUM OF ANGLES: CHECK SPECIFICATIONS: (NOTE 5)	SUM OF ANGLES: 3639.708	SUM OF ANGLES: 3678.372
RECORD EAST OCC STA:	EASTING OF P: 552231.47	EASTING OF P: 552231.41
RECORD NORTH OCC STA:	NORTHING OF P: 3841046.00	NORTHING OF P: 3841046.11
RECORD HEIGHT OCC STA:	HEIGHT OF P (METERS): 382.5	HEIGHT OF P (METERS): 382.5
RECORD AZ FROM OCC STA TO CENTER:	AZ FROM P TO CENTER (MILS): 4412.113	AZ FROM P TO CENTER (MILS): 4412.077

REMARKS/SKETCH:

P-C AZ: 4412.113 DIST: 3587.695
P-C AZ:4412.077 DIST: 3587.681
P-P AZ: 5891.370 DIST: (RE): .125
AR: 1/28 700

E: 552231.44 N: 3841046.06 EL: 382.5

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Figure 10-11. **Sample DA Form 7360-R for Star**

COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 19 AUG 93
CHECKER: SFC HUTCHINSON	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select ALTITUDE METHOD SUN (option E) or STAR (option F) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the ALTITUDE METHOD SUN/STAR SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶ . 3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD		
NAME AZIMUTH MARK: ?	NAME AZ MK: OCS WT	APPROX AZIMUTH TO AZIMUTH MARK (MILS): 4300 STAR POSITION: ? EAST (WEST)	
NAME OBS STATION: ?	NAME OBS STA: SD 296	STAR NO/NAME: 47 : SPICA 4TH/5TH ORDER: ? 4TH 5TH	
ENTER GRID ZONE: ?	GRID ZONE: 14	TEMPERATURE: 80°	
ENTER LATITUDE: ?	LATITUDE: 34 °	39 '	48 " (N) S
ENTER LONGITUDE: ?	LONGITUDE: 98 °	24 '	21 " E (W)
ENTER DECLINATION: ?	DECLINATION: + (−) 11 °	07 '	44 "
ENTER DAILY CHANGE OF DECLN: ?	DAILY CHANGE (SECONDS): + − (SUN ONLY)		
ENTER WATCH CORRECTION: ?	WATCH CORRECTIONS: HOURS (SLOW) + (SUN ONLY) (FAST) −	MINUTES	SECONDS
ENTER TIME ZONE CORRECTION: ?	TIME ZONE CORRECTION: + − (SUN ONLY)		W E
DAYLIGHT SAVINGS TIME (Y/N): ?	ENTER (Y) OR N (SUN ONLY)		

	SET 1	SET 2	SET 3
ENTER MEAN WATCH TIME: ? (SUN ONLY)	HOURS ▶21 : MINUTES 05 : SECONDS 23	HOURS ▶21 : MINUTES 06 : SECONDS 49	HOURS ▶21 : MINUTES 07 : SECONDS 56
ENTER VERT ANGLE TO SUN/STAR: ?	VERT ANGLE (MILS): ▶ +302.4	VERT ANGLE (MILS): ▶ +297.8	VERT ANGLE (MILS): ▶ +294.2
ENTER REFRACTION: ?	ENTER AS +: .88 MILS	ENTER AS +: .88 MILS	ENTER AS +: .91 MILS
ENTER HORZ AZMK TO SUN/STAR: ?	HORZ ANGLE (MILS): ▶ 6390.8	HORZ ANGLE (MILS): ▶ 6395.1	HORZ ANGLE (MILS): ▶ 6398.5
RECORD OBS 1 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 4326.642	REMARKS:	
RECORD OBS 2 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 4326.622		
RECORD OBS 3 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 4326.582		
RECORD MEAN ASTRO AZ TO AZMK: ?	MEAN ASTRONOMIC AZ (MILS): 4326.615		
RECORD GRID AZ TO AZMK: ?	GRID AZIMUTH (MILS): 4320.607		

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Figure 10-12. **Sample DA Form 7360-R for Sun**

COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 22 AUG 94
CHECKER: SFC HUTCHINSON	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select ALTITUDE METHOD SUN (option E) or STAR (option F) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶.
3. Select the desired record from the ALTITUDE METHOD SUN/STAR SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	

REQUIRED FIELDS	DATA RECORD		
NAME AZIMUTH MARK: ?	NAME AZ MK: OCS WT	APPROX AZIMUTH TO AZIMUTH MARK (MILS): 4300 STAR POSITION: ? EAST WEST	
NAME OBS STATION: ?	NAME OBS STA: SD 305	STAR NO/NAME: 4TH/5TH ORDER: ? 4TH (5TH)	
ENTER GRID ZONE: ?	GRID ZONE: 14	TEMPERATURE: 70°	
ENTER LATITUDE: ?	LATITUDE: 34°	39'	48" (N) S
ENTER LONGITUDE: ?	LONGITUDE: 98°	24'	21" E (W)
ENTER DECLINATION: ?	DECLINATION: (+) - 11°	55'	50"
ENTER DAILY CHANGE OF DECLN: ?	DAILY CHANGE (SECONDS): (SUN ONLY) + (-) 1210		
ENTER WATCH CORRECTION: ?	WATCH CORRECTIONS: HOURS (SLOW) + (SUN ONLY) (FAST) - 00	MINUTES 00	SECONDS 00
ENTER TIME ZONE CORRECTION: ?	TIME ZONE CORRECTION: (SUN ONLY) (+) - 05		(W) E
DAYLIGHT SAVINGS TIME (Y/N): ?	ENTER (Y) OR N (SUN ONLY)		

	SET 1	SET 2	SET 3
ENTER MEAN WATCH TIME: ? (SUN ONLY)	HOURS MINUTES SECONDS ▶ 08 : 41 : 14	HOURS MINUTES SECONDS ▶ 08 : 42 : 04	HOURS MINUTES SECONDS ▶ 08 : 42 : 52
ENTER VERT ANGLE TO SUN/STAR: ?	VERT ANGLE (MILS): ▶ +354.4	VERT ANGLE (MILS): ▶ +357.3	VERT ANGLE (MILS): ▶ +360.2
ENTER REFRACTION: ?	ENTER AS + : .76 MILS	ENTER AS + : .74 MILS	ENTER AS + : .74 MILS
ENTER HORZ AZMK TO SUN/STAR: ?	HORZ ANGLE (MILS): ▶ 3667.3	HORZ ANGLE (MILS): ▶ 3669.5	HORZ ANGLE (MILS): ▶ 3671.4
RECORD OBS 1 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 4319.647	REMARKS:	
RECORD OBS 2 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 4319.458		
RECORD OBS 3 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 4319.557		
RECORD MEAN ASTRO AZ TO AZMK: ?	MEAN ASTRONOMIC AZ (MILS): 4319.554		
RECORD GRID AZ TO AZMK: ?	GRID AZIMUTH (MILS): 4313.546		

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Figure 10-13. **Sample DA Form 7360-R (reverse)**

ALPHABETICAL STAR LIST

STAR NAME	NO	MAG	STAR NAME	NO	MAG	STAR NAME	NO	MAG
ACAMAR	12	3.4	CAPH	2	2.4	MIRFAK	14	1.9
ACHERNAR	9	0.5	CASTOR	28	1.5	MIZAR	46	2.4
ACRUX	42	1.0	DENEB	68	1.3	NUNKI	65	2.1
ADHARA	26	1.6	DENEBOLA	39	2.2	NU	69	3.7
ALDEBARAN	15	1.1	DIPHDA	6	2.2	PEACOCK	67	2.1
ALHENA	24	1.9	DSCHUBBA	56	2.5	PHECDA	40	2.5
ALIOTH	45	1.7	DUBHE	38	1.9	POLARIS	10	2.1
ALKAID	48	1.9	ELNATH	19	1.8	POLLUX	30	1.2
AL NA 'IR	71	2.2	ELTANIN	62	2.4	PROCYON	29	0.5
ALNILAM	20	1.7	ENIF	70	2.5	RASALHAGUE	51	2.1
ALNITAK	21	2.0	FORMALHAUT	72	1.3	REGULUS	35	1.3
ALPHARD	35	2.2	GACRUX	43	1.6	RIGEL	16	0.3
ALPHECCA	55	2.3	GAMMA CASSIOPEIAE	7	1.6-2.8	RIGIL KENTAURUS	52	0.1
ALPHERATZ	1	2.1	GAMMA VELORUM	31	1.9	RUCHBUH	8	2.8
ALTAIR	66	0.9	GIENAH	41	2.8	SABIK	59	2.6
ANKAA	4	2.4	HADAR	49	0.8	SCAULA	60	1.7
ANTARES	57	1.2	HAMAL	11	2.2	SCHEDAR	5	2.3
ARCTURUS	51	0.2	KAUS AUSTRALIS	63	1.9	SIRIUS	25	-1.6
ATRIA	58	1.9	KOCHAB	54	2.2	SPICA	47	1.2
AVIOR	32	1.7	MARKAB	73	2.6	SUHAIL	33	2.2
BELLATRIX	18	1.7	MENKAR	13	2.8	VEGA	64	0.1
BETA HYDRUS	3	2.9	MENKENT	50	2.3	WEZEN	27	2.0
BETELGEUSE	22	0.1	MEPAK	37	2.4	ZEBENELGENUBI	53	2.9
CANOPUS	23	-0.9	MISPLACIDUS	34	1.8			
CAPELLA	17	0.2	MIMOSA	44	1.5			

REMARKS:

(BACK) DA FORM 7360-R, SEP 96

Figure 10-14. **Sample DA Form 7361-R**

COMPUTATION OF ASTRONOMIC AZIMUTH BY THE HASTY ASTRO METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 1 NOV 94
CHECKER: SFC HUTCHINSON	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select HASTY ASTRO (SUN) (option G) or STAR (option H) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶ .
3. Select the desired record from the HASTY ASTRO SUN/STAR SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	4. Two observation computations can be recorded on this form.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OBS STATION: ?	NAME OBS STATION: TIM	NAME OBS STATION:
ENTER EAST OBS STATION: ?	EASTING OBS STATION: 556015.00	EASTING OBS STATION:
ENTER NORTH OBS STATION: ?	NORTHING OBS STATION: 3835855.60	NORTHING OBS STATION:
ENTER APPROX AZ TO AZMK: ?	APPROX AZ TO AZMK: 2100	APPROX AZ TO AZMK:
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID: 1	SPHEROID:

REQUIRED FIELDS	DATA RECORD	
HEMISPHERE (N/S): ?	ENTER (N) or S	ENTER N or S
ENTER GRID ZONE: ?	GRID ZONE: 14	GRID ZONE:
ENTER STAR NO/NAME: ?	STAR NO: ; STAR NAME:	STAR NO: ; STAR NAME:
DAYLT SAVINGS TIME (Y/N): ?	ENTER Y or (N)	ENTER Y or N
ENTER TIME ZONE LETTER: ?	TIME ZONE LETTER: S	TIME ZONE LETTER:
USE TIME MODULE (Y/N): ?	ENTER Y or (N)	ENTER Y or N
ENTER/RECORD OBS DATE: ?	▶ DATE: 01 dd : 11 mm : 94 yy	▶ DATE: dd : mm : yy
ENTER/RECORD OBS 1 TIME: ?	▶ TIME: 08 hh : 12 mm : 43 ss	▶ TIME: hh : mm : ss
ENTER OBS 1 POSITION AT TIP: ? A = TRAILING EDGE B = LEADING EDGE C = CENTER	ENTER A, B, or (C) C	ENTER A, B, or C:
ENTER/RECORD OBS 2 TIME: ?	▶ TIME: 08 hh : 13 mm : 12 ss	▶ TIME: hh : mm : ss
ENTER OBS 2 POSITION AT TIP: ? A = TRAILING EDGE B = LEADING EDGE C = CENTER	ENTER A, B, or (C) C	ENTER A, B, or C:
RECORD GRID AZIMUTH:	GRID AZIMUTH: 2110.923	GRID AZIMUTH:
RECORD CHECK ANGLE:	CHECK ANGLE: 1.439	CHECK ANGLE:

REMARKS:

DA FORM 7361-R, SEP 96

Figure 10-15. **Sample DA Form 7361-R (reverse)**

ALPHABETICAL STAR LIST

STAR NAME	NO	MAG	STAR NAME	NO	MAG	STAR NAME	NO	MAG
ACAMAR	12	3.4	CAPH	2	2.4	MIRFAK	14	1.9
ACHERNAR	9	0.5	CASTOR	28	1.5	MIZAR	46	2.4
ACRUX	42	1.0	DENEB	68	1.3	NUNKI	65	2.1
ADHARA	26	1.6	DENEBOLA	39	2.2	NU	69	3.7
ALDEBARAN	15	1.1	DIPHDA	6	2.2	PEACOCK	67	2.1
ALHENA	24	1.9	DSCHUBBA	56	2.5	PHECDA	40	2.5
ALIOTH	45	1.7	DUBHE	38	1.9	POLARIS	10	2.1
ALKAID	48	1.9	ELNATH	19	1.8	POLLUX	30	1.2
AL NA 1R	71	2.2	ELTANIN	62	2.4	PROCYON	29	0.5
ALNILAM	20	1.7	ENIF	70	2.5	RASALHAGUE	61	2.1
ALNITAK	21	2.0	FORMALHAUT	72	1.3	REGULUS	35	1.3
ALPHARD	35	2.2	GACRUX	43	1.6	RIGEL	16	0.3
ALPHECCA	55	2.3	GAMMA CASSIOPEIAE	7	1.6-2.8	RIGIL KENTAURUS	52	0.1
ALPHERATZ	1	2.1	GAMMA VELORUM	31	1.9	RUCHBUH	8	2.8
ALTAIR	66	0.9	GIENAH	41	2.6	SABIK	59	2.6
ANKAA	4	2.4	HADAR	49	0.8	SCAULA	60	1.7
ANTARES	57	1.2	HAMAL	11	2.2	SCHEDAR	5	2.3
ARCTURUS	51	0.2	KAUS AUSTRALIS	63	1.9	SIRIUS	25	-1.6
ATRIA	58	1.9	KOCHAB	54	2.2	SPICA	47	1.2
AVIOR	32	1.7	MARKAB	73	2.6	SUHAIL	33	2.2
BELLATRIX	18	1.7	MENKAR	13	2.8	VEGA	64	0.1
BETA HYDRUS	3	2.9	MENKENT	50	2.3	WEZEN	27	2.0
BETELGEUSE	22	0.1	MEPAK	37	2.4	ZEBENELGENUBI	53	2.9
CANOPUS	23	-0.9	MISPLACIDUS	34	1.8			
CAPELLA	17	0.2	MIMOSA	44	1.5			

REMARKS:

(BACK) DA FORM 7361-R, SEP 96

10-13. STAR ID CALCULATION FILE

a. The Star ID Calculation File computes the approximate azimuth and altitude to a selected star at a date and time chosen by the user. The orientation data will help identify survey stars for astronomic observation or navigation. The program will compute the approximate azimuth and altitude (vertical angle) to any of the 73 survey stars listed in FM 6-300. The orientation data are accurate to within 5 mils. (See TM 11-7250-300-10, page 5-71, for step-by-step procedures.)

b. DA Form 7362-R (Computation of Azimuth and Vertical Angle to Selected Star (Star ID) (FED MSR)) (Figure 10-16) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form.

10-14. POLARIS TABULAR METHOD CALCULATION FILE

a. The Polaris Tabular Method Calculation File computes a grid azimuth from three sets of observations of the star Polaris, using the Polaris Tabular method. The program checks the accuracy specifications in the same manner as described for the altitude method (paragraph 10-11). (See TM 11-7025-300-10, page 5-75, for step-by-step procedures.)

b. DA Form 7363-R (Computation of Astronomic Azimuth by Polaris Tabular Method (FED MSR) (Figure 10-17) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form.

10-15. GRID CONVERGENCE CALCULATION FILE

a. The Grid Convergence Calculation File converts a UTM grid azimuth from a gyroscopic (true) azimuth. The program also computes the convergence from true to grid azimuth for an area of operations. (See TM 11-7250-300-10, page 5-78, for step-by-step procedures.

b. DA Form 7364-R (Computation--Convergence of True Azimuth to Grid Azimuth (FED MSR)) (Figure 10-18) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form.

10-16. TRIG TRAVERSE CALCULATION FILE

a. The Trig Traverse File computes horizontal distances and comparative accuracy from trig-traverse fieldwork. (See TM 11-7025-10, page 5-90, for step-by-step procedures.)

> **Note.** M=SUBTENSE is no longer used and will be removed from the next version.

b. DA Form 7365-R (Computation of Trig Traverse (FED MSR)) (Figure 10-19) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form.

10-17. INTERSECTION CALCULATION FILE

a. The Intersection Calculation File computes the coordinates and height of an unknown point (target) from intersection fieldwork. The program can be used for either intervisible or nonintervisible bases. The Survey Control Point File can be accessed from the initiation screen. This program has the capacity to store 40 targets for three sets of OPs. For example, in file A= from the two selected OPs, the program will store data for 40 targets. The same amount of targets can be stored in files B= and C= regardless of whether the OPs are the same or one or both are new OPs. If additional targets are required from the same two OPS, press the next open target record (that is, B=), enter data, confirm data, and press the C key. Continue to record target data and select open target records until all targets have been computed. If more than 40 targets are required, then go to Summary List. Select a blank file, and start a new calculation. (See TM 11-7025-300-10, page 5-96, for step-by-step procedures.)

b. DA Form 7366-R (Computation of Coordinates and Height by Intersection (FED MSR)) (Figure 10-20) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form.

Figure 10-16. **Sample DA Form 7362-R**

COMPUTATION OF AZIMUTH AND VERTICAL ANGLE TO SELECTED STAR (STAR ID) (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SSG HERNDON	NOTEBOOK REFERENCE:	DATE: 1 NOV 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select STAR ID (option I) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the STAR ID SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER OBS STATION: ?	NAME OBS STATION: TED	NAME OBS STATION:
ENTER EAST OBS STATION: ?	EASTING: 556015.00	EASTING:
ENTER NORTH OBS STATION: ?	NORTHING: 3835855.60	NORTHING:
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID: 1	SPHEROID:

REQUIRED FIELDS	DATA RECORD	
HEMISPHERE (N/S): ?	ENTER (N) or S	ENTER N or S
ENTER GRID ZONE: ?	GRID ZONE: 14	GRID ZONE:
ENTER OBS DATE: ?	DATE: dd mm yy 01 : 11 : 94	DATE: dd mm yy : :
ENTER OBS TIME: ?	TIME: hh mm 23 : 00	TIME: hh mm :
ENTER TIME ZONE LETTER: ?	TZ LTR: S	TZ LTR:
DAYLT SAVINGS TIME (Y/N): ?	ENTER Y or (N)	ENTER Y or N
ENTER/RECORD STAR NO/NAME:	STAR NO: 68 : STAR NAME: DENEB	STAR NO: : STAR NAME:
RECORD LOCAL SIDEREAL TIME:	LST: 017.9 degrees	LST: degrees
RECORD AZIMUTH TO STAR:	AZIMUTH: 5390.351	AZIMUTH:
RECORD ALTITUDE TO STAR:	ALTITUDE: 688.515	ALTITUDE:

REMARKS:

DA FORM 7362-R, SEP 96

Figure 10-17. **Sample DA Form 7363-R**

COMPUTATION OF ASTRONOMIC AZIMUTH BY POLARIS TABULAR METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 26 JUL 93
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select POLARIS TABULAR METHOD (option J) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶.
3. Select the desired record from the POLARIS TABULAR METHOD SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	

REQUIRED FIELDS	DATA RECORD		
NAME AZIMUTH MARK: ?	NAME AZ MK: SW WT	APPROX AZIMUTH TO AZIMUTH MARK (MILS): 5750	
NAME OBS STATION: ?	NAME OBS STA: SD 377		
ENTER LATITUDE: ?	LATITUDE: 34 °	17 '	15 " (N) S
ENTER LONGITUDE: ?	LONGITUDE: 98 °	28 '	40 " E (W)
ENTER GRID ZONE: ?	GRID ZONE: 14		
ENTER TIME ZONE CORRECTION: ?	TIME ZONE CORRECTION: (+) -	05	(W) E
ENTER SIDEREAL TIME: ? (FM 6-300, TABLE 2)	SIDEREAL TIME: HOURS + 20	MINUTES 14	SECONDS 48.2
ENTER WATCH CORRECTION: ?	WATCH CORRECTIONS: (SLOW) + (FAST) - HOURS 00	MINUTES 00	SECONDS 02
4TH/5TH ORDER: ?	ENTER 4 OR 5		
	SET 1	SET 2	SET 3
ENTER MEAN WATCH TIME: ?	HOURS 22 MINUTES 18 SECONDS 40	HOURS 22 MINUTES 23 SECONDS 46	HOURS 22 MINUTES 27 SECONDS 10
ENTER HORZ ANGLE AZMK TO STAR: ?	HORZ ANGLE (MILS): 0642.0	HORZ ANGLE (MILS): 0642.3	HORZ ANGLE (MILS): 0642.6
RECORD LOCAL SIDEREAL TIME: (hrs/min)	HOURS 17 MINUTES 04.1	HOURS 17 MINUTES 09.2	HOURS 17 MINUTES 12.6
ENTER B /B_0 /B_1 :B_2 (FM 6-300, TABLE 12):	B_0 +28.7 B_1 +.2 B_2 +.1	B_0 +29.6 B_1 +.2 B_2 +.1	B_0 +30.1 B_1 +.2 B_2 +.1
RECORD OBS 1 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 5768.400	REMARKS:	
RECORD OBS 2 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 5768.423		
RECORD OBS 3 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS): 5768.302		
RECORD MEAN ASTRO AZ TO AZMK: ?	MEAN ASTRONOMIC AZ (MILS): 5768.375		
RECORD GRID AZ TO AZMK: ?	GRID AZIMUTH (MILS): 5763.145		

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Figure 10-18. **Sample DA Form 7364-R**

COMPUTATION – CONVERGENCE OF TRUE AZIMUTH TO GRID AZIMUTH (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 8 JAN 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select GRID CONVERGENCE (option K) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶ .
3. Select the desired record from the GRID CONVERGENCE SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	4. Four convergence computations can be recorded on this form.

REQUIRED FIELDS	DATA RECORD	
NAME AZIMUTH MARK: ?	NAME AZ MK: TED	NAME AZ MK:
NAME OCC STATION: ?	NAME OCC STA: MK 4	NAME OCC STA:
ENTER LATITUDE: ?	LATITUDE: 60° 29' 31" (N) S	LATITUDE: ° ' " N S
ENTER LONGITUDE: ?	LONGITUDE: 115° 21' 31" E (W)	LONGITUDE: ° ' " E W
ENTER TRUE AZIMUTH: ?	TRUE AZIMUTH (MILS): ▶ 4800.0	TRUE AZIMUTH (MILS): ▶
ENTER GRID ZONE: ?	GRID ZONE: 11	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	
RECORD CONVERGENCE: ?	CONVERGENCE (MILS): -25.397	CONVERGENCE (MILS):
RECORD GRID AZIMUTH: ?	GRID AZIMUTH (MILS): 4774.603	GRID AZIMUTH (MILS):

REQUIRED FIELDS	DATA RECORD	
NAME AZIMUTH MARK: ?	NAME AZ MK:	NAME AZ MK:
NAME OCC STATION: ?	NAME OCC STA:	NAME OCC STA:
ENTER LATITUDE: ?	LATITUDE: ° ' " N S	LATITUDE: ° ' " N S
ENTER LONGITUDE: ?	LONGITUDE: ° ' " E W	LONGITUDE: ° ' " E W
ENTER TRUE AZIMUTH: ?	TRUE AZIMUTH (MILS): ▶	TRUE AZIMUTH (MILS): ▶
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	
RECORD CONVERGENCE: ?	CONVERGENCE (MILS):	CONVERGENCE (MILS):
RECORD GRID AZIMUTH: ?	GRID AZIMUTH (MILS):	GRID AZIMUTH (MILS):

REMARKS:

DA FORM 7364-R, SEP 96

Figure 10-19. **Sample DA Form 7365-R**

COMPUTATION OF TRIG TRAVERSE (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 8 JAN 94
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select TRIG TRAVERSE (option L) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶.
3. Select the desired record from the TRIG TRAVERSE SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	4. Four trig traverse computations can be recorded on this form.
	5. If the response to PERPENDICULAR (Y/N) is Y, no data are required for ANGLE Y.

REQUIRED FIELDS	DATA RECORD	
4TH OR 5TH ORDER: ?	ENTER 4 OR 5	ENTER 4 OR 5
ENTER HORZ ANGLE Q1: ?	▶ANGLE Q1 (MILS): 0036.9	▶ANGLE Q1 (MILS):
ENTER HORZ ANGLE Q2: ?	▶ANGLE Q2 (MILS): 0042.6	▶ANGLE Q2 (MILS):
ENTER BASE DIST B TO C1: ?	▶BASE B TO C1 (METERS): 100.00	▶BASE B TO C1 (METERS):
ENTER BASE DIST B TO C2: ?	▶BASE B TO C2 (METERS): 115.71	▶BASE B TO C2 (METERS):
PERPENDICULAR BASE (Y/N): ?	ENTER Y OR (N)	ENTER Y OR N
ENTER ANGLE Y: ? (IF NONPERP)	▶ANGLE Y (MILS): 1959.7	▶ANGLE Y (MILS):

REQUIRED FIELDS	DATA RECORD	
RECORD DIST AB FROM BASE B/C1:	DIST NO 1 (METERS): 2554.358	DIST NO 1 (METERS):
RECORD DIST AB FROM BASE B/C2:	DIST NO 2 (METERS): 2554.441	DIST NO 2 (METERS):
RECORD MEAN HORZ DISTANCE:	MEAN DIST (METERS): 2554.399	MEAN DIST (METERS):
RECORD COMPARATIVE ACCURACY:	COMPARATIVE ACCURACY: 1/30 600	COMPARATIVE ACCURACY: 1/

REQUIRED FIELDS	DATA RECORD	
4TH OR 5TH ORDER: ?	ENTER 4 OR 5	ENTER 4 OR 5
ENTER HORZ ANGLE Q1: ?	▶ANGLE Q1 (MILS):	▶ANGLE Q1 (MILS):
ENTER HORZ ANGLE Q2: ?	▶ANGLE Q2 (MILS):	▶ANGLE Q2 (MILS):
ENTER BASE DIST B TO C1: ?	▶BASE B TO C1 (METERS):	▶BASE B TO C1 (METERS):
ENTER BASE DIST B TO C2: ?	▶BASE B TO C2 (METERS):	▶BASE B TO C2 (METERS):
PERPENDICULAR BASE (Y/N): ?	ENTER Y OR N	ENTER Y OR N
ENTER ANGLE Y: ? (IF NONPERP)	▶ANGLE Y (MILS):	▶ANGLE Y (MILS):

REQUIRED FIELDS	DATA RECORD	
RECORD DIST AB FROM BASE B/C1:	DIST NO 1 (METERS):	DIST NO 1 (METERS):
RECORD DIST AB FROM BASE B/C2:	DIST NO 2 (METERS):	DIST NO 2 (METERS):
RECORD MEAN HORZ DISTANCE:	MEAN DIST (METERS):	MEAN DIST (METERS):
RECORD COMPARATIVE ACCURACY:	COMPARATIVE ACCURACY: 1/	COMPARATIVE ACCURACY: 1/

REMARKS:

DA FORM 7365-R, SEP 96

Figure 10-20. **Sample DA Form 7366-R**

COMPUTATION OF COORDINATES AND HEIGHT BY INTERSECTION (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 2 DEC 95
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select INTERSECTION (option N) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ►.
3. Select the desired record from the INTERSECTION SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	4. Two intersection computations can be recorded on this form.

REQUIRED FIELDS	DATA RECORD	
NAME OF OB POST 1: ?	NAME 01: FINN	NAME 01: FINN
ENTER EAST OF OB POST 1: ?	EASTING 01: 560680.13	EASTING 01: 560680.13
ENTER NORTH OF OB POST 1: ?	NORTHING 01: 3835650.55	NORTHING 01: 3835650.55
ENTER HEIGHT OF OB POST 1: ?	HEIGHT 01 (METERS): 371.2	HEIGHT 01 (METERS): 371.2
NAME OF OB POST 2: ?	NAME 02: QM 81-1	NAME 02: QM 41-1
ENTER EAST OF OB POST 2: ?	EASTING 02: 589858.43	EASTING 02: 559526.03
ENTER NORTH OF OB POST 2: ?	NORTHING 02: 3836637.31	NORTHING 02: 3838568.42
RECORD DIST OB POST 1/OB POST 2:	DIST 01 TO 02 (METERS): 1284.090	DIST 01 TO 02 (METERS): 3137.820
RECORD AZ OB POST 1/OB POST 2:	AZIMUTH 01 TO 02 (MILS): 5692.711	AZIMUTH 01 TO 02 (MILS): 6016.352
ENTER AZ OB POST 1/TARGET: ?	AZ 01 TO TARGET (MILS): ► 4774.1	AZ 01 TO TARGET (MILS): ► 4774.1
ENTER VERT ANGLE OB POST 1/TARGET: ?	VERT ANGLE 01 TO TARGET (MILS): ► ± 4.3	VERT ANGLE 01 TO TARGET (MILS): ► ± 4.3
ENTER AZ OB POST 2/TARGET: ?	AZ 02 TO TARGET (MILS): ► 4527.0	AZ 02 TO TARGET (MILS): ► 4100.6
RECORD TARGET NO:	TGT NO: 01	TGT NO: 01
RECORD TGT EASTING:	EASTING OF TGT: 555814.72	EASTING OF TGT: 555815.38
RECORD TGT NORTHING:	NORTHING OF TGT: 3835526.81	NORTHING OF TGT: 3835526.83
RECORD TGT HEIGHT:	HEIGHT OF TGT: 352.3	HEIGHT OF TGT: 352.3

REMARKS/SKETCH:

1 AZ TO UNK 4774.100 DIST: 4866.983
2 AZ TO UNK 4774.101 DIST: 4866.323
AZ UNK TO UNK 1569.143 DIST: (RE) .660
AR: 1/7300

E: 555815.05 N: 3835526.82 EL: 352.3

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10-18. ARTY ASTRO CALCULATION FILES (SUN AND STAR)

a. Arty Astro Observation (Sun). This program computes a grid azimuth from three observations of the sun. This program uses an internal electronic ephemeris, which eliminates the need to extract data from FM 6-300. The program provides the option of using the internal timer or manually entering the date and time of tip for each observation.

(1) To use the internal timer, the correct date and accurate time must be entered during the FED STATUS setup as mentioned in Section I. If the time module is selected, the DETERMINE TIP OF OBSERVATION screen will appear. When tip is determined, press the K key.

(2) The user also has the option to press the N key and return to the initiation screen. The user can then select not to use the time module. The ability to manually input date and time of observation allow the fieldwork to be performed without the FED MSR being at the site of observation. The user can access the Survey Control Point File to import location data for the observing station only if the latitude and longitude are entered in the Survey Control Point File. If the geographic location is not entered in the Survey Control Point File, the program will display NO APPLICABLE SURVEY POINTS AVAILABLE FOR ACCESS. The program checks the accuracy of the observation in the same manner as described in the altitude method (paragraph 10-11). (See TM 11-7250-300-10, page 5-81, for step-by-step procedures.)

b. Arty Astro Observation (Star). This program computes a grid azimuth from three observations of any survey star. This program functions the same as the Arty Astro Sun program with the exception that it computes azimuth from observations of survey stars. The program will compute the azimuth from any of the 73 survey stars listed in FM 6-300. (See TM 11-7250-300-10, page 5-85, for step-by-step procedures.)

c. DA Form 7367-R. DA Form 7367-R (Computation of Astronomic Azimuth by the Arty Astro Method (FED MSR)) (Figure 10-21) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form. The star names and numbers are located on the back of the form (Figure 10-22).

Figure 10-21. **Sample DA Form 7367-R**

COMPUTATION OF ASTRONOMIC AZIMUTH BY THE ARTY ASTRO METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 4 DEC 90
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select ARTY ASTRO (SUN) (option O) or STAR (option P) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the ARTY ASTRO SUN/STAR SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶ . 3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OBS STATION: ?	NAME OBS STATION: PAT	APPROX AZIMUTH TO AZIMUTH MARK:
ENTER EAST OBS STATION: ?	EASTING OBS STATION: 554414.7	
ENTER NORTH OBS STATION: ?	NORTHING OBS STATION: 3835695.8	
ENTER NAME AZIMUTH MARK: ?	NAME AZ MK: OCS WT	
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID: 1	

REQUIRED FIELDS	DATA RECORD		
HEMISPHERE (N/S): ?	ENTER (N) OR S		
ENTER/RECORD STAR NO/NAME: ?	STAR NO: STAR NAME:		
ENTER GRID ZONE: ?	GRID ZONE: 14		
DAYLT SAVINGS TIME (Y/N): ?	ENTER Y OR (N)		
ENTER TIME ZONE LETTER: ?	TIME ZONE LETTER: S		
USE TIME MODULE (Y/N): ?	ENTER Y OR (N)		
4TH OR 5TH ORDER: ?	ENTER 4 OR (5)		
ENTER DIRECT READ TO AZMK: ?	▶ (D) RDG AZMK: 0001.0		
ENTER/RECORD OBS DATE: ?	DATE: dd mm yy ▶ 04 : 12 : 90	DATE: dd mm yy ▶ 04 : 12 : 90	DATE: dd mm yy ▶ 04 : 12 : 90
ENTER/RECORD OBS TIME: ?	TIME: hh mm ss ▶ 14 : 50 : 48	TIME: hh mm ss ▶ 14 : 51 : 49	TIME: hh mm ss ▶ 14 : 52 : 39
ENTER OBS POSITION AT TIP: ? A = TRAILING EDGE B = LEADING EDGE C = CENTER	ENTER A, B, or (C) C	ENTER A, B, or (C) C	ENTER A, B, or (C) C
ENTER DIRECT HORZ READING AT TIP: ?	HORZ RDG (D): ▶ 5970.2	HORZ RDG (D): ▶ 5974.0	HORZ RDG (D): ▶ 5977.2
RECORD GRID AZ TO AZ MK:	GRID AZ: 4282.829		

REMARKS:

DA FORM 7367-R, SEP 96

Figure 10-22. **Sample DA Form 7367-R (reverse)**

ALPHABETICAL STAR LIST

STAR NAME	NO	MAG	STAR NAME	NO	MAG	STAR NAME	NO	MAG
ACAMAR	12	3.4	CAPH	2	2.4	MIRFAK	14	1.9
ACHERNAR	9	0.5	CASTOR	28	1.5	MIZAR	46	2.4
ACRUX	42	1.0	DENEB	68	1.3	NUNKI	65	2.1
ADHARA	26	1.6	DENEBOLA	39	2.2	NU	69	3.7
ALDEBARAN	15	1.1	DIPHDA	6	2.2	PEACOCK	67	2.1
ALHENA	24	1.9	DSCHUBBA	56	2.5	PHECDA	40	2.5
ALIOTH	45	1.7	DUBHE	38	1.9	POLARIS	10	2.1
ALKAID	48	1.9	ELNATH	19	1.8	POLLUX	30	1.2
AL NA 'IR	71	2.2	ELTANIN	62	2.4	PROCYON	29	0.5
ALNILAM	20	1.7	ENIF	70	2.5	RASALHAGUE	51	2.1
ALNITAK	21	2.0	FORMALHAUT	72	1.3	REGULUS	35	1.3
ALPHARD	35	2.2	GACRUX	43	1.6	RIGEL	16	0.3
ALPHECCA	55	2.3	GAMMA CASSIOPEIAE	7	1.6-2.8	RIGIL KENTAURUS	52	0.1
ALPHERATZ	1	2.1	GAMMA VELORUM	31	1.9	RUCHBUH	8	2.8
ALTAIR	66	0.9	GIENAH	41	2.8	SABIK	59	2.6
ANKAA	4	2.4	HADAR	49	0.6	SCAULA	60	1.7
ANTARES	57	1.2	HAMAL	11	2.2	SCHEDAR	5	2.3
ARCTURUS	61	0.2	KAUS AUSTRALIS	63	1.9	SIRIUS	25	-1.6
ATRIA	58	1.9	KOCHAB	54	2.2	SPICA	47	1.2
AVIOR	32	1.7	MARKAB	73	2.6	SUHAIL	33	2.2
BELLATRIX	18	1.7	MENKAR	13	2.8	VEGA	64	0.1
BETA HYDRUS	3	2.9	MENKENT	50	2.3	WEZEN	27	2.0
BETELGEUSE	22	0.1	MEPAK	37	2.4	ZEBENELGENUBI	53	2.9
CANOPUS	23	-0.9	MISPLACIDUS	34	1.8			
CAPELLA	17	0.2	MIMOSA	44	1.5			

REMARKS:

(BACK) DA FORM 7367-R, SEP 96

Section III

CONVERSION AND TRANSFORMATION WITH THE FED MSR

The transformations function of the FED MSR will allow the operator to perform various types of survey conversions and transformations. The type of transformation desired is selected from the TRANSFORMATIONS MENU (Figure 10-23). The FED MSR will maintain up to three completed calculations in its data base for each type of transformation. Completed calculations are automatically saved in the data base. Records remain in the data base until the operator either deletes or writes over the record. The device will allow the operator to establish a new calculation record or view or edit an existing one.

10-19. TRANSFORMATIONS

The transformations function of the FED MSR will allow the operator to perform conversion of UTM coordinates to geographic coordinates and geographic coordinates to UTM coordinates. It also provides for zone-to-zone transformation of coordinates and azimuth and datum-to-datum coordinate transformations. The FED MSR transformation forms and calculation procedures were designed to be similar to the FED MSR survey calculations to simplify their use. See Section II, paragraphs 10-6a through e, for an explanation of the following:

- How different parts of the FED MSR forms are used.
- How to select a calculation.
- How to enter data.
- How to edit a calculation.
- How to perform various special operations.

Detailed instructions for the use of the FED MSR are in TM 11-7025-300-10. For further reference, conversions and transformations are discussed in Chapter 11.

Figure 10-23. **TRANSFORMATIONS MENU**

TRANSFORMATIONS MENU

A = UTM TO GEO COORD
B = GEO TO UTM COORD
C = ZONE TO ZONE
D = UTM TO UTM DATUM
E = UTM TO GEO DATUM
F = GEO TO UTM DATUM
G = GEO TO GEO DATUM
H = KRASSOVSKY TO UTM DATUM
I = UTM TO KRASSOVSKY DATUM
J = BESSEL TO UTM DATUM
K = UTM TO BESSEL DATUM
L = USER DEF TO USER DEF DATUM
M = USER DEF TO LISTED DATUM
N = LISTED TO USER DEF DATUM

(PRESS KEY CORRESPONDING TO THE DESIRED OPTION, <PREV>=RETURN)

00:00:00

10-20. UTM TO GEO COORDINATE CONVERSION FILE

a. This program converts UTM coordinates to geographic coordinates. The Survey Control Point File can be accessed from this calculation. (See TM 11-7025-300-10, page 5-100, for step-by-step procedures.)

b. DA Form 7368-R (Computation--Conversion UTM to GEO Coordinate, GEO to UTM Coordinate, Zone-To-Zone Transformation (FED MSR)) (Figure 10-24) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form.

10-21. GEO TO UTM COORDINATE CONVERSION FILE

a. This program converts geographic coordinates to UTM coordinates. The Survey Control Point File cannot be accessed from this calculation. (See TM 11-7025-300-10, page 5-103, for step-by-step procedures.)

b. DA Form 7368-R is also used for recording the GEO to UTM coordinate conversion data. (See Figure 10-24.)

10-22. ZONE-TO-ZONE COORDINATE CONVERSION FILE

a. This program, also refered to as zone-to-zone transformation, transforms UTM grid coordinates and azimuth from one grid zone into terms of an adjacent grid zone. The Survey Control Point File can be accessed from this calculation. (See TM 11-7025-300-10, page 5-106, for step-by-step procedures.)

b. DA Form 7368-R is also used for recording the zone-to-zone transformation data. (See Figure 10-24.)

10-23. UTM TO UTM DATUM CONVERSION FILE

a. This program transforms UTM coordinates from a selected UTM datum to another selected UTM datum. The program also allows the option of zone-to-zone transformation. If yes (option Y) is selected, the ending grid zone must be entered. The datum numbers must be entered (known) for all calculations. The Survey Control Point File can be accessed from these calculations. (See TM 11-7025-300-10, page 5-109, for step-by-step procedures.)

b. DA Form 7369-R (Computation--Datum to Datum Coordinate Transformation Listed Datums (FED MSR)) (Figure 10-25) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form. A list of datum names and corresponding numbers are located on the back of the form (Figure 10-26), in Appendix E, and in TM 11-7025-300-10 (pages B-34 through B-37).

10-24. UTM TO GEO DATUM CONVERSION FILE

a. This program transforms UTM coordinates from a selected UTM datum to GEO coordinates of a selected GEO datum. (See TM 11-7025-300-10, page 5-112, for step-by-step procedures.)

b. DA Form 7369-R is also used for recording data transformed from UTM to GEO datum. (See Figure 10-25.)

10-25. GEO TO UTM DATUM CONVERSION FILE

a. This program transforms GEO coordinates from a selected GEO datum to UTM coordinates of a selected UTM datum. (See TM 11-7025-300-10, page 5-115, for step-by-step procedures.)

b. DA Form 7369-R is also used for recording data transformed from GEO to UTM datum. (See Figure 10-25.)

10-26. GEO TO GEO DATUM CONVERSION FILE

a. This program transforms GEO coordinates from a selected GEO datum to another selected GEO datum. (See TM 11-7025-300-10, page 5-118, for step-by-step procedures.)

b. DA Form 7369-R is also used for recording data transformed from one GEO datum to another. (See Figure 10-25.)

10-27. KRASSOVSKY TO UTM DATUM CONVERSION FILE

a. Krassovsky to UTM datum coordinate transformations transform UTM coordinates from a selected Krassovsky datum to a selected UTM datum. The datum numbers must be entered (known) for all calculations. (See TM 11-7025-300-10, page 5-121, for step-by-step procedures.)

b. DA Form 7370-R (Computation--Datum-To-Datum Coordinate Transformation Gauss Kruger (GK) Datums (FED MSR)) (Figure 10-27) is used to record the data determined. The instructions for computing the data to be recorded are shown on the front of the form. A list of datum names and corresponding numbers is located on the back of the form (Figure 10-26), in Appendix E, and in TM 11-7025-300-10 (pages B-34 through B-37). The Survey Control Point File can be accessed from these calculations.

Figure 10-24. **Sample DA Form 7368-R**

COMPUTATION – CONVERSION UTM TO GEO COORDINATE, GEO TO UTM COORDINATE, ZONE-TO-ZONE TRANSFORMATION (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 2 JAN 95
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select UTM TO GEO COORD (option A), GEO TO UTM COORD (option B), or ZONE TO ZONE (option C) from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD: UTM TO GEO	DATA RECORD: GEO TO UTM	DATA RECORD: ZONE TO ZONE
ENTER STATION NAME: ?	STATION NAME: EDWARD	STATION NAME: DUNCAN	STATION NAME: BN SCP
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID (NAME/NUMBER): 7	SPHEROID (NAME/NUMBER): 1	SPHEROID (NAME/NUMBER): 1
ENTER STARTING GRID ZONE: ?			STARTING GRID ZONE: 16
ENTER EASTING: ?	EASTING: 552571.13		EASTING: 800000.00
ENTER NORTHING: ?	NORTHING: 3834412.82		NORTHING: 3500000.00
ENTER LATITUDE: ?		LATITUDE: 34° 30' 31" (N) S	
ENTER LONGITUDE: ?		LONGITUDE: 97° 33' 14" E (W)	
HEMISPHERE (N/S): ?	ENTER (N) OR S		ENTER (N) OR S
ENTER GRID ZONE: ?	GRID ZONE: 14	GRID ZONE: 14	
ENTER AZIMUTH: ?			AZIMUTH: 0000.00
ENTER ENDING GRID ZONE: ?			ENDING GRID ZONE: 17
REQUIRED FIELDS	**DATA RECORD**		
ENTER EASTING: ?		EASTING: 632752.16	EASTING: 230676.25
ENTER NORTHING: ?		NORTHING: 3819305.28	NORTHING: 3499157.61
ENTER AZIMUTH: ?			AZIMUTH: 0055.926
ENTER LATITUDE: ?	LATITUDE: 34° 39' 01.093" (N) S		
ENTER LONGITUDE: ?	LONGITUDE: 98° 25' 34.758" E (W)		

REMARKS:

DA FORM 7368-R, SEP 96

Figure 10-25. **Sample DA Form 7369-R**

COMPUTATION—DATUM–TO–DATUM COORDINATE TRANSFORMATION LISTED DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 25 JAN 95
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select UTM TO UTM DATUM (option D), UTM TO GEO DATUM (option E), GEO TO UTM DATUM (option F), or GEO TO GEO DATUM (option G) from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER STATION NAME: ?	STATION NAME: ALPHA	STATION NAME: CHARLIE
ENTER FROM UTM/GEO DATUM: ?	FROM DATUM: 65 NAD 27 (CANAL ZONE)	FROM DATUM: 7 ASCENSION ISLAND
ENTER EASTING: ?	EASTING: 256779.41	EASTING: 569991.62
ENTER NORTHING: ?	NORTHING: 0898757.03	NORTHING: 9121982.89
ENTER LATITUDE: ?	LATITUDE: ° ' " N S	LATITUDE: ° ' " N S
ENTER LONGITUDE: ?	LONGITUDE: ° ' " E W	LONGITUDE: ° ' " E W
ENTER GRID ZONE: ?	GRID ZONE: 18	GRID ZONE: -28
ENTER FROM UTM/GEO DATUM: ?	TO DATUM: 80 PROV S. AMERICAN 56	TO DATUM: 98 WGS-84
ZONE TO ZONE:	ENTER Y OR (N)	ENTER Y OR (N)
ENTER ENDING GRID ZONE: ?	GRID ZONE: 18	GRID ZONE: -28

REQUIRED FIELDS	DATA RECORD	
RECORD EASTING: ?	EASTING: 257045.28	EASTING:
RECORD NORTHING: ?	NORTHING: 0899336.71	NORTHING:
RECORD LATITUDE: ?	LATITUDE: ° ' " N S	LATITUDE: 07° 56' 31.938" (S)
RECORD LONGITUDE: ?	LONGITUDE: ° ' " E W	LONGITUDE: 14° 21' 52.252" (W)
RECORD GRID ZONE: ?	GRID ZONE: 18	GRID ZONE: -28
RECORD ELLIPSOID: ?	ELLIPSOID: INTERNATIONAL	ELLIPSOID: WGS 1984

REMARKS:

DA FORM 7369-R, SEP 96

Figure 10-26. **Reverseof DA Forms 7369-R, 7370-R, and 7371-R**

KRASSOVSKY DATUMS			BESSEL DATUMS		
DATUM NAME	CODE	DISPLAYED NAME	DATUM NAME	CODE	DISPLAYED NAME
Afgooye	1	AFGOOYE	Potsdam	1	POTSDAM
Herat North	2	HERAT NORTH	Tokyo	2	TOKYO
Peking 1954	3	PEKING 1954			
Pulkovo 1942	4	PULKOVO 1942			
UTM DATUMS					
Adindan[1]	1	ADINDAN	Massawa	51	MASSAWA
Afgooye	2	AFG	Merchich	52	MERCHICH
Ain el Abd 1970	3	AIN EL ABD 1970	Midway Astro 1961	53	MIDWAY AST 1961
Anna 1 Astro 1965	4	ANNA 1 AST 1965	Minna	54	MINNA
Arc 1950	5	ARC 1950	Nahrwan 1 (Masirah Island [Oman])	55	NAHRWAN 1 OMAN
Arc 1960	6	ARC 1960	Nahrwan 2 (United Arab Emirates)	56	NAHRWAN 2 UAE
Ascension Island 1958	7	ASCENSION IL 1958	Nahrwan 3 (Saudi Arabia)	57	NAHRWAN 3 SAUDI
Astro Beacon E	8	ASTRO BEACON E	Schwarzech (Namibia)	58	NAMIBIA
Astro Tern Island (FRIG) 1961[2]	9	AST B4 SOR ATOL	Naparima, BWI	59	NAPARIMA BWI
Astro DOS[2]	10	ASTRO POS 71 4	North American 1927 (Continental United States)	60	NAD 27 CONUS
Astronomic Station 1952	11	ASTRO STA 52	North American 1927 (Alaska)	61	NAD 27 ALASKA
Australian Geodetic 1966	12	AUSTRL GEO 1966	North American 1927 (Bahamas, excluding San Salvador Island)	62	NAD 27 BAHAMAS
Australian Geodetic 1984	13	AUSTRL GEO 1984	North American 1927 (San Salvador Island)	63	NAD 27 SALVADOR
Bellevue (IGN)	14	BELLEVUE IGN	North American 1927 (Canada)	64	NAD 27 CANADA
Bermuda 1957	15	BERMUDA 1957	North American 1927 (Canal Zone)	65	NAD 27 CANAL ZO
Bogota Observatory	16	BOGOTA OBSERVY	North American 1927 (Caribbean)	66	NAD 27 CARIBEAN
Compo Inchauspe	17	COMPO INCHAUSPE	North American 1927 (Central America)	67	NAD 27 CENT AM
Canton Astro 1966[2]	18	CANTON IL 1966	North American 1927 (Cuba)	68	NAD 27 CUBA
Cape	19	CAPE	North American 1927 (Greenland)	69	NAD 27 GREENLD
Cape Canaveral	20	CAPE CANAVERAL	North American 1927 (Mexico)	70	NAD 27 MEXICO
Carthage	21	CARTHAGE	North American 1983	71	NORTH AMER 1983
Chatham 1971	22	CHATHAM 1971	Meteorologico 1963[2]	72	OBSERVATOR 1966
Chua Astro	23	CHUA ASTRO	Old Egyptian 1907[2]	73	OLD EGYPT 1930
Corrego Alegre	24	CORREGO ALEGRE	Old Hawaiian	74	OLD HAWAIIAN
Djakarta (Batavia)	25	DJAKARTA BATAV	Oman	75	OMAN
DOS 1968	26	DOS 1968	Ordnance Survey of Great Britain 1936	76	ORD SV GR BR 36
Easter Island 1967	27	EASTER IL 1967	Pico de Las Nieves	77	PICO DE LAS NVS
European 1950	28	EUROPEAN 1950	Pitcairn Astro 1967	78	PITCRN AST 1967
European 1979	29	EUROPEAN 1979	Provisional South Chilean 1963 or Hito XVIII 1963[2]	79	PROV S CHIL 63
Gandajika Base	30	GANDAJIKA BASE	Provisional South American 1956	80	PROV S AMER 56
Geodetic Datum 1949	31	GEO DATUM 1949	Puerto Rico	81	PUERTO RICO
Guam 1963	32	GUAM 1963	Qatar National	82	QATAR NATIONAL
Gux 1 Astro	33	GUX 1 ASTRO	Qornoq	83	QORNOQ
Hjorsey 1955	34	HJORSEY 1955	Rome 1940	84	ROME 1940
Hong Kong 1963	35	HONG KONG 1963	Sao Braz[2]	85	SANTA BRAZ
Indian 1 (Thailand, Vietnam)	36	IND 1 THAI VIET	Santa (DOS)	86	SANTA (DOS)
Indian 2 (Bangladesh, India, Nepal)	37	INDIAN 2	Sapper Hill 1943	87	SAPPR HILL 1943
Ireland 1965	38	IRELAND 1965	South American 1969	88	SOUTH AMERICAN
ISTS 073 Astro 1969	39	IST 73 AST 1969	South Asia	89	SOUTH ASIA
Johnston Island 1961	40	JOHNSTON IL 61	Porto Santo 1936[2]	90	SOUTHEAST BASE
Kandawala	41	KANDAWALA	Graciosa Base SW End 1948[2]	91	SOUTHWEAST BASE
Kerguelen Island	42	KERGUELEN IL	Timbalai 1948	92	TIMBALAI 1948
Kertau 1948	43	KERTAU 1948	Tokyo	93	TOKYO
Reunion[2]	44	LA REUNION	Tristan Astro 1968	94	TRISTN AST 1968
L. C. 5 ASTRO	45	L. C. 5 ASTRO	Viti Levu 1916	95	VITI LEVU 1916
Liberia 1964	46	LIBERIA 1964	Wake-Eniwetok 1960	96	WK ENIWETK 1960
Luzon 1 (Philippines)	47	LUZON 1 PHILIP	World Geodetic System 1972	97	WORLD GEO 1972
Luzon 2 (Mindanao Island)	48	LUZON 2 MINDAN	World Geodetic System 1984	98	WORLD GEO 1984
Mahe 1971	49	MAHE 1971	Zanderij	99	ZANDERIJ
Selvagem Grande 1938[2]	50	MARCO ASTRO			

[1] The transformation parameters for the Adindan datum have been updated by the Defense Mapping Agency. Use Program 16 (user-defined) with the following transformation parameters:

Semimajor Axis	Flattening	X-Shift	Y-Shift	Z-Shift
6378249.145	293.465	-166	-15	204

[2] Datum names were incorrect in DMA Technical Report (TR) 83501, 2 Dec 87, but are correct above. The FED-displayed names for these datums differ from the correct name.

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10-28. UTM TO KRASSOVSKY DATUM CONVERSION FILE

a. UTM to Krassovsky datum coordinate transformations transform UTM coordinates from a selected UTM datum to a selected Krassovsky datum. (See TM 11-7025-300-10, page 5-122, for step-by-step procedures.)

b. DA Form 7370-R is also used to record UTM to Krassovsky datum coordinated transformation. (See Figure 10-27.)

10-29. BESSEL TO UTM DATUM CONVERSION FILE

a. Bessel to UTM datum coordinate transformations transform UTM coordinates from a selected Bessel datum to a selected Bessel datum to a selected UTM datum. (See TM 11-7025-300-10, page 5-127, for step-by-step procedures.)

b. DA Form 7370-R is also used to record Bessel to UTM datum coordinate transformations. (See Figure 10-27.)

10-30. UTM TO BESSEL DATUM CONVERSION FILE

a. UTM to Bessel datum coordinate transformations transform UTM coordinates from a selected UTM datum to a selected Bessel datum. (See TM 11-7025-300-10, page 5-130, for step-by-step procedures.)

b. DA Form 7370-R is also used to record UTM to Bessel datum coordinate transformations. (See Figure 10-27.)

Note. When performing a Krassovsky or Bessel to UTM datum coordinate transformation, the user must select datums and/or numbers from the box at the top of the back of DA Form 7370-R. When performing a UTM to Krassovsky or Bessel datum coordinate transformation, select datums and/or numbers from the 99 listed datums.

10-31. USER-DEFINED TO USER-DEFINED DATUM CONVERSION FILE

a. User-defined to user-defined datum coordinate transformations transform UTM coordinates from a selected user-defined datum to another selected user-defined datum. These programs allow the option of zone-to-zone transformation. If yes (option Y) is selected, the ending grid zone must be entered. The Survey Control Point file cannot be accessed from any of these calculations. (See TM 11-7025-300-10, page 5-133, for step-by-step procedures.)

b. DA Form 7371-R (Computation--Datum-To-Datum Coordinate Transformation User-Defined Datums (FED MSR)) (Figure 10-28) is used to record the data determined. The instructions for recording the data determined are shown on the front of the form. The listed datums for computing these transformations and datum numbers are located on the back of the form. This information can also be found in Appendix E. Also, the Defense Mapping Agency (DMA) or a higher headquarters will disseminate user-defined datum parameters when needed.

10-32. USER-DEFINED TO LISTED DATUM CONVERSION FILE

a. User-defined to listed datum coordinate transformations transform UTM coordinates from a selected user-defined datum to a selected listed datum. (See TM 11-7025-300-10, page 5-139, for step-by-step procedures.)

b. DA Form 7371-R is also used to record user-defined to listed datum coordinate transformations. (See Figure 10-29.)

10-33. LITSTED TO USER-DEFINED DATUM CONVERSION FILE

a. Listed to user-defined datum coordinate transformations transform UTM coordinates from a selected listed datum to a selected user-defined datum. (See TM 11-7025-300-10, page 5-142, for step-by-step procedures.)

b. DA Form 7371-R is also used to record listed to user-defined datum coordinate transformations. (See Figure 10-30.)

Figure 10-27. **Sample DA Form 7370-R**

COMPUTATION—DATUM-TO-DATUM COORDINATE TRANSFORMATION
GAUSS KRUGER (GK) DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 4 JAN 95
CHECKER: SFC KNOX	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select KRASSOVSKY UTM DATUM (option H) UTM TO KRASSOVSKY DATUM (option I), BESSEL TO UTM DATUM (option J), or UTM TO BESSEL DATUM (option K) from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER STATION NAME: ?	STATION NAME: RAYMOND	STATION NAME:
ENTER FROM KRASS/UTM/BESSEL DATUM: ?	FROM DATUM: PEKING 1954	FROM DATUM:
ENTER GK/UTM EASTING: ?	EASTING: 400126.43	EASTING:
ENTER GK/UTM NORTHING: ?	NORTHING: 4470516.30	NORTHING:
ENTER GK/UTM GRID ZONE: ?	GRID ZONE: 20	GRID ZONE:
ENTER TO UTM/KRASS/BESSEL DATUM: ?	TO DATUM: WGS 1984	TO DATUM:
REQUIRED FIELDS	**DATA RECORD**	
RECORD UTM/GK EASTING:	EASTING: 400227.61	EASTING:
RECORD UTM/GK NORTHING:	NORTHING: 4468682.49	NORTHING:
RECORD UTM/GK GRID ZONE:	GRID ZONE: 50	GRID ZONE:
RECORD ELLIPSOID:	ELLIPSOID: WGS 1984	ELLIPSOID:
REQUIRED FIELDS	**DATA RECORD**	
ENTER STATION NAME: ?	STATION NAME:	STATION NAME:
ENTER FROM KRASS/UTM/BESSEL DATUM: ?	FROM DATUM:	FROM DATUM:
ENTER GK/UTM EASTING: ?	EASTING:	EASTING:
ENTER GK/UTM NORTHING: ?	NORTHING:	NORTHING:
ENTER GK/UTM GRID ZONE: ?	GRID ZONE:	GRID ZONE:
ENTER TO UTM/KRASS/BESSEL DATUM: ?	TO DATUM:	TO DATUM:
REQUIRED FIELDS	**DATA RECORD**	
RECORD UTM/GK EASTING:	EASTING:	EASTING:
RECORD UTM/GK NORTHING:	NORTHING:	NORTHING:
RECORD UTM/GK GRID ZONE:	GRID ZONE:	GRID ZONE:
RECORD ELLIPSOID:	ELLIPSOID:	ELLIPSOID:

REMARKS:

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Figure 10-28. **Sample DA Form 7371-R (user-defined to user-defined)**

COMPUTATION—DATUM–TO–DATUM COORDINATE TRANSFORMATION
USER-DEFINED DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 3 MAR 95
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select USER DEF TO USER DEF DATUM (option L), USER DEF TO LISTED DATUM (option M), or LISTED TO USER DEF DATUM from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD		
	USER DEF TO USER DEF	USER DEF TO LISTED	LISTED TO USER DEF
ENTER STATION NAME: ?	STATION NAME: HOWARD	STATION NAME:	STATION NAME:
ENTER FROM LISTED DATUM: ?			FROM DATUM:
ENTER X SHIFT USER DEF1: ?	X SHIFT: -104	X SHIFT:	
ENTER Y SHIFT USER DEF1: ?	Y SHIFT: -129	Y SHIFT:	
ENTER Z SHIFT USER DEF1: ?	Z SHIFT: 239	Z SHIFT:	
ENTER SEMI-MAJOR USER DEF1: ?	SEMI-MAJOR AXIS: 6378388.0	SEMI-MAJOR AXIS:	
ENTER FLAT/MINOR USER DEF1: ?	ENTER (F) OR M	ENTER F OR M	
ENTER FLATTENING USER DEF1: ?	FLATTENING: 297	FLATTENING:	
ENTER SEMI-MINOR USER DEF1: ?	SEMI-MINOR AXIS:	SEMI-MINOR AXIS:	
ENTER EASTING: ?	EASTING: 396676.13	EASTING:	EASTING:
ENTER NORTHING: ?	NORTHING: 2877823.95	NORTHING:	NORTHING:
ENTER GRID ZONE: ?	GRID ZONE: -53	GRID ZONE:	GRID ZONE:
ENTER TO LISTED DATUM: ?		TO DATUM:	
ENTER X SHIFT USER DEF2: ?	X SHIFT: 0		X SHIFT:
ENTER Y SHIFT USER DEF2: ?	Y SHIFT: 0		Y SHIFT:
ENTER Z SHIFT USER DEF2: ?	Z SHIFT: 0		Z SHIFT:
ENTER SEMI-MAJOR USER DEF2: ?	SEMI-MAJOR AXIS: 6378137.0		SEMI-MAJOR AXIS:
ENTER FLAT/MINOR USER DEF2: ?	ENTER (F) OR M		ENTER F OR M
ENTER FLATTENING USER DEF2: ?	FLATTENING: 298.2572236		FLATTENING:
ENTER SEMI-MINOR USER DEF2: ?	SEMI-MINOR AXIS:		SEMI-MINOR AXIS:
ZONE TO ZONE: ?	ENTER Y OR (N)	ENTER Y OR N	ENTER Y OR N
ENTER ENDING GRID ZONE: ?	GRID ZONE:	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	REMARKS:
RECORD EASTING: ?	EASTING: 396840.08	
RECORD NORTHING: ?	NORTHING: 2878159.86	
RECORD GRID ZONE: ?	GRID ZONE: -53	
RECORD ELLIPSOID: ?	ELLIPSOID: USER DEFINED	

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Figure 10-29. **Sample DA Form 7371-R (user-defined to listed)**

COMPUTATION—DATUM–TO–DATUM COORDINATE TRANSFORMATION
USER-DEFINED DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 2 FEB 95
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select USER DEF TO USER DEF DATUM (option L), USER DEF TO LISTED DATUM (option M), or LISTED TO USER DEF DATUM from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD: USER DEF TO USER DEF	DATA RECORD: USER DEF TO LISTED	DATA RECORD: LISTED TO USER DEF
ENTER STATION NAME: ?	STATION NAME:	STATION NAME: JOHN	STATION NAME:
ENTER FROM LISTED DATUM: ?			FROM DATUM:
ENTER X SHIFT USER DEF1: ?	X SHIFT:	X SHIFT: -166	
ENTER Y SHIFT USER DEF1: ?	Y SHIFT:	Y SHIFT: -15	
ENTER Z SHIFT USER DEF1: ?	Z SHIFT:	Z SHIFT: 204	
ENTER SEMI-MAJOR USER DEF1: ?	SEMI-MAJOR AXIS:	SEMI-MAJOR AXIS: 6378249.145	
ENTER FLAT/MINOR USER DEF1: ?	ENTER F OR M	ENTER (F) OR M	
ENTER FLATTENING USER DEF1: ?	FLATTENING:	FLATTENING: 293.465	
ENTER SEMI-MINOR USER DEF1: ?	SEMI-MINOR AXIS:	SEMI-MINOR AXIS:	
ENTER EASTING: ?	EASTING:	EASTING: 168931.69	EASTING:
ENTER NORTHING: ?	NORTHING:	NORTHING: 14113.78	NORTHING:
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE: 48	GRID ZONE:
ENTER TO LISTED DATUM: ?		TO DATUM: KERTAU 1948	
ENTER X SHIFT USER DEF2: ?	X SHIFT:		X SHIFT:
ENTER Y SHIFT USER DEF2: ?	Y SHIFT:		Y SHIFT:
ENTER Z SHIFT USER DEF2: ?	Z SHIFT:		Z SHIFT:
ENTER SEMI-MAJOR USER DEF2: ?	SEMI-MAJOR AXIS:		SEMI-MAJOR AXIS:
ENTER FLAT/MINOR USER DEF2: ?	ENTER F OR M		ENTER F OR M
ENTER FLATTENING USER DEF2: ?	FLATTENING:		FLATTENING:
ENTER SEMI-MINOR USER DEF2: ?	SEMI-MINOR AXIS:		SEMI-MINOR AXIS:
ZONE TO ZONE: ?	ENTER Y OR N	ENTER Y OR (N)	ENTER Y OR N
ENTER ENDING GRID ZONE: ?	GRID ZONE:	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	REMARKS:
RECORD EASTING: ?	EASTING: 169313.12	
RECORD NORTHING: ?	NORTHING: 14312.65	
RECORD GRID ZONE: ?	GRID ZONE: 48	
RECORD ELLIPSOID: ?	ELLIPSOID: MOD EVEREST	

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Figure 10-30. **Sample DA Form 7371-R (listed to user-defined)**

COMPUTATION—DATUM–TO–DATUM COORDINATE TRANSFORMATION
USER-DEFINED DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER: SGT HILSMAN	NOTEBOOK REFERENCE:	DATE: 1 JAN 95
CHECKER: SFC HOVSEPIAN	AREA: FT SILL, OK	SHEET 1 OF 1 SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select USER DEF TO USER DEF DATUM (option L), USER DEF TO LISTED DATUM (option M), or LISTED TO USER DEF DATUM from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD		
	USER DEF TO USER DEF	USER DEF TO LISTED	LISTED TO USER DEF
ENTER STATION NAME: ?	STATION NAME:	STATION NAME:	STATION NAME: JOE
ENTER FROM LISTED DATUM: ?			FROM DATUM: EUROPEAN 1950
ENTER X SHIFT USER DEF1: ?	X SHIFT:	X SHIFT:	
ENTER Y SHIFT USER DEF1: ?	Y SHIFT:	Y SHIFT:	
ENTER Z SHIFT USER DEF1: ?	Z SHIFT:	Z SHIFT:	
ENTER SEMI-MAJOR USER DEF1: ?	SEMI-MAJOR AXIS:	SEMI-MAJOR AXIS:	
ENTER FLAT/MINOR USER DEF1: ?	ENTER F OR M	ENTER F OR M	
ENTER FLATTENING USER DEF1: ?	FLATTENING:	FLATTENING:	
ENTER SEMI-MINOR USER DEF1: ?	SEMI-MINOR AXIS:	SEMI-MINOR AXIS:	
ENTER EASTING: ?	EASTING:	EASTING:	EASTING: 520105.62
ENTER NORTHING: ?	NORTHING:	NORTHING:	NORTHING: 6796958.97
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:	GRID ZONE: 34
ENTER TO LISTED DATUM: ?		TO DATUM:	
ENTER X SHIFT USER DEF2: ?	X SHIFT:		X SHIFT: 0
ENTER Y SHIFT USER DEF2: ?	Y SHIFT:		Y SHIFT: 0
ENTER Z SHIFT USER DEF2: ?	Z SHIFT:		Z SHIFT: 0
ENTER SEMI-MAJOR USER DEF2: ?	SEMI-MAJOR AXIS:		SEMI-MAJOR AXIS: 6378137.0
ENTER FLAT/MINOR USER DEF2: ?	ENTER F OR M		ENTER (F) OR M
ENTER FLATTENING USER DEF2: ?	FLATTENING:		FLATTENING: 298.2572236
ENTER SEMI-MINOR USER DEF2: ?	SEMI-MINOR AXIS:		SEMI-MINOR AXIS:
ZONE TO ZONE: ?	ENTER Y OR N	ENTER Y OR N	ENTER Y OR (N)
ENTER ENDING GRID ZONE: ?	GRID ZONE:	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	REMARKS:
RECORD EASTING: ?	EASTING: 520045.27	
RECORD NORTHING: ?	NORTHING: 6796764.11	
RECORD GRID ZONE: ?	GRID ZONE: 34	
RECORD ELLIPSOID: ?	ELLIPSOID: USER DEFINED	

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*CHAPTER 12

BACKUP COMPUTER SYSTEM

12-1. BUCS CONFIGURATIONS

The BUCS has two configurations-the BUCS General and the BUCS Special. The quantity and configuration authorized to survey elements are shown in Table 12-1.

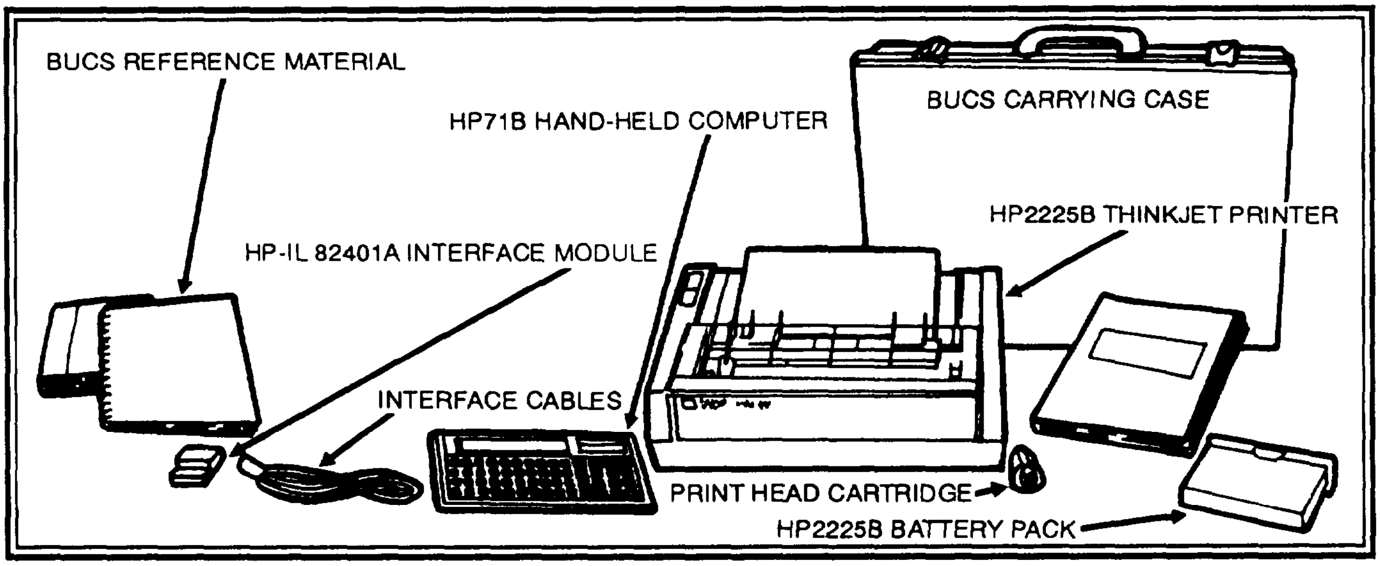
Table 12-1. **Authorization to survey elements**

SURVEY ELEMENT	BUCS GENERAL	BUCS SPECIAL
Conventional survey party	2	-
SPCE	1	1
PADS survey party	1	-

a. BUCS General. The BUCS General consists of the HP71B computer, a carrying case, and reference material. The HP71B is powered by four AAA 1.5-volt batteries or through an AC adapter by 120- or 240-v AC current. The average battery life of the four AAA batteries is 60 hours. The HP71B can perform rapid and accurate calculations. The computer has an operating system that accepts any RAM or read-only memory (ROM) combination to a maximum of four plug-in custom or prewritten memory modules. It has a continuous memory that can be expanded with the use of plug-in memory modules. The continuous memory allows the operator to turn the computer off and later resume operation without losing memory programs or the previous program calculations. The HP71B has a liquid crystal display that can display up to 22 characters. The contrast of the display characters and annunciator and the viewing angle are adjustable. The computer can function as a perpetual clock and/or calendar.

b. BUCS Special. The BUCS Special consists of the HF71B computer, the HP2225B ThinkJet printer, the interface cable, the HP-IL 82401A interface module, the HP2225B battery pack, a 120-volt and a 240-volt AC adapter, the carrying case, and reference material. (See Figure 12-1.) The ThinkJet printer is designed for portability. It is powered by a rechargeable battery pack or by a 120- or 240-v AC adapter. The print head cartridge in the ThinkJet printer is disposable and easy to replace. The printer is designed to print on standard 8.5- by 11-inch or European size A-4 single-sheet or fanfold paper. It can print 150 characters per second, print bold characters, and underline in four print pitches.

Figure 12-1. **BUCS with components**



12-2. ALPHANUMERIC KEYBOARD FUNCTIONS

Most keys on the computer perform one primary operation and two alternate operations. The primary operation of any key is indicated by the white or black character(s) on the face of the key. The alternate operations are indicated by the gold characters printed above the keys and the blue characters below the keys. To select the character or operation printed on the face of a key, press only that key. To select the alternate character or operation printed in gold and blue, press the like-colored prefix key f or g and then the operation key. The functions of each key are described in TM 9-7000-200-13&P and the HP71B Reference Manual.

12-3. STATUS ANNUNCIATORS

Table 12-2 lists and briefly describes the status annunciators.

Table 12-2. **Status annunciators**

DISPLAY	MEANING
BAT	Battery is low.
CALC	HP71B is in the calculate mode.
USER	User keyboard is active.
RAD	Angular setting is radians.
PRGM	A program is running.
SUSP	A program is suspended.
←	Data extend to the left 01 the display,
→	Data extend to the right of the display.

12-4. PREPARATION FOR BUCS OPERATION

a. BUCS Operating Precautions. Certain electronic circuits in the computer function continuously. Improper operation can disrupt performance in unexpected ways or damage the electronics. Observe the precautions below in assembling or operating the BUCS General or BUCS Special.

(1) When installing batteries or RAM or ROM modules, the operator must ground himself to metal to remove static electricity from the computer. This is particularly important for the handling of the HP-IL 82401A interface module.

(2) Turn the computer off before installing or removing batteries. When removed, the batteries must be replaced within 30 seconds or the contents of the computer memory are lost. If the AC adapter is connected to the computer, the memory will not be lost when the batteries are changed.

(3) Turn the computer off before installing or removing plug-in modules. Memory loss will occur if the interface module or a RAM or ROM module is removed when the computer is on.

(4) Turn the computer and printer off before connecting or disconnecting the interface cables to either component.

(5) Do not place the computer in strong magnetic fields (for example, near a telephone).

(6) Do not place fingers, tools, or other foreign objects into any of the computer plug-in ports.

(7) Place the printer on a clean and level surface for operation.

b. BUCS Turn-On and Turn-off Procedures. To place the computer in operation, press the ON key. To turn the computer off, perform one of the following:

Ž Press the f key and then the ON key.

Ž Type in OFF, and press the END LINE key.

Ž Type in BYE, and press the END LINE key (only in basic mode).

> **Note.** A power supply safeguard automatical turns the computer off with loss of memory after 10 minutes of inactivity.

c. BUCS General Assembly. To use the BUCS General for survey computations, perform the steps discussed below.

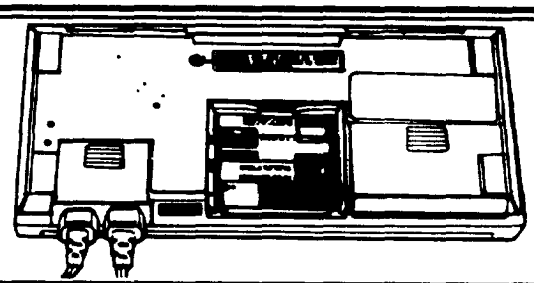
(1) Ensure the computer is off. No prompts or characters should appear in the display window.

(2) Turn the computer upside down, and set it on a soft, flat surface.

(3) Using your thumb, press down on the battery compartment door (the door to the center compartment). Slide the compartment door toward the rear of the computer. When you press down on the compartment door, the catch will snap as it unlatches from the computer.

(4) Insert the batteries. Be careful to align the batteries according to the indicators in the compartment. (See Figure 12-2.)

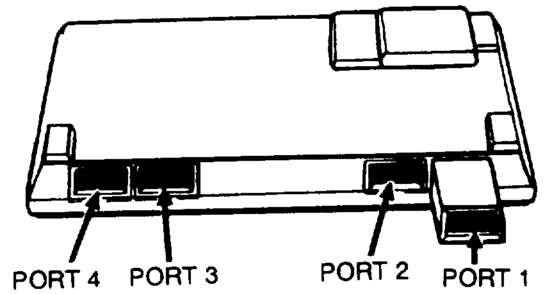
Figure 12-2. **HP71B battery installation**



(5) Lay the compartment door imposition. Slide it toward the front of the computer until the catch snaps.

(6) Insert and secure the program ROM module in the appropriate plug-in port on the computer. Port 1 is the preferred port to use. If port 1 is in use, take the next numbered port. (See Figure 12-3.)

Figure 12-3. **Survey ROM module installation**



CAUTION

Inserting or retrieving the program ROM module while the computer is on can damage the module and/or cause the display to be frozen.

d. BUCS Special Assembly. The computer for the BUCS Special is assembled in the same manner as that for the BUCS General. To use the printer with the computer, follow the procedures discussed below.

(1) Insert and secure the HP-IL 82401A interface module in the appropriate plug-in port on the computer. (See Figure 12-4.)

(2) Connect the interface cables to the interface module connectors of the computer. (See Figure 12-5.)

(3) connect the interface cables to the printer interfaee connectors. (See Figure 12-6.)

(4) Insert the battery pack into its slot on the printer. Push the battery pack inward until the latch snaps shut.

(5) Insert the AC adapter plug into the receptacle on the battery pack; then connect the AC adapter to the AC power source.

(6) To turn the printer on, press the POWER switch to the 1 position. The PWR light should be on.

Figure 12-4. **HP-IL 62401A interface installation**

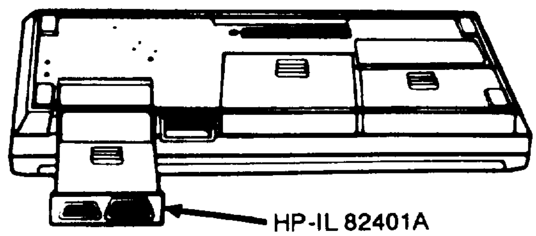


Figure 12-5. **HP71B interface cables**

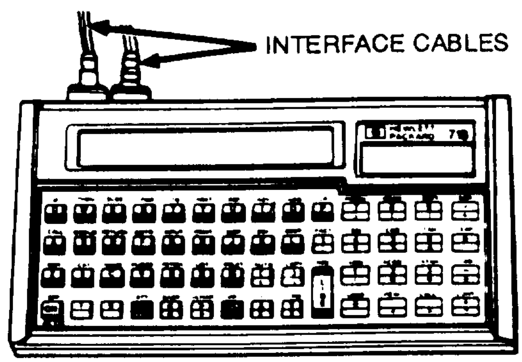
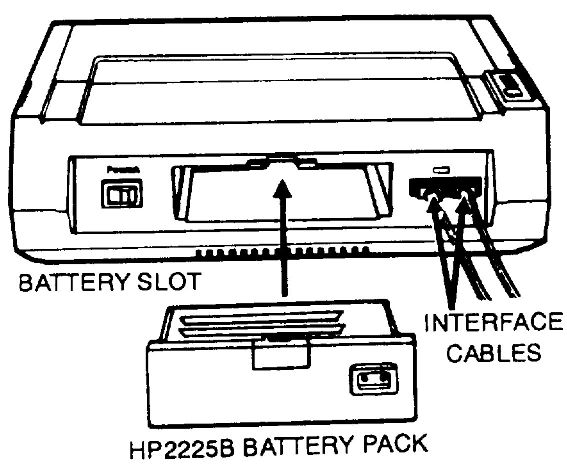


Figure 12-6. **HP2225B printer (rear view)**



(7) Open the front cover of the printer, and pull back the carriage latch. Insert the paper ink absorber into its holder. Insert the print head cartridge into the carriage. (See Figure 12-7.)

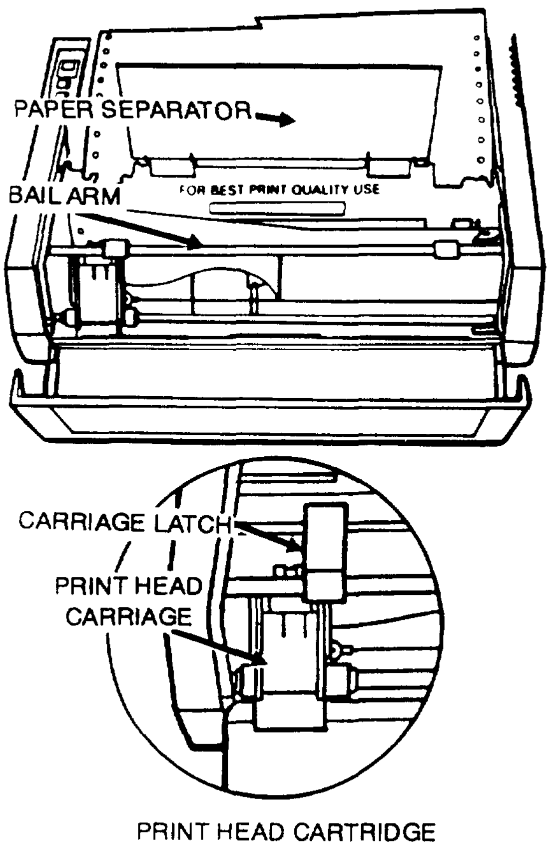
(8) Close and snap the carriage latch, and pull the bail arm back. Install the paper separator onto the printer, and raise it to the vertical position. (See Figure 12-7.)

(9) Insert the paper, and slide it along the paper channel into the slot under the paper separator. Pull the top edge of the paper 1/4 inch above the bail arm rollers.

(10) Align the right-hand pinwheel to the paper holes, and push the bail arm forward. Lower the paper separator to the operating position, and close the printer cover. The BUCS Special is now ready for operation.

e. HF71B Computer Operational Self-Test. The self-test can be conducted with or without the AC adaptor. If you suspect that the computer is not operating properly, perform the self-test as specified below.

Figure 12-7. **HP2225B printer (front view)**



Note. It is advisable to perform the self-test after prolonged periods of storage or when installing new batteries and/or ROM modules.

(1) Turn the computer off.

(2) Remove all custom or prewritten program ROM modules from the computer. Reinsert the plug-in port covers into the computer plug-in ports.

(3) Plug the AC adapter into the receptacle on the back of the computer. Connect the AC adapter to an AC power outlet.

(4) Turn the computer on.

(5) Type PI, and then press the END LINE key. The result 3.14159265359 should be displayed, which indicates that about 60 percent or more of the computer circuits are operating properly.

(6) If the computer repeatedly fails to perform a particular operation or repeatedly displays an error message, such as EXCESS CHARS, carefully reread the instruction regarding that operation. You may be improperly specifying the operation.

(7) If the computer still does not operate properly, press the ON key and / key at the same time. INIT:1 will appear in the display. Press the END LINE key to execute a Level 1 initialization. The display should now display the replace cursor (BASIC mode) or insert cursor (CALC mode).

(8) Press the ON key and/ key at the same time. Then press the 2 key and END LINE key. This executes a Level 2 initialization (INIT: 2). The computer will do a self-test of its circuitry and will display ROM TEST 1 as it begins to test the circuits. When the first portion of the test verifies the proper operation of the circuits, the computer will display ROM TEST 1G 2. This indicates that the computer is continuing the test. When the test is completed, the computer will display ROM TEST 1G 2G 3G 4G. Then it will return to the BASIC mode if the test revealed no faulty circuits. If faulty circuits are detected, at least one of the numbers will be followed by a B instead of a G. Thus, ROM TEST 1G 2B 3G 4G indicates that the computer has a faulty ROM. If the computer indicates a faulty ROM after an INIT: 2 test, it requires service.

(9) If the display remains blank when the ON key is pressed, or if characters remain "frozen" in the display, then reset the memory by using the procedure below.

(a) Press and release the ON and / keys at the same time.

(b) The display prompts INIT: 1. All keys are now inactive except 1, 2,3, and END LINE. To reset the memory, press the 3 and END LINE keys.

(c) The display prompts MEMORY LOST. Clear the display by prosing the ON key.

(10) If the procedure outlined in (9) above did not solve the problem, reset the memory as discussed below.

(a) Unplug the AC adapter, and turn the computer off.

(b) Remove all modules.

(c) Remove the batteries.

(d) Press and hold down the ON key for about 30 seconds to discharge the circuits.

(e) Install the batteries, or connect the AC adapter. Then press the ON key. The message MEMORY LOST should appear in the display. Pressing any key should display the BASIC prompt and replace the cursor.

f. HP2225B ThinkJet Printer Operational Self-Test. If you suspect that the printer is not operating properly, perform the self-test in the order specified below.

(1) Turn the HP2225B printer off.

(2) Depress and hold the line feed (LF button while turning the power switch on.

(3) Release the LF button to start the self-test sequence.

(4) You can terminate the self-test at any time by turning the printer off.

12-5. SURVEY PROGRAM MODULE

The survey programs in the survey program module are user-friendly. The user is guided through each program by numerous prompts that are simple and understandable. The prompts displayed must be followed step-by-step to determine the correct data or solution in that program. The known or field data required for computer computations are the same as those required for manual computations. Survey data and computations may be recorded on the appropriate computation forms developed for use with the computer or recorded directly by the printer when the BUCS Special computer is used. The prompt abbreviations are explained in the Glossary and in the instructions section of each form.

Note. Record data **exactly** as shown on the display. Computations will be rounded off only before survey data are passed to the user.

a. Initial Turn-On. To activate the survey module for the initial turn-on, type RUN SURVEY; then press the END LINE key. The display shows SURVEY PGM MENU REV1. After the initial turn-on, the user need only press the RUN key to call up the survey program menu. Anytime the survey module is removed, the initial turn-on procedure applies.

b. Program Selection. Two different procedures can be used to select a program from the survey module.

(1) Follow the steps in Table 12-3 to call a program for which the program or module number is known.

(2) Follow the steps in Table 12-4 to call a program for which the program or module number is unknown.

Table 12-3. **Program or module number known**

STEP	INSTRUCTION	ENTER	PRESS	DISPLAY
1	Initial turn-on	RUN SURVEY	END LINE	^DATE 01-JAN-00
2			END LINE (three times)	MODULE DESIRED-
3	Select module	MODULE #	END LINE	(program title)
4	Enter the required Input data, and follow the program prompts.			

Table 12-4. **Program or module number unknown**

STEP	INSTRUCTION	ENTER	PRESS	DISPLAY
1	Initial turn-on	RUN SURVEY	END LINE	^DATE 01 JAN-00
2			END LINE (three times)	MODULE DESIRED-
3	Select module		END LINE	(program title)

Table 12-4. **Program or module number unknown (continued)**

STEP	INSTRUCTION	ENTER	PRESS	DISPLAY
4	Continue to press END LINE key to obtain next program or until desired program title and number are displayed.			
5	When desired program title and number are displayed, press X key and END LINE key.			
6	Enter required input data, and follow program prompts.			

c. Survey Program Menu. Table 12-5 is a complete list of the programs contained in the menu as each appears in the display.

Table 12-5. **Survey program menu**

TITLE	NUMBER
AZIMUTH/DISTANCE	#1
TRAVERSE	#2
TRIANGULATION	#3
RESECTION	#4
ALT METHOD	#5
HASTY ASTRO	#6
STAR ID	#7
POLARIS TABULAR	#8
CONVERGENCE	#9
CONVERSION/TRANS	#10
SUBT/TRIG TRAV	#11
INTERSECTION	#12
ARTILLERY ASTRO	#13

d. Program Functions. The operator can back Up to or recall a previous display, or he can go to the top of a file and review the entire program. He can correct data, if required, by entering the correct data. The operator can abort a survey program at any time. These capabilities are inherent to the survey program software.

(1) Backup. To backup to a prior prompt or data display, press the Band END LINE keys. To backup to each previous prompt or data display, repeatedly press the B and END LINE keys.

> **Note.** Specific display prompts are preceded by a circumflex (^). The circumflex is used with the backup function. It tells the operator performin the backup operation that some data have been bypassed. To review the bypassed data, the operator must proceed in the program. In the following example, Program 1, Azimuth and Distance, is used to demonstrate the backup procedures when a prompt with a circumflex is displayed.

EXAMPLE

DISPLAY PROMPT	EXPLANATION
DISPLAY PROMPT SURVEY PGM MENU REV1 MODULE DESIRED- AZIMUTH/DISTANCE E OCC STA: N OCC STA: E OF AZMK: N OF AZMK: ^AZ TO AZMK: DIST AZMK: MORE POINTS (Y/N):	If a backup operation is performed at display prompt MORE POINTS (Y/N):, the computer will bypass the display prompt DIST AZMK: and proceed directly to the display prompt with the circumflex (^AZ TO AZMK:). To review the display prompt DIST AZMK:, proceed in the program by pressing the END LINE key.

(2) Top of file. To go back to the beginning of a program, press the T (top of file) and END LINE keys. This allows the operator to review the entire program and check the data displays to ensure correct information was entered.

(3) Error correction. After performing a backup of a prior input, the operator can correct input data by entering the corrected data where the error exists. Key in the correct data, and press the END LINE key. To recompute all outputs by using the corrected data, press the END LINE key as required.

(4) Abort. The operator can abort a survey program at any point in the program calculation by pressing the A and END LINE keys. A safety prompt, ABORT (Y/N), is displayed to preclude accidentally aborting a program. To complete the abort procedure, press the Y and END LINE keys. The next display prompt will be SURVEY PGM MENU REV1.

(5) Warning messages. Table 12-6 lists the warning messages that may be encountered in the survey programs.

12-6. SURVEY PROGRAMS

a. Program 1–Azimuth and Distance. This program computes the grid azimuth and distance between two known stations. The user must input the known UTM coordinates of both stations. Computations are recorded on DA Form 5590-R.

b. Program 2–Traverse. This program computes the grid azimuth, coordinates, and height of up to 40 main scheme traverse stations from the known data of the starting station and the field data of the traverse. Offset stations (doglegs) are not included. The program converts slope distance to horizontal (sea level) distance and computes total traverse length, total azimuth and height corrections, radial error of closure, and accuracy ratio. (See Appendix B for accuracy requirements.) It also computes traverse adjustment. A sketch of a sample traverse is shown in Figure 12-8. The known data and field data to be used in computation of this traverse are recorded on DA Form 5591-R. The closure and adjustment data are recorded on the reverse of DA Form 5591-R. The data for a dogleg cannot be recalled for correction or review after the prompt AZ TO REAR: 0.000 is displayed and the END LINE key is pressed (step 6).

c. Program 3–Triangulation. This program computes coordinates, height, azimuth, and distance by triangulation. It will compute a single triangle or a chain of triangles up to 40 triangles. Data for triangulation computations are recorded on DA Form 5592-R.

d. Program 4-Resection. This program computes the coordinates and height of one or more stations from the UTM coordinates of three known stations. Resection computations are recorded on DA Form 5593-R.

Figure 12-8. **Sketch of a sample traverse**

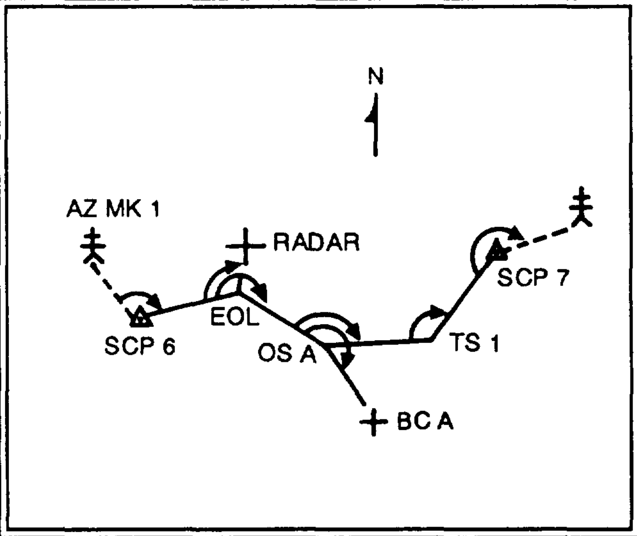


Table 12-6. **Warning messages**

MESSAGES	INDICATION
FILE FULL	Occurs in traverse, triangulation, and intersection when 40 stations or targets are exceeded.
NO VALID SOLUTION	Occurs in three-point resection when sum of angles falls between 2,845 and 3,555.
SET # REJECTED	Occurs in the astronomic programs when a single set is rejected.
REJECT CRIT NOT MET	Occurs in the astronomic programs when rejection criteria are not met.
MAXIMUM 3 SETS	Occurs when operator tries to compute more than three sets of astronomic computations.
INSUFFICIENT MEMORY	May occur if RAM has not been cleared before survey module is inserted.
MEMORY LOST	Occurs when memory is cleared.
NO SOLUTION - CHECK INPUT	Occurs when computation based on input data is not possible.
ILLEGALENTRY	Occurs when operator tries to enter data which are not within input parameters.
WARNING: DATE <1950	Occurs when the operator tries to enter a pre-1950 date.
SET#1 AZ ___.___ SET #2 AZ ___.___ SET #3 AZ ___.___	Occurs in artillery astro program when rejection criteria are not met These three messages follow the prompt REJECTION CRIT NOT MET
LAT NOT WITHIN UTM	Occurs when the operator tries to enter a latitude greeter than 84° (north) or less than -80° (south).

e. Program 5–Altitude Method. This program computes a grid azimuth from three sets of observations of the sun or a survey star. The program contains two separate computations–one for sun and one for stars. Computation of the sun altitude is recorded on DA Form 5594-R. Computation of star altitude method is recorded on DA Form 5595-R. Azimuth from three sets of observations are computed, and the azimuth of each set is compared to the mean of the three sets. If one of the three sets does not meet the rejection criteria, the computer will display SET #_REJECTED. The computer will then calculate a mean azimuth from the two remaining sets. Should two sets fail to meet accuracy specifications, the display will be REJECT CRIT NOT MET. In this case, check the input data and recompute. If rejection criteria still arc not met, determine new field data.

CAUTION

Once the user has obtained the final grid azimuth and it is shown in the GRID AZ/MK display, the backup function cannot be used, To review any previously entered data, the operator must use the top of file function (press T and END LINE keys). The backup function can be used at any time before the final grid azimuth is shown in the GRID AZ/MK display.

f. Program 6—Hasty Astronomic Observation (Hasty Astro). This program computes a grid azimuth and check angle from observations of the sun or a survey star. Data for either operation are recorded on DA Form 7286-R. The accuracy of the computation depends on the instrument used to perform the observation (0.3 roils for the T16). The program uses the electronic ephemeris, which eliminates the need to extract data from FM 6-300. The program provides the option of using the internal timer to determine date and time of observation or manually inputting dale and time. The ability to manually input date and time of observation allows the surveyor to perform fieldwork without BUCS being at the site of observation.

g. Program 7—Star 11). This program computes the approximate azimuth and altitude to a selected star at a date and time chosen by the user. The orientation data will help identify survey stars for astro observation or navigation. The program will compute the approximate azimuth and altitude (vertical angle) to any of the 73 survey stars listed in FM 6-300. The orientation data are accurate to 5.0 roils. Data for Star ID are recorded on DA Form 7284-R. The form has space for six sets of data.

h. Program 8—Polaris Tabular Method. This program computes a grid azimuth from three sets of observations of Polaris by using the Polaris tabular method. Computations are recorded on DA Form 5598-R. This program checks the accuracy specifications in the same manner as Program 5.

i. Program 9—Grid Convergence. This program computes a UTM grid azimuth from a gyroscopic (true) azimuth. Computations are recorded on DA Form 5599-R.

j. Program 10—Conversion and Transformation. This program has three separate operations which are described below.

(1) Geographic to UTM. This operation computes conversion of geographic coordinates to UTM coordinates. Computations are recorded on DA Form 5600-R. This operation requires the following data:

- Spheroid.
- Latitude of station.
- Longitude of station.
- Grid zone.

(2) UTM to geographic. This operation computes conversion of UTM coordinates to geographic coordinates. Computation are recorded on DA Form 5601-R. This operation requires the following data:

- Spheroid.
- UTM casting.
- UTM northing.
- Grid zone.

(3) Zone to zone. This operation transforms UTM grid coordinates and grid azimuth from one grid zone to an adjacent grid zone. Computations are recorded on DA Form 5602-R. The operation requires the following data:

- Spheroid.
- Starting grid zone.
- Ending grid zone.
- UTM casting.
- UTM northing.
- UTM grid azimuth.

k. Program 11–Trig Traverse and Subtense. This program has two separate operations-trig traverse and subtense. Both operations of this program compute horizontal distances. Computations for both operations are recorded on DA Form 5603-R.

1. Program 12—Intersection. This program computes the UTM coordinates of a target by intersection. Computations are recorded on DA Form 5604-R. A maximum of 40 targets can be computed when the same OPs are common to subsequent targets. This program can be used for either type of target area base. (intervisible or nonintervisible). The following data are required:

- Coordinates of OP 1 (01).
- Coordinates of OP 2 (02).
- Azimuth from OP 1 to target.
- Azimuth from OP 2 to target.
- Vertical angle from OP 1 to target.

m. Program 13–Artillery Astronomic Observation (Arty Ash). This program computes a grid azimuth from three observations of the sun or survey star. Data for either observation is recorded on DA Form 7285-R. This program uses an electronic ephemeris, which eliminates the need to extract data from FM 6-300. The program provides the option of using the internal timer or manually entering the date and time of **tip** for each observation. The ability to manually input the date and time of observation allows surveyors to perform fieldwork without BUCS being at the site of observation. The program cheeks the accuracy specifications in the same manner as Program 5.

12-7. SPECIAL APPLICATIONS

Several special applications of the BUCS can be performed by the user. These applications are as follows:

- Using the continuous memory.
- Exiting and reentering the program mode.
- Setting the time and date.
- Making time corrections and adjustments (internal timer).
- Determining time accuracy requirements.
- Adjusting the contrast of the display.
- Increasing the speed of data input and calculations.
- Clearing the memory.
- Inserting RUNNING CLOCK program into BUCS memory.

a. Using BUCS Continuous Memory. To protect the BUCS from running down the batteries, a built-in safety feature turns the computer off after 10 minutes of inactivity. The BUCS has a continuous memory which allows the operator to recall the last program and its calculations at any time without loss of survey data.

(1) The operator uses the following steps to recall the last program and its calculations before the computer is turned off:

Step 1. Turn the computer on.

Step 2. Press the f key.

Step 3. Press the CONT key.

Step 4. Press the END LINE key.

(2) This procedure will recall the program and the calculations. The computer will display the prompt which follows the prompt at which the computer turned itself off. Use the backup procedure to verify the data of the previous display prompt, and continue computations.

b. Exiting and Reentering BUCS Program Mode. The BUCS allows the operator to exit the survey program at any time for the purpose of performing mathematical calculations independent of the program. The operator may reenter the survey program at any time without loss of memory.

(1) The following steps must be performed to exit the program mode and go to the calculation mode:

Step 1. Press the ON key to clear the display.

Step 2. Press the f key.

Step 3. Press the CALC key.

The computer is now in the CALC mode and ready to perform mathematical problems independent from the survey program.

(2) The following steps must be performed to reenter the program mode:

Step 1. Press the f key.

Step 2. Press the CALC key.

Step 3. Press the f key.

Step 4. Press the CONT key.

Step 5. Press the END LINE key.

The computer will return to the display prompt which follows the display prompt where the program was exited.

(3) The following steps must be performed to reenter the program mode at the very start of the display prompt ^DATE 01-JAN-00:

Step 1. Press the f key.

Step 2. Press the CALC key.

Step 3. Press the RUN key.

Step 4. Press the END LINE key.

The computer is now in the program mode and ready to perform survey programs 1 through 13.

> **Note.** The procedure in (3) will discard the program which was run before this procedure.

c. Setting Date and Time (Internal Timer). The BUCS contains an accurate quartz-crystal clock and a calendar covering several thousand years. The clock and calendar are referred to as the *internal timer* in this chapter. The internal timer is accessed at the TIME MODULE prompt in the program instructions. This internal timer runs whether the BUCS is on or off. It begins as soon as the batteries are installed. The steps for setting the date and time are as follows:

Step 1. Turn BUCS on.

Step 2. Type RUN SURVEY.

- The SURVEY routine will call a subroutine (DATIME) which will then request the proper date by displaying ^DATE:DD:-MMM-YY. The DD is the day; MMM, the month; and YY the year. The operator can either accept the date that is displayed by pressing the END LINE key or type in a new date in the same format as given in the prompt and then pressing the END LINE key.
- The subroutine DATIME will next request the proper time of day by displaying TIME: hh:mm:ss. The hh is the hour (24 hour clock); mm the minute; and SS, the second. The operator can either accept the displayed time by pressing the END LINE key or change it by typing in a new one. If the operator decides to change the time given, he must input the entire time, including the seconds.

The example below shows this procedure.

d. Making Time Corrections and Adjustments (Internal Timer). BUCS has a versatile set of statements and functions to set and adjust the quartz-controlled clock and to change its speed. The system clock is regulated by a quartz crystal with a typical accuracy of 1.5 minutes per month. The accuracy of the clock is affected by temperature, physical shock, humidity, and aging. HP71 Owner's Manual (Section 5, page 90) describes how to refine the time keeping accuracy of the clock if required. The time adjustment statements described in Section 5 must be followed exactly. An improper use of these statements could lead to a very inaccurate clock speed.

e. Determining Time Accuracy Requirements. The new astro programs within the SURVEY MODULE REV1 (Star ID, Hasty Astro, and Arty Astro) use the hour-angle formulas to compute azimuth. The new astro programs require the time accuracies shown in Table 12-7.

Table 12-7. **Time accuracies for astro programs**

CELESTIAL BODY	ACCURACY OF TIME
Sun	1 second
Stars (other than Polaris)	1 second
Polaris	10 seconds

EXAMPLE

DISPLAY	OPERATOR RESPONSE	RESULT
	RUN SURVEY END LINE	Survey program runs.
^DATE:16-DEC-87	26-MAR-91 END LINE	The operator inputs a new date by using the same format as that given in the prompt. Note that the entire date must be entered.
TIME:10:06:50	11:06:00 END LINE	Operator changes the time. Note that the entire time (including seconds) must be input.

f. Adjusting the Contrast of Display.

(1) The BUCS allows you to adjust the contrast by controlling the display intensity and optimum viewing angle. You may choose a contrast value from 0 to 15. Contrast 0 gives you the least contrast and shallowest viewing angle. Contrast 15 gives you the sharpest contrast and steepest viewing angle and also makes all the annunciators easily visible. After memory reset, contrast value is set to 9. You can adjust the contrast value to suit your own preference.

(2) To adjust the contrast and the viewing angle, type CONTRAST 15 and press the END LINE key. This will give you the sharpest contrast. Choose your own preference by selecting any number from 0 to 15.

> **Note.** If the contrast is set to 0, the display appears blank unless it is viewed at a low angle. Therefore, when BUCS is turned on with the contrast set to 0, the BUCS may appear to be off. This problem can be remedied by setting the contrast to 8.

g. Increasing Speed of Data Input and Calculations. The BUCS allows the operator to increase the speed of data input and calculations. This feature has the advantage of being able to type in the data without waiting for the next display prompt. The disadvantage is that the operator cannot verify the data until the program is completed. When using this rapid application, the operator must have the program prompts completely memorized.

(1) To activate the rapid application type DELAY 0,0 and press the END LINE key.

(2) To deactivate the rapid application, type DELAY .1,.1 and press the END LINE key.

h. Clearing BUCS Memory. When the SURVEY REV1 module is installed, BUCS has a 64K memory and is able to store many programs of CALC mode and BASIC mode. However, when your unit begins field operation, you should clear the computer memory if it is cluttered with your personal program. Having the computer memory filled with your own programs could result in the BUCS not accepting the survey programs and prompting INSUFFICIENT MEMORY. Should this occur, you must clear and reset the BUCS memory. To clear and reset the BUCS main user memory (also called RAM), the operator must perform the steps discussed below.

Step 1. Press and release the ON and / keys at the same time.

Step 2. The display prompts INIT: 1. All the keys are now inactive except 1, 2, 3, and END LINE. To reset the memory, press the 3 and END LINE keys.

Step 3. The display prompts MEMORY LOST. Clear the display ‘by pressing the ON key.

i. Inserting RUNNING CLOCK Program Into BUCS Memory.

> **WARNING**
>
> **This routine may be used only with the BUCS SURVEY REV 1 module. Use with any other module (for example, cannon) is not authorized because of memory restrictions.**

(1) The following program can be inserted into the BUCS memory to create a RUNNING CLOCK routine:

Step 1. Press the ON key.

Step 2. Type in EDIT CL, and press the END LINE key.

Step 3. Type in 5 DELAY 0,0, and press the END LINE key.

Step 4. Type in 10 TIME $, and press the END LINE key.

Step 5. Type in 20 GOTO 10, and press the END LINE key.

This routine will now remain in your BUCS indefinitely unless BUCS power has been lost for more than 30 seconds. If the program is lost, it can be reinserted again following the procedure in (1) above. If you make a mistake while inserting the program into BUCS memory, press the ON key and start again with step 1.

(2) To check the accuracy of your BUCS clock once the RUNNING CLOCK routine has been inserted into the BUCS memory, perform the following:

Step 1. Press the ON key.

Step 2. Type in RUN CL, and press the END LINE key.

BUCS will now display a running clock. The displayed time should be checked against a time signal received via a time signal receiver. BUCS displayed time may be about 1/2 second behind the actual time. This discrepancy is due to the inserted RUNNING CLOCK routine and should not be construed as an error in the time setting. Once the BUCS clock has been viewed long enough to ascertain i fit is correct, press the ON key to stop the clock. If the time is correct, key in RUN SURVEY to start your survey computations. If the time is not accurate enough to compute astro observations (hasty astro or arty astro) by using the BUCS internal clock, key in RUN SURVEY and set the correct time into the BUCS internal clock at step 2 (TlME prompt). To recheck your BUCS clock, press the ON key and perform steps 1 and 2 above.

12-8. MAINTENANCE AND TROUBLESHOOTING

a. Computer and Printer Maintenance The HP71B computer and HP2225B printer can be cleaned with a soft cloth, dampened either in clean water or in water containing a mild detergent. Do not use an excessive y wet cloth or allow water to get inside these components. Do not use abrasive cleaners on the computer display window. The printer battery pack is not use-serviceable.

WARNING

Do not incinerate or mutilate the printer battery pack. The battery pack may release toxic materials or burst under extreme heat. Do not connect together or otherwise short-circuit the battery pack terminals. The battery pack may melt or cause serious burns.

b. Print Head Maintenance. The HP2225B print head cartridge is easy to maintain. Avoid touching the print head face with your fingers. Avoid allowing the print head face to come into prolonged contact with other materials. This may cause the ink to wick out of the print head.

WARNING

The ink in the print head cartridge contains diethylene glycol, which is harmful if swallowed.

c. Troubleshooting. Table 12-8 lists the possible error conditions that may occur on the ThinkJet printer and the corrective action for eliminating the problem.

Table 12-8. **Troubleshooting**

ERROR CONDITIONS	CORRECTIVE ACTIONS
1. Red power light is off or flashing.	Ensure battery pack is installed correctly and POWER switch is turned on. If power light remains off or is blinking, the battery pack should be recharged.
2. Yellow attention light is on continuously.	Load paper into printer. Attention light will start blinking.
3. Yellow attention light is blinking.	Press blue button. Print head cartridge will move, and attention light will go out. Remove any obstruction from around print head cartridge, and push blue button again. If attention light continues blinking, printer is signaling an error condition and should be turned in for repair.
4. Printer does not respond to computer.	Make sure that power light is on or blinking and attention light is off. If this is not the case, refer to error conditions 1 through 3 above. Verify that printer is operational by running the self-test (Chapter 1 of HP71B Owner's Manual). Verify that the HP-IL cables are property connected, and repeat the procedure for assigning printer as system print device. This procedure is explained for several different HP systems in appendixes of HP2225B Reference Manual. You may also need to refer to HP71B Owner's Manual. Computer may not be sending printer a carriage return and line feed at end of each line. In this case, printer will continue storing data because it never recognizes end of the line. Refer to automatic line termination on page 3-7 of the HP2225B Reference Manual and to the HP71B Owner's Manual for the reset procedures.
5. Paper does not feed properly.	Remove paper from printer, and discard any that is crumpled. If using fanfold paper, verify that it can travel freely without catching and that right side pinwheel is adjusted correctly for width of paper. Reload paper according to instructions in Chapter 1 of the HP2225B Reference Manual.
6. Print quality is poor, dot rows are missing, and carriage moves but printer does not print.	Ensure there is sufficient ink in cartridge by viewing the ink bladder. If bladder is collapsed, replace cartridge. Using a tissue, gently wipe face of print head to remove any accumulated dust if print head cartridge has not been used for several days, moisten tissue with water before wiping. Using a cotton swab dipped in alcohol, lightly wipe electrical connector of print head cartridge, if problem continues, replace print head cartridge.

★Chapter 13

SATELLITE SIGNALS NAVIGATION SET AN/PSN-11

The satellite signals navigation set AN/PSN-11 (NSN 5825-01-374-6643) will provide worldwide position, velocity, and time to the field artillery surveyor. When survey control is not available and time or the tactical situation preclude the use of existing survey control, the surveyor can use the AN/PSN-11 to establish positioning data.

The AN/PSN-11 (Figure 13-1) is a receiver. It is used in the global positioning system (GPS), standard positioning system (SPS), and precise positioning system (PPS).

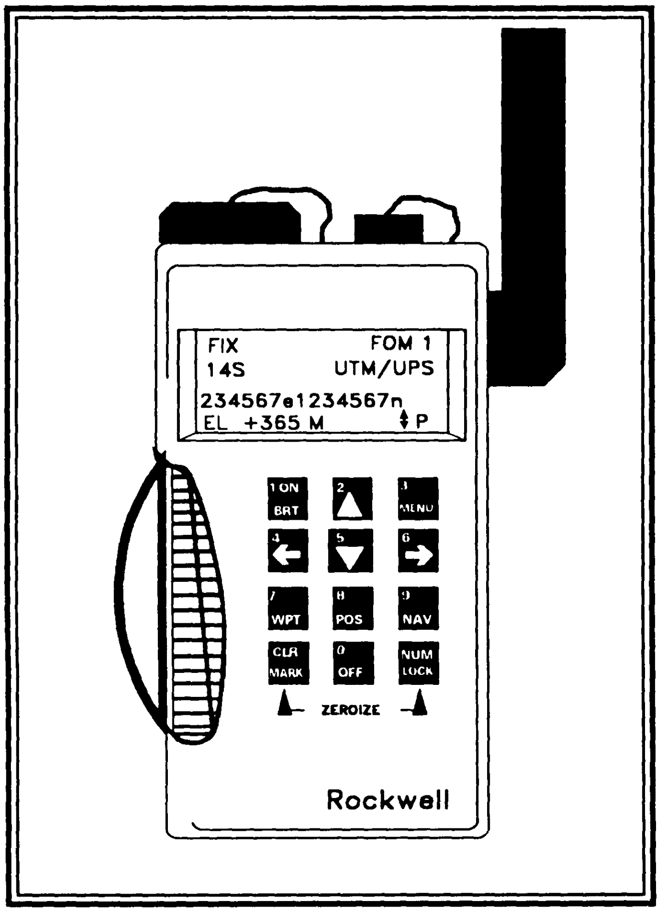


Figure 13-1. **AN/PSN-11**

13-1. GLOBAL POSITIONING SYSTEM

The NAVSTAR GPS is a space-based navigation and positioning system that provides accurate, three-dimensional position and velocity information, and time. The GPS is comprised of three major segments as depicted in Figure 13-2.

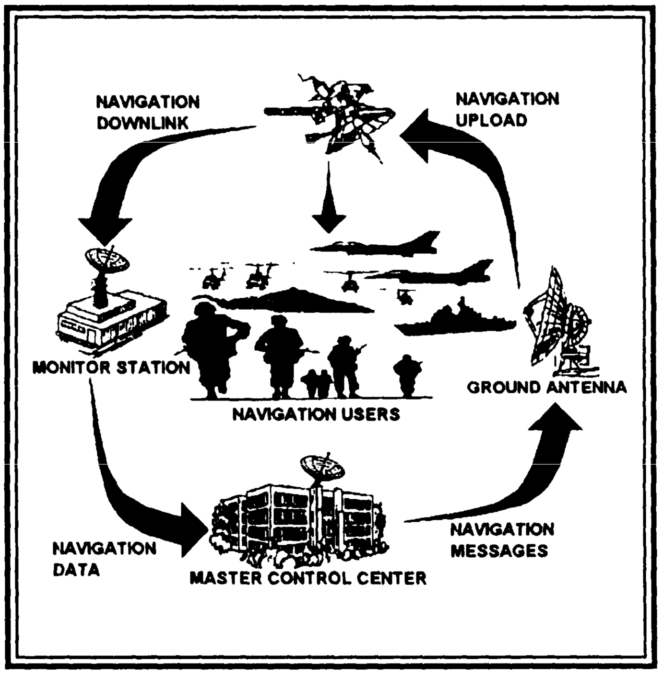


Figure 13-2. **Global positioning system**

a. The **space segment** is made up of a 24-satellite constellation that orbits the earth once every 12 hours. These satellites are deployed in six orbital planes and are configured so that four or more satellites will be in view at all times. This arrangement allows for 24-hour, three-dimensional, worldwide coverage. As with the stars, the satellites rise above the horizon about 4 minutes earlier than the previous day.

b. The **control segment** consists of five passive-tracking monitoring stations, active-tracking ground antennas, and the master control station located at Falcon Air Force Base, Colorado. These tracking stations, located around the world, are capable of monitoring the satellite navigation messages and time signals better than 90 percent of the time. This information is relayed to the master control station, which has the capability to effect any needed corrections to the satellite timing and navigation messages.

c. The **user segment** consists of navigation receivers designed for marine, aircraft, and manpack or vehicle use. The receivers must have electrical line-of-site with the satellites to receive and decode the satellite signals. The internal computer uses these satellite data to generate a precise time, velocity, and three-dimensional (3D) position data. The receiver must track four satellites to obtain a 3D position, and three satellites will yield a two-dimensional (2D) position. Current position coordinates and height are obtained from a 3D position and only current coordinates are obtained from a 2D position. The receiver needs only one satellite for precise time.

13-2. STANDARD POSITIONING SYSTEM AND PRECISE POSITIONING SYSTEM

a. The SPS is available to all GPS receivers worldwide, both military and civilian. When a receiver is in the SPS mode, almanac, navigation, and timing information are received on the **nonencrypted** course acquisition (CA) code satellite signal. To deny unauthorized users the full accuracy of GPS, the Department of Defense (DoD) intentionally places errors in the navigation and timing signal. This process is called **selective availability** (SA). The SA errors are unpredictable and can produce significant horizontal and elevation errors. This is one reason why SPS receivers are not authorized for combat operations.

b. The satellites also broadcast an **encrypted precise** (P/Y) code. This transmission is the basis for the PPS that is used by military GPS receivers. These receivers must have crypto keys loaded to detect and nullify the SA errors, which allows for more accurate position data. Also, the crypto keys provide a means of unscrambling the encrypted P/Y code, which is an **antispoofing** (AS) protection. Receivers such as the AN/PSN-11 have this capability and are considered to be PPS receivers. Only PPS receivers are authorized for combat operations.

13-3. FA SURVEY APPLICATION

a. The current AN/PSN-l1 basis of issue plan (BOIP) calls for one receiver with each PADS team, each conventional survey team or party, and the survey headquarters or SPCE.

b. Field artillery survey personnel will primarily use the AN/PSN-11 to initiate surveys when existing survey control is not available. This receiver allows the surveyor to begin surveying immediately with more accuracy than assumed data or a map spot.

c. A description of all parts, components, and detailed operating procedures for the AN/PSN-11 can be found in TM 11-5825-291-13. All operators should be thoroughly trained on all functions of the system before using the AN/PSN-11. The general how-to procedures for operating the AN/PSN-l1 will not be in this manual. Only those issues that deal with survey positioning and orientation or specific recommended procedures will be addressed.

(1) Setup. The setup selections allow the AN/PSN-11 operator to select several options and modes of operation. (See TM 11-5825 -291-13.) An example of a typical setup for artillery surveyors is shown in Table 13-1.

Table 13-1. **Example AN/PSN-11 setup**

PROMPT	EXPLANATION
SETUP MODE: **AVG**	The **averaging** mode is used for static positions. This is the recommended mode setting for critical positions and PADS operations. Averaging produces more stable and accurate coordinates and height. The receiver tracks satellites, updates position data every second, and continuously averages each data set to the previous average.
SV-TYPE: **all-Y**	The selection for the satellite vehicle (SV) type causes the system to use only the encrypted "Y" code satellite signal, which provides the most protection against jamming and spoofing.
SETUP UNITS: **UTM/UPS Metric**	Artillery surveyors normally use UTM coordinates for PADS and conventional survey operations. The metric selection will cause the AN/PSN-11 to calculate speed in kilometers per hour and to calculate distance in meters.

Table 13-1. **Example AN/PSN-11 setup (Continued)**

PROMPT	EXPLANATION
ELEV: **Meters MSL**	Most military topo maps express elevation as a value above or below mean sea level (MSL) and measure it in meters. The alternate selection, DTM (datum), should only be used when expressly directed by higher authority or when the map legend indicates that elevations are referenced to the ellipsoid.
ANGL: **Mil Grid**	Artillery azimuth is normally expressed in mils and referenced to grid north.
SET UP MVAR TYPE: **Calc**	This selection is only used when calculating a magnetic azimuth with the AN/PSN-11. This function is not required with PADS or conventional survey operations. **Any type of calculated azimuth determined from an AN/PSN-11 should never be used as orientation data for indirect firing systems.**
SET UP ELHold: **automatic**	Elevation hold (ELHold) set to automatic will cause the AN/PSN-11 to automatically show the elevation as ELh whenever less than four satellites are being observed or the satellite geometry is causing excessive elevation error. Regardless of the figure of merit (FOM) noted on the position screen, **do not use** elevation values when ELh is being observed. Only use elevation values associated with an EL on the position screen.
TIME: **Zulu**	Zulu time will allow for global operations without regard to any local time offset.
ERR: **FOM**	Figure of merit is a system estimate of position accuracy. FOM 1 or 2 can be used for PADS initialization. Only a FOM 1 can be used for a PADS update point or other critical locations.
SET UP DTM: **NAS-C**	This is where the datum selection is made. It is **extremely** important that the datum selected be the same as the directed operational datum.
AUTOMATIC OFF TIMER: **off**	This setting can cause the system to automatically shut down after a selected time. The normal setting for survey operations will be off.
SETUP I/O SERIAL: **Standard**	Used primarily during AN/PSN-11 download operation. During system-to-system download, both receivers should be set to standard.
HAVEQUICK: & 1PPS: **off**	Used primarily for timing and radio synchronization. Normally set to off.
SET UP AUTOMARK MODE: **off**	Can cause the system to automatically activate and mark locations on a timed basis. For normal survey operations, set to off.

(2) Position. Whenever coordinates are being determined for a critical position such as an orienting station, howitzer location, and PADS initialization or update point, use extreme care. To meet required accuracy, the system must have **crypto keys loaded,** be set on the **correct datum,** and indicate a FOM 1 before the coordinates will be used. **The AN/PSN-11 with a FOM 1 will meet or exceed an accuracy of 10 meters CEP for horizontal and 10 meters PE for vertical.** The averaging mode will yield a more stable and accurate set of coordinates. After the set attains FOM 1, switch to the averaging mode, and allow the counter to increment to at least 300 counts. (This will take about 5 minutes.) Position data should always be checked by a second independent mean; for example, a second receiver, an accurate map spot, or the current coordinates on the PADS.

(3) Height. The AN/PSN-11 can determine height (elevation) relative to either the horizontal datum ellipsoid (spheroid) or mean sea level. Both modes of operation can be set for meters or feet as a unit of measurement. Normally, mean sea level and meters will be the preferred selections.

(4) Direction. The **AN/PSN-11 should never be used to determine orientation azimuth** for firing positions. As with the PADS, azimuth computed between two sets of GPS coordinates will produce erratic results.

(5) PADS operation. The AN/PSN-11 does not require any special installation for PADS operation. Position coordinates for initialization or update can be obtained by moving a short distance away from the vehicle and placing the set directly over the desired location. Using the system away from the vehicle will reduce the possibility of antenna masking. When the averaged FOM 1 coordinates have been recorded, move the PADS vehicle to the AN/PSN-11 position. If the AN/PSN-11 auxiliary antenna is mounted on the vehicle, the precise GPS vehicle lever arms information (X, Y, Z) must be entered during system initialization as outlined in TM 5-6675-308-12 with Change 3. The operating

instructions in the current PADS TM (Chapter 3, in Change 3) applies to older GPS receivers. When using the AN/PSN-11 during PADS operations, only data determined from a FOM 1 will be used.

13-4. GPS LIMITATIONS AND CONSIDERATIONS

a. Masking. GPS receivers rely on electronic line of sight with the satellites. Therefore, dense foliage, buildings, mountains, and canyons may mask the signl. The AN/PSN-11 will initially select satellites that are 10° or more above the **true** horizon. If for usable satellites are not detected, the set will switch to 0° until satellite acquisition. After acquisition, the set will switch to 5° above the horizon for normal operation. If enough satellites cannot be acquired, the receiver must be moved to a more suitable location.

b. Jamming. The AN/PSN-11 is subject to jamming. When low signal to noise ratios are detected or reception is blicked altogether, jamming may be the cause. Move to a new location, and try to place something between the receiver and the suspected jammer. When the signal to noise ration is above 34 decibels (db), jamming has probably been eliminated.

c. Spoofing. The AN/PSN-11 may be subject to spoofing errors. These errors are caused by false satellite signals designed to generate errors in navigation and position data. Maximum protection against spoofing is attained by using the crypto keys and the All-Y setup selection. If the AN/PSN-11 is in a spoofing environment, the system may sense spoofer activity and generate a POSSIBLE SPOOFERS warning screen.

d. Temperature. The AN/PSN-11 operating range is -4 to +158° F. When operating in cold regins, protect the receiver by carrying it inside your outer clothing or operating it from a heated vehicle. This can be done by using the auxiliary antenna.

e. Power. The AN/PSN-11 will normally be operated by using either a BA5800/U lithium battery or 24-volt vehicle power. Operating in the continuouts mode, the battery will provide adequate power for about 15 hours at 71° F. During extended missions, spare batteries must be readily available. Using vehicle power eliminates this problem; however, the correct polarity must be observed to prevent damage to the system.

CHAPTER 14
SURVEY OPERATIONS

★ To support current Army doctrine, survey operations must be responsive, accurate, and flexible. The artillery surveyor's primary mission is to provide accurate orientation and determine the coordinates and height of weapons and target-locating systems relative to one another. This is known as establishing a common grid. The task of providing a common grid involves different levels of command and echelons of survey. Beginning at the echelon above corps, topo surveyors establish third-order or higher SCPs in the corps and EAC areas for Patriot, corps general support units, and other units. Topographic surveyors also provide SCPs in the division area for the div arty surveyors. Div arty and TAB surveyors extend control to battalion areas, where the battalion surveyors extend control to the weapons and target-locating devices. This chapter discusses the survey operations typical of the following:

- *Common grid.*
- *Cannon battalion.*
- *Missile and rocket battalions.*
- *Division artillery.*
- *Target acquisition battery and detachment.*
- *SPCE (corps and brigade).*
- *Special environments.*

Section I
CANNON BATTALION SURVEY

The primary mission of the surveyors in a cannon battalion is to provide timely and accurate survey control to the firing batteries and any other battalion assets as required. Survey control consists mainly of establishing a line of known direction and determining the locations, both horizontally and vertically, of the weapons and the target-locating systems. In addition, FA battalion survey must provide control for other weapons, instruments, and electronic equipment as required.

14-1. REASONS FOR COMMON GRID

★ Accomplishment of the battalion survey mission provides a common grid for firing units and target-locating systems within prescribed accuracies. A common grid allows the cannon battalion to do the procedures below.

a. Mass Fires. Accurate survey permits rapid and economical massing of fires. For artillery to mass fires accurately without survey requires an observed adjustment of all units on the target or prior registration of all units on a common registration point.

b. Deliver Surprise Observed Fires. If survey is not available and all batteries are required to adjust on a target, the element of surprise is lost. Complete surprise is impossible without survey.

c. Deliver Effective Unobserved Fires. Without survey, consistently effective unobserved fires are possible only if the target has been fired on previously and replot data have been computed.

d. Transfer Target Data Between Units. Transfer of target data between units is possible only when units are located relative to each other and to the target (on a common grid).

14-2. VARIATIONS IN STARTING CONTROL

Starting control for FA survey consists of the coordinates and height of a survey control point and a starting azimuth. Although there are several ways in which starting control can be obtained, the best control available for the area should be used to begin a survey. The variations of starting control can be grouped into three general categories as follows:

- Known coordinates, height, and azimuth.
- .Assumed coordinates and height and correct grid azimuth.
- ★Known or assumed coordinates, height, and azimuth.

a. Known Coordinates, Height, and Azimuth. Starting control for which the station data are known may be points established by survey done by a higher echelon, or it may be confirmed data established before the start of military operations. Data for stations established by engineer topo units and data for survey control established before the start of military operations are in trig lists prepared and published by the DMA. Survey data for survey stations established by div arty are published in trig lists prepared in the div arty SPCE and distributed to all using units in the area.

★*(1)* If the PADS is to use starting control established by conventional survey methods, the SCPs at both ends of a PADS survey must be on a common grid.

★*(2)* If conventional survey starts from a point established by the PADS or GPS, the survey must close on that same point.

★**b. Assumed Coordinates and Height and Correct Grid Azimuth.** When survey control is not available in the area, the coordinates and height of the starting station must be assumed. Correct grid azimuth can be determined through astronomic observation, an azimuth gyro, or the PADS. Correct grid azimuth should always be used whenever possible. If both higher and lower survey echelons initiate surveys by using correct grid azimuths, any discrepancy between surveys that is due to assumption of coordinates will be constant for all points located (Figure 14-1). The approximate coordinates and height of the starting point can be determined from a large-scale map and should closely approximate the correct coordinates and height to facilitate operations. Starting data determined from a map must always be considered as assumed data. A survey starting on an assumed point must close on that same point.

★**c. Known or Assumed Coordinates, Height, and Assumed Azimuth.** Assumed azimuth should be used for a starting azimuth only when azimuth cannot be determined from astronomic observations, an azimuth gyro, the PADS, computation, or a published trig list. The assumed azimuth should approximate the correct grid azimuth as closely as possible. The approximate grid azimuth can be determined by using a compass (preferably declinated) or scaling from a large-scale map. If either a higher or lower survey echelon or both initiate survey operations with assumed azimuths, differences of varying magnitude will exist between the coordinates of points located by their surveys (Figure 14-1). This variation complicates the problem of conversion to common control. For this reason, an assumed azimuth should never be used if the correct azimuth can be determined.

14-3. CONVERSION TO COMMON GRID

a. A battalion SCP is a point provided by a higher survey echelon for the purpose of initiating survey control for the battalion. More than one of these points may be required for a battalion. SCPs on the grid of the next higher echelon may be available in the form of one or more trig points in the vicinity of the battalion installations. When available, trig points from DMA or other published trig lists should be used as the basis for all echelons of survey operations. When one or more SCPs have been established by the next higher echelon, these SCPs should be used as the basis for battalion survey operations. In either situation, the common grid is established.

★**b.** The mission of the subordinate unit requires it to initiate survey operations without waiting for survey control to be established by a higher echelon. Thus, a battalion assigned or attached to a div arty may have to operate first on the grid established by the battalion (battalion grid) and finally on the grid established by corps (corps grid). When survey at one or more echelons is based on assumed data, data established by the lower echelon should be converted to the grid established by the higher echelon. An exception to this rule would be when prescribed accuracies are met or when the tactical situation, time constraints, or SOP causes the commander to decide otherwise.

★**c.** When both higher and lower survey echelons start PADS or conventional survey operations with correct grid azimuth but one or both of them start with assumed coordinates and height, the lower echelon must apply coordinate and height corrections to the location of each critical point in its survey to convert to the grid of the higher echelon. This coordinate and height conversion is commonly known as *sliding the grid* (Figure 14-2) and is done as follows:

★*(1)* Determine the differences in casting coordinates, northing coordinates, and height between the assumed starting point and the common grid starting point provided by the higher echelon. The difference, with its appropriate sign, becomes the correction. (See the example below.)

★EXAMPLE

	Easting	Northing	Height
Assumed starting point	550000.00	3838000.00	400.0
Common grid starting point	550196.52	3837887.89	402.3
Correction	+196.52	-112.11	+2.3

Figure 14-1. **Discrepancies in survey control caused by use of assumed starting data**

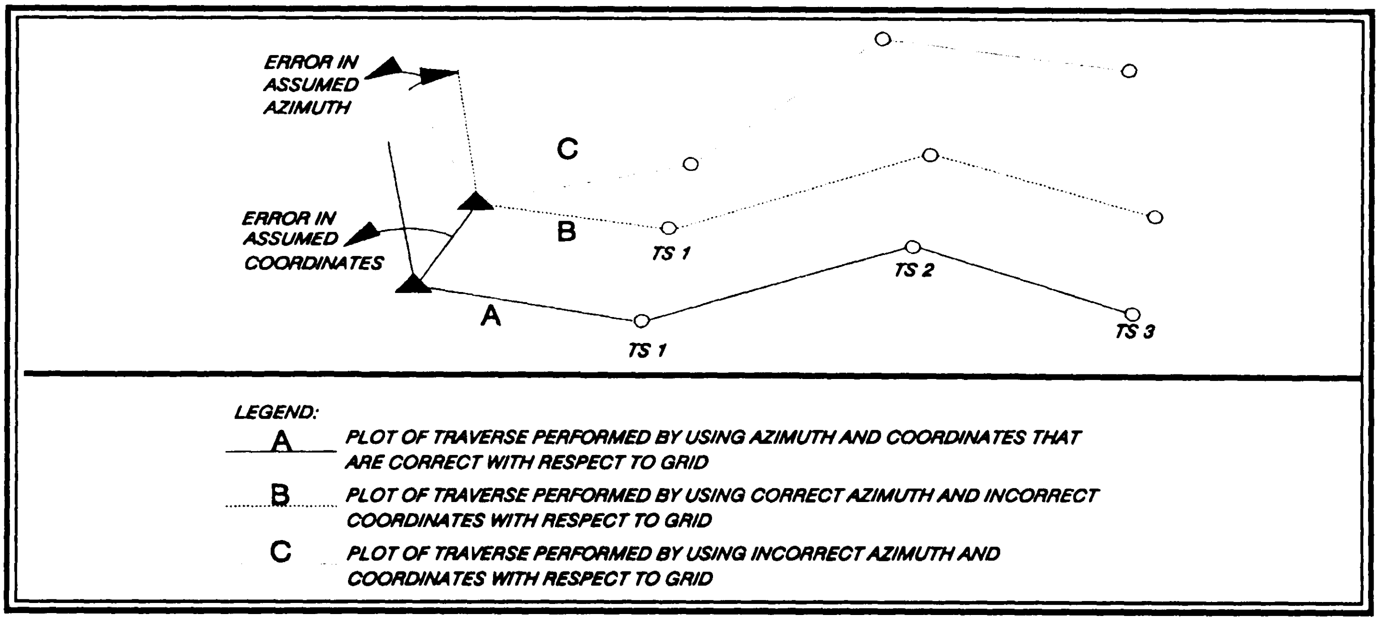
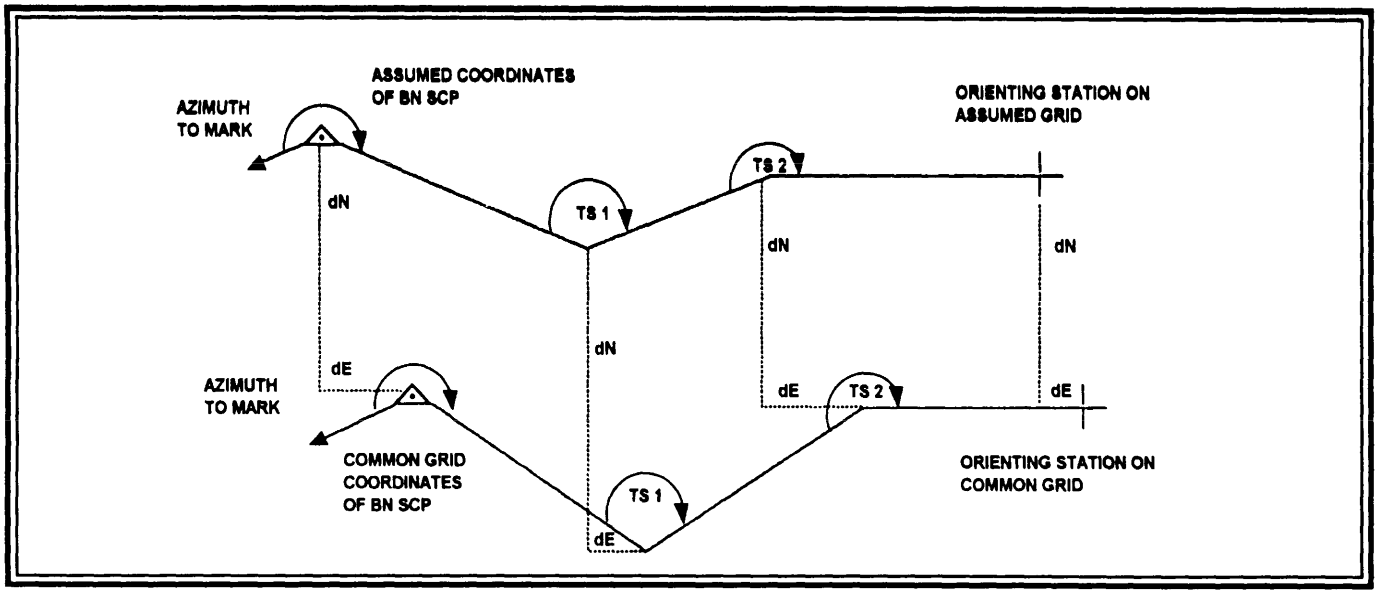


FIGURE 14-2. **Sliding the grid.**



★ (2) Apply the corrections (differences) to the assumed data to make the assumed data equal the common grid data (coordinates and height) at all critical points.

★ **d.** Whenever survey operations are started with an assumed azimuth, regardless of whether the coordinates and height are known or assumed, the coordinates of each station and the azimuths determined will be in error. To convert the assumed data to correct grid data, all azimuths and coordinates determined in the scheme must be corrected. Application of the azimuth correction when using known coordinates and height with an assumed azimuth was referred to as swinging the grid. When both assumed coordinates and height and azimuth are used, it is known as *swinging and sliding the grid.* With the acquisition of more rapid means of computing (BUCS and FED MSR), these methods are no longer required. The procedures for converting assumed azimuth and/or coordinates to common control are discussed below.

★ *(1)* When using the BUCS to convert assumed azimuth and/or coordinates to common control, use the following procedures:

★ (a) If the survey data that needs converting is still in the BUCS, recompute the entire survey. This is done by going to the top of file (T, END LINE) and exchanging the assumed data with the correct (common) data. Then repeat by pressing END LINE and recording all critical data as they appear.

★ (b) If you have started computing another survey or the survey that needs converting is no longer in the BUCS, you must recompute the entire survey again. This is done by entering the correct (common) starting data and all field data and by following normal computational procedures.

★ *(2)* When using the FED MSR, recompute the entire survey by recalling the survey that needs converting to common control and exchange the assumed data with the correct (common) data. Then repeat by pressing the C button and recording all critical data as they appear.

Note. The FED MSR will hold three computations of each type of survey. However, if the survey requiring conversion is no longer in the FED MSR, you must recompute the entire survey by entering the correct (common) starting data and all field data and by following normal computational procedures.

14-4. POSITION AREA SURVEY REQUIREMENTS

Survey control is required in the position area of each firing battery of an FA cannon battalion. The HQ battery survey section using the PADS or a conventional survey team performs the survey. Position area survey requirements are identical for light, medium, and heavy artillery batteries. (See Figure 14-3.) If the battery is using the split-battery concept of operations, survey control is provided for each firing platoon. (See Figure 14-4.) Requirements for position area survey are described in paragraphs a through g on the next two pages.

Figure 14-3. **Conventional position area survey**

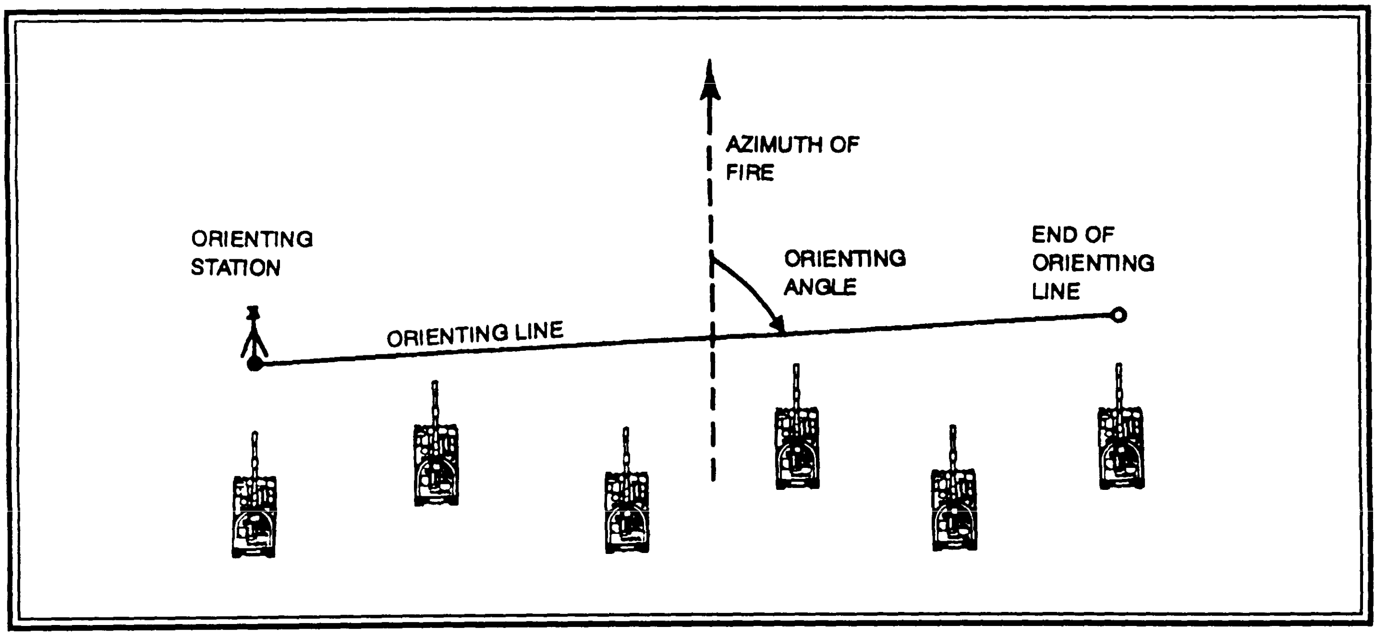
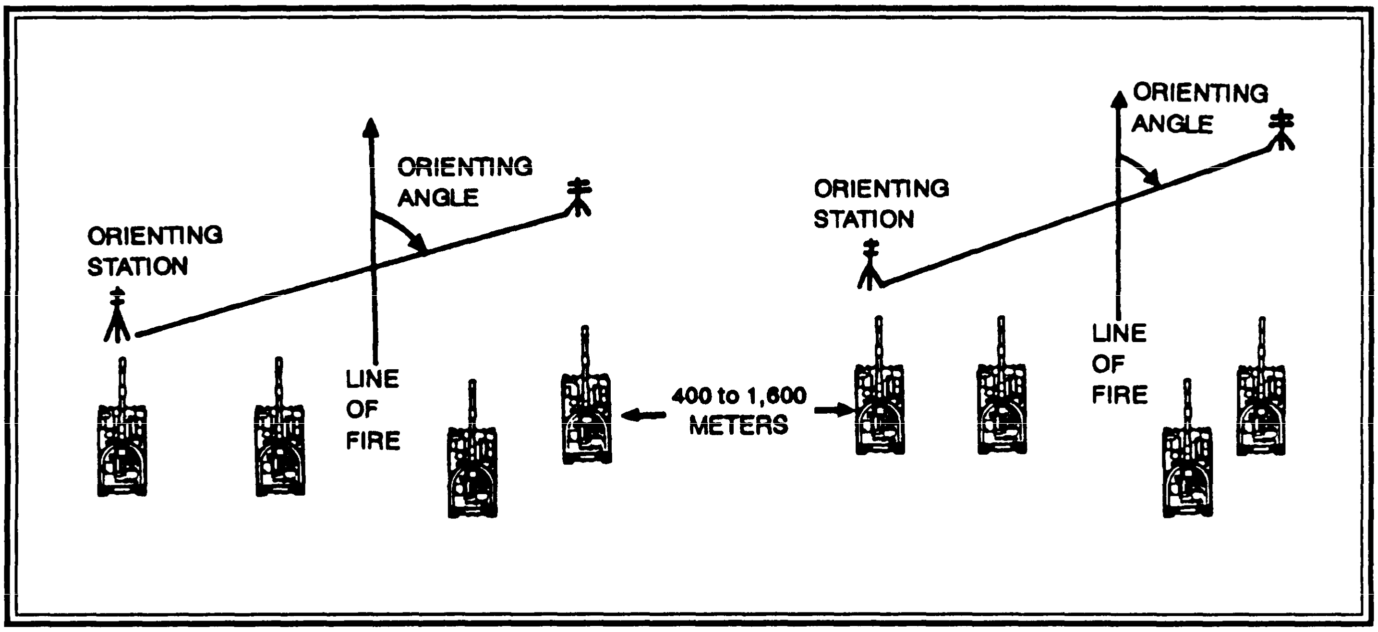


Figure 14-4. **Split-battery position area survey**



a. Battalion and Battery Survey Control Points. As mentioned earlier, survey control for artillery units may be available in the form of SCPs established by higher echelons or trig lists containing data for stations located near the unit. The locations of SCPs established by div arty must allow for the survey capability of the battalion. An SCP must be provided within 5 km of the center of the battalion position area if the PADS is the primary method of survey. When the battalion is limited to conventional survey methods, div arty survey must provide SCPs within 2,000 meters of the firing positions. If the firing elements are widely dispersed or operating separately, it may be necessary to establish more than one SCP. If there are no SCPs in the battalion area, the battalion RSO will select a convenient point near a prominent terrain feature and assume starting control. The div arty survey officer (survey platoon leader) may task direct support (DS) battalions to provide survey control for supporting units located in the battalion area of operations.

b. Firing Battery Positions. Survey requirements in each firing battery position are described in (1) through (3) below.

(1) Orienting station. The OS is a station used by the firing battery or platoon personnel to orient the weapons. The coordinates and height of the OS and a line of known direction are required. The position of the OS is usually selected by the battery commander or executive officer (XO), but it can be selected by the survey personnel. The frequent moves and the many positions required will not always allow the battery commander and/or XO to select all 0Ss. The relative locations of the OS and EOL usually are addressed in the unit survey SOP.

(2) End of the orienting line. The EOL is a survey station used as an azimuth mark for the OS. The EOL must be located so that it is visible and at least 100 meters from the OS.

(3) Orienting line. An OL is a line of known direction materialized on the ground in each position area. It is used as a reference direction for orienting instruments and for laying weapons for direction. When the PADS is used to establish the OL, the two-position mark is the preferred method. If autoreflection is used, a one-position angle must be measured. When the OL is established by conventional survey, it should be a main scheme leg to ensure accuracy.

c. Field Artillery Radar Locations. One weapons-locating radar (WLR) section (AN/TPQ-36) normally is attached to each DS howitzer battalion. The coordinates and the height of the radar position (near stake) and a line of known direction to an azimuth mark (far stake) are required. The distance and vertical angle to an azimuth mark are also required. The battalion survey section is responsible for determining these data. Usually, the WLR (AN/TPQ-37) will be located near one of the artillery battalions. Div arty may task the nearest battalion to provide survey control. The radars require coordinates and height of the radar position and distance and direction to an azimuth mark. (See Figure 14-5.) The PADS is the primary means of obtaining survey control for the Firefinder radars (AN/TPQ-36 and AN/TPQ-37). When the PADS is not available before the radar section occupies the radar site, fifth-order survey will be provided by a conventional survey team or the radar section will conduct a hasty survey. The hasty survey will provide the data for initializing the radar. If the PADS or conventional survey team arrives after the hasty survey has been completed, the data determined by the PADS or conventional survey will be entered into the radar computer instead of the hasty survey data. Azimuth required by the Firefinder radars must be accurate within 0.4 mil. The position accuracy required is 10 meters. The vertical interval accuracy is 10 meters for the AN/TPQ-36 and 3 meters for the AN/TPQ-37. However, the weapon location accuracy of the AN/TPQ-36 is greatly enhanced by keeping the vertical interval accuracy within 3 meters. This accuracy is within the capabilities of the PADS and fifth-order survey.

★ **d. Declination stations.** A declination station should be established at a place that is convenient to using units. It may be established by an FA battalion, a div arty, or a TAB. The ideal declination station should have known grid azimuhs to four prominent features (for example, a church steeple, radio towers, quad markers). Preferably there should be one prominent feature in each quadrant and at least 1,000 meters from the declination station. When time, tactical situation or lack of prominent features limit operations, azimuth marks can be established (for example, range pole). However, a minimum distance of 300 meters should be used if possible.

(1) In establishing a declination station, the direction of each azimuth mark may be determined by computing the azimuth (if the coordinates of the declination station and azimuth marks are known), by applying a measured angle to a known direction, by astro observations, or by using PADS with optical transfer. The theodolite is used in measuring angles or making astro observations to determine the azimuths for the declination station.

(2) Declination stations should be established in an area free from local magnetic attraction. The following minimum distances from common objects with magnetic attraction are prescribed:

- Power lines and electronic equipment: 150 meters.
- Railroad tracks, artillery, tanks, and vehicles: 75 meters.
- Barbwire and personal weapons: 10 meters.

(3) Whenever a declination station is established, the vertical angle to each azimuth mark should be determined. The vertical angle correction for the aiming circle can then be determined at the same time it is being declinated.

(4) Any SCP with an azimuth mark may be used as a declination station if the area is free from local magnetic attraction.

e. Intelligence Electronic Warfare Sites. When IEW sites are established in the battalion area, the div arty survey officer may task the battalion survey section to provide survey control.

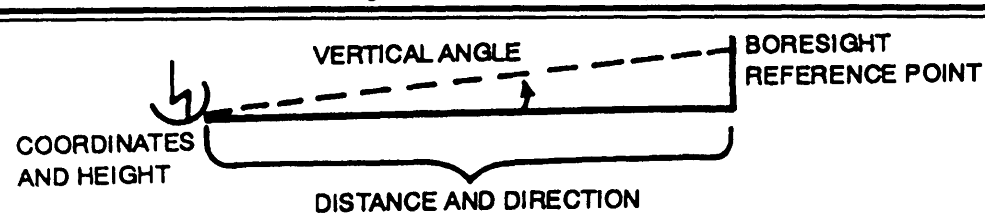
f. Meteorological Sites. Met sites usually do not require survey control. A map spot and the met section declinated theodolite usually are accurate enough. However, when the map accuracy is doubtful or maps of the area are not available, the nearest artillery battalion may be tasked to provide survey control.

g. Alternate, Supplementary, and Offset Registration Positions. Survey of alternate, supplementary, and offset registration positions should be performed as soon as survey operations for primary positions are completed. Survey requirements for alternate positions are the same as those for primary positions.

14-5. CONVENTIONAL METHODS OF POSITION AREA SURVEY

★ **a.** Any conventional survey method or combination of methods may be used to perform the position area survey. The method most commonly used is traverse, electronic or taped. The position area survey starts at an SCP, moves to its destination, and ends on another SCP (on the same common grid) or the starting point. All surveys should be started and closed on an SCP of greater accuracy than the survey being performed. All position area survey requirements are executed to fifth-order accuracy.

Figure 14-5. **Radar survey**



Note. Vertical angle is needed for the AN/TPQ-36 only. The point to which the vertical angle is measured will be identified to the radar technician.

b. When a firing battery or platoon position is surveyed, an OS is established from which all weapons will be visible. This point is used as one EOL, and the traverse leg used to establish the station is used as the OL. This makes the OL a leg of the closed traverse and thus permits the detection of any error in the OL should the traverse not close in azimuth, The OL should be checked by using a compass. Marking of the OS and EOL is established by unit SOP.

14-6. CONNECTION AREA SURVEY

a. Connection area survey, when required, is that part of the survey operation performed for the purpose of placing target area surveys and position area surveys on a common grid. Surveyors performing the connection area survey may establish the actual OPs or provide only a target area SCP. If only a target area SCP is established, then survey control must be extended to the desired target locators by FA surveyors during target area survey operations.

b. The connection area survey normally is started from the battalion SCP and is closed on either the starting point or any other SCP on the same grid network. When the PADS is unavailable and time is critical, the connection area survey may be limited to a directional traverse or astro observation performed at the OPs. The OP locations can then be determined by resection or map spot if the common grid and the grid of the map are the same.

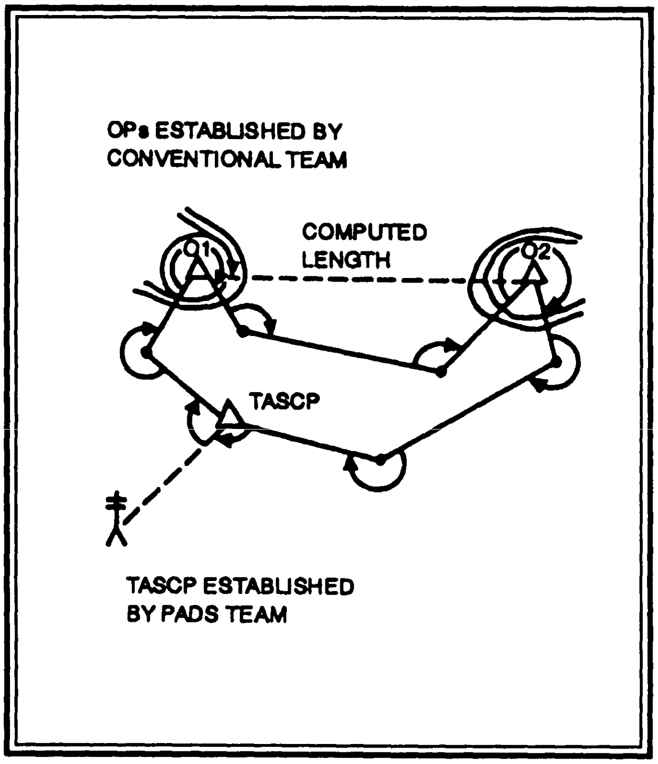
c. Additional requirements in the connection area survey may include providing survey control for mortars within the supported brigade and combat electronic warfare and intelligence (CEWI) target-locating devices located within the area. The div arty survey officer will designate priorities. Control is extended to these installations as provided in the survey plan. Priorities of the FA battalion requirements must be indicated in an SOP or in the operation order (OPORD).

14-7. TARGET AREA SURVEY

a. The need for target area survey performed by the FA surveyor decreases as new positioning and/or navigational devices are fielded. As the capability of target locators to locate themselves and targets increases, the requirements for target area survey will eventually disappear. Also, the emplacement of fixed OPs does not complement ALB doctrine, and the fast-moving battlefield situation will require the survey effort of the entire survey section to provide survey control for weapons and target-locating systems. However, until the target locators are totally self-sufficient in providing accurate target data and for environments that favor fixed OP locations (static situations), the FA surveyor must be able to perform target area survey. For surveyors, this means being able to effectively mix conventional survey methods with PADS operations. When target area survey is required, the PADS crew will establish an SCP with an azimuth mark as close as possible to the OPs as part of the connection area survey. The conventional survey team will then perform the target area survey.

b. Accomplishment of the target area survey mission requires that a base be established from which the targets and critical points can be surveyed. The requirements for establishing a target area base are to locate two or more OPs relative to each other that overlook the target area, to determine the azimuth and distance between the two, and to determine an azimuth to a visible azimuth mark for each. The OPs are designated 01, 02, and so forth; and 01 is considered the control OP. 01 may be on the right or left of the base. However, it is always the OP requiring the least amount of fieldwork to establish its location. This is because less directional accuracy is lost through angular measurements when the number of main scheme angles is held to a minimum. (For example, if the OP on the left can be established in two traverse legs from the target area survey control point [TASCP] and five traverse legs are required to establish the OP on the right, then the OP on the left would be designated as 01.) (See Figure 14-5a.)

Figure 14-5a. **Target area base**



★ 14-8. PALADIN SURVEY

a. Paladin Element. The Paladin is an M109A6 self-propelled howitzer equipped with a modular azimuth positioning system (MAPS). With MAPS, the Paladin has more flexibility and requires fewer crewmen and less equipment. The Paladin battery normally operates in a two-platoon configuration (three howitzers per platoon). Normally, an M109A2/A3 platoon is allocated a position area goose egg of about 1,000 meters in diameter. In contrast, a Paladin platoon requires a position area on the order of 2,000 by 1,000 meters and it uses all of that terrain during normal operations. Limitations of the on-board navigational system restrict the howitzer displacement distance. The Paladin must be updated every 16 miles or 27 kilometers to ensure it meets position accuracy requirements.

b. Survey Requirments. If the Paladin battalion is to accomplish its mission effectively, survey operations must be continuous and carefully coordinated. The battalion S3 and RSO must use their limited survey assets (two PADS and one conventional team for six platoons) wisely. The primary responsibility of the PADS teams are to establish update points along the routes of march and two update points per platoon position area to ensure that no Paladin has to travel more than 16 miles/27 kilometers without updating. If the battalion has set up a rearm, refuel resupply, and survey point (R3SP), update points should be set up next to the fuel trucks so the howitzers can perform an update while refueling. If no R3SP is set up, establish four update points, spaced 50 to 100 meters apart near the release point of a tactical road march. These points should be easily identifiable and accessible without detouring far from the route of march, and without clogging traffic along the route of march. This will allow the entire platoon to update at once, so that they will not hold up the rest of the battalion.

c. Alternative Survey Control. If one or both PADS become inoperative, the RSO must ensure that the survey mission continues. The conventional team supplemented by the inoperative PADS team members must provide update points. They can use whichever conventional method that time allows to provide the best available update points possible until the PADS is operating again. Hasty survey methods or a PPS GPS receiver can also be used by the howitzer crew as a last resort.

Section II

MISSILE AND ROCKET BATTALION SURVEY

The survey mission in MLRS and Patriot missile units is to provide timely survey control within prescibed accuracies. Numerous alternate position areas are essential for survival, and all require the same survey as the primary position area. Each system has individual requirements that vary slightly from other FA systems. These differences are due to equipment design, number of launchers, and auxiliary equipment requiring survey control.

14-9. MLRS SURVEY

a. MLRS Element. The MLRS is a fully tracked, highly mobile, rapid-fire, free-flight rocket system that is designed to complement cannon artillery and supplement other fire support systems. MLRS battalions are assigned to corps, and MLRS batteries are organic to armored and mechanized infantry division artilleries. MLRS batteries are organized so that each is a relatively self-sufficient unit. Each MLRS firing battery has three firing platoons with three launchers per platoon. Each launcher is equipped with an SRP/PDS, which is an on-board navigational system. The SRP/PDS provides direction, elevation, location, and launcher cant angle data to the fire control system. Once updated at a survey control point, the SRP/PDS continuously carries accurate location data that are used by the fire control system to compute fire missions. The SRP/PDS must be updated every 6 to 8 km traveled to minimize location error. The survey section must provide update points for the SRP/PDS.

b. Survey Requirements. The ability to deliver MLRS rocket fires accurately and effectively largely depends on accurate survey information. The battery operations officer directs and monitors survey operations. The survey chief is the battery commander's immediate advisor on all survey matters. The primary responsibility of the PADS team is to establish SCPs every 6 to 8 km throughout primary, future, and alternate locations. Each platoon could occupy from three to six new positions per day. (See Figure 14-6.)

(1) SCPs are used to initialize, update, and calibrate the SRP/PDS aboard the launcher. These SCPs are established with the PADS by using 10-minute Z-VEL corrections. Directional control is not required for the MLRS. At least one SCP must be available in each of the three firing platoon positions.

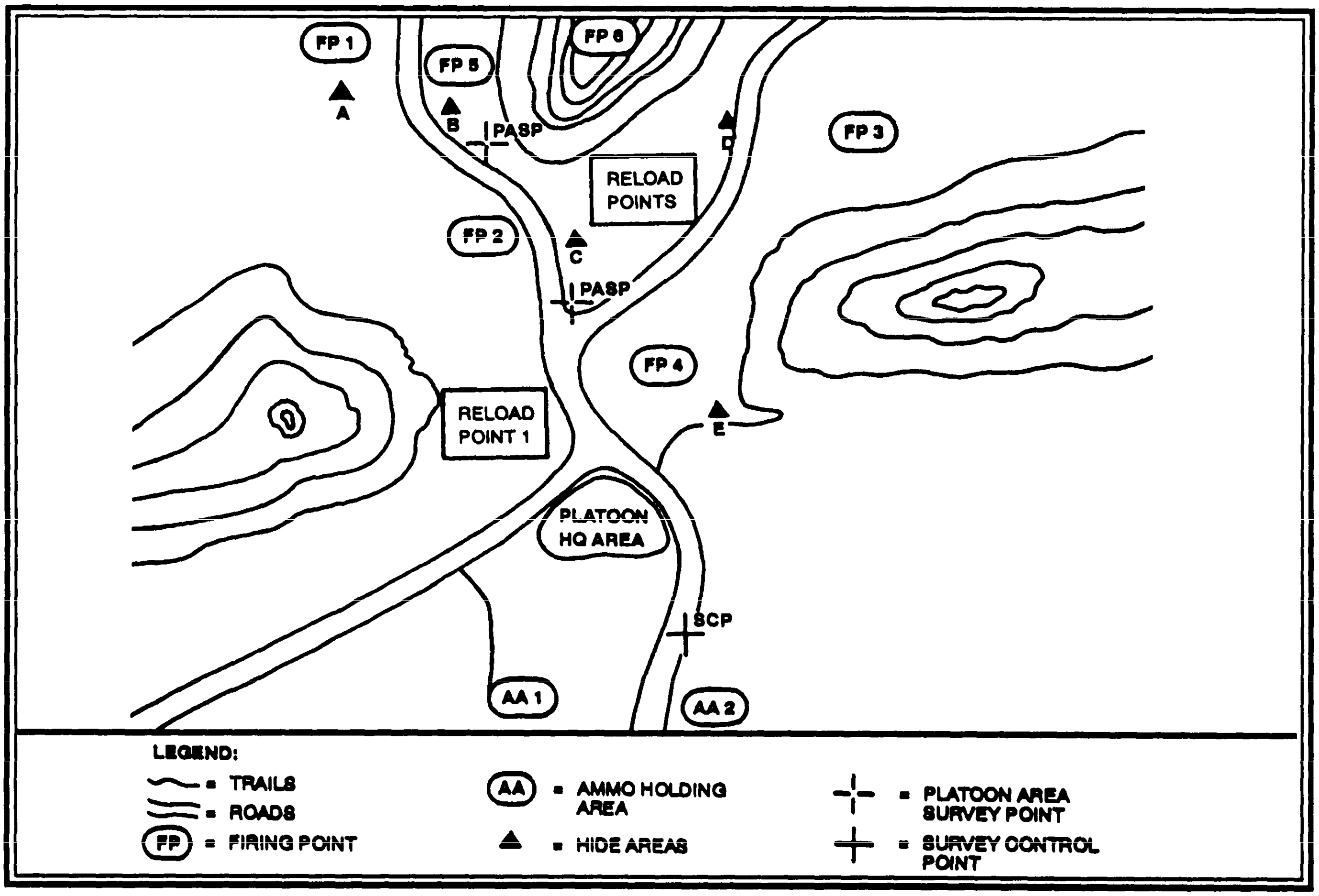
(2) Although cover and concealment are considerations in platoon area survey point (PASP) selection, utility should be the primary consideration. The PASP must be readily accessible so that the driver can stop the launcher next to the SCP without a ground guide or excessive maneuvering.

(3) In the motor park area, each launcher should have an individual SCP for initialization. This option will enable the launcher to leave the motor park area in a HOT status and be able to accept fire missions immediately.

(4) The launcher crew calibrates the SRP/PDS whenever the launcher carrier track system is replaced or repaired. Calibration must also be performed when there is a significant change in the terrain of the operating area. Two SCPs located 4 to 6 km apart are required for conducting calibration. The launcher must be calibrated every 30 days, after PDS maintenance, and after major suspension or track drive maintenance.

★ **c. Alternative Survey Control.** If the PADS becomes inoperative, the battery commander must ensure that the survey mission is continued. In this situation, survey control should be obtained from other FA units operating in the area or may be established by using a combination of conventional and hasty survey techniques. The PADS team can continue the mission by using conventional survey methods that can be performed by two men with a theodolite and the BUCS. Battery personnel must help the PADS team in the survey effort by using the AN/PSN-11 (PLGR) to establish coordinates at the firing point. For guidance on the use of the AN/PSN-11, see Chapter 13. When location data are determined by hasty survey or map reading skills, the distance traveled by the MLRS between update points cannot exceed 6 km. The unit must train and rehearse these techniques at every opportunity, both in the field and in garrison, to ensure that personnel have the skills needed to consistently obtain accurate results. It must be understood that these alternative methods are to be used only in emergency situations.

Figure 14-6. **Typical MLRS firing platoon position area**



14-10. PATRIOT MISSILE BATTALION SURVEY

a. Battalion Survey Elements. The mission of the Patriot missile battalion requires that the unit be employed, in most cases, over a very wide frontage and in great depths. Under the present organization, the battalion consists of three batteries of six launchers each. Future plans are to increase the organization to six batteries of eight launchers each. The battalion HQ battery (one of three battalion batteries) is authorized three PADS teams. Each PADS team consists of one E5 and one E3 (MOS 82C). The six-battery battalion will be authorized four PADS teams. A survey HQ element and an SPCE are organic to the HQ battery. The HQ element consists of the chief surveyor and an E3 driver. The SPCE consists of an E5 and E4. The chief surveyor, who works directly under the battalion reconnaissance, selection, and occupation of position (RSOP) officer does the detailed survey planning and supervision to ensure that adequate survey control is available. He also has responsibility to train, supervise, and coordinate the activities of the PADS teams and SPCE personnel. The primary mission of the Patriot survey personnel is to place the firing units and supporting elements on a common grid. This mission is accomplished by proper planning, coordination, and organization for survey by the chief surveyor. The common grid on which the Patriot battalions operate should be the corps grid. If corps SCPs are not available within the battalion area, the chief surveyor must select a known point or assume survey control and establish his own grid. Control is then extended from this point to the firing units. This control can be converted to the corps grid when corps control becomes available.

b. Employment. The Patriot battalion is employed in two basic configurations. These are the area (belt) defense (Figure 14-7) and the forward area defense engagement coverage (Figure 14-8). Figures 14-7 and 14-8 show the six-battery battalion. Battalions with fewer than six batteries should modify these defense designs to use available tiring units effectively.

(1) Area (belt) defense. Patriot battalions are employed in the area defense to counter enemy attempts to penetrate the rear operations area to attack deep strike assets. In this type of employment, the batteries are spread across a front of about 200 km. Because of this wide frontage and the limitations of the PADS, the topo survey company must provide at least three SCPs for the battalion. Each of the PADS teams must extend survey control to two batteries. Even with the SCPs conveniently located between the batteries, each PADS will have to travel about 80 km to accomplish the mission. Since this type of employment will be used against the initial attack, ample time should be available to complete the survey before the outbreak of hostilities.

(2) Forward area defense engagement coverage. In this configuration, Patriot battalions are employed to protect a frontline division against attacks. The batteries of the battalion are positioned in the division rear area in a five-point perimeter formation that looks much like a pentagon. When the battalion is deployed in this formation, the topo survey company or the div arty survey section must provide two centrally located SCPs.

Figure 14-7. **Area (belt) defense employment**

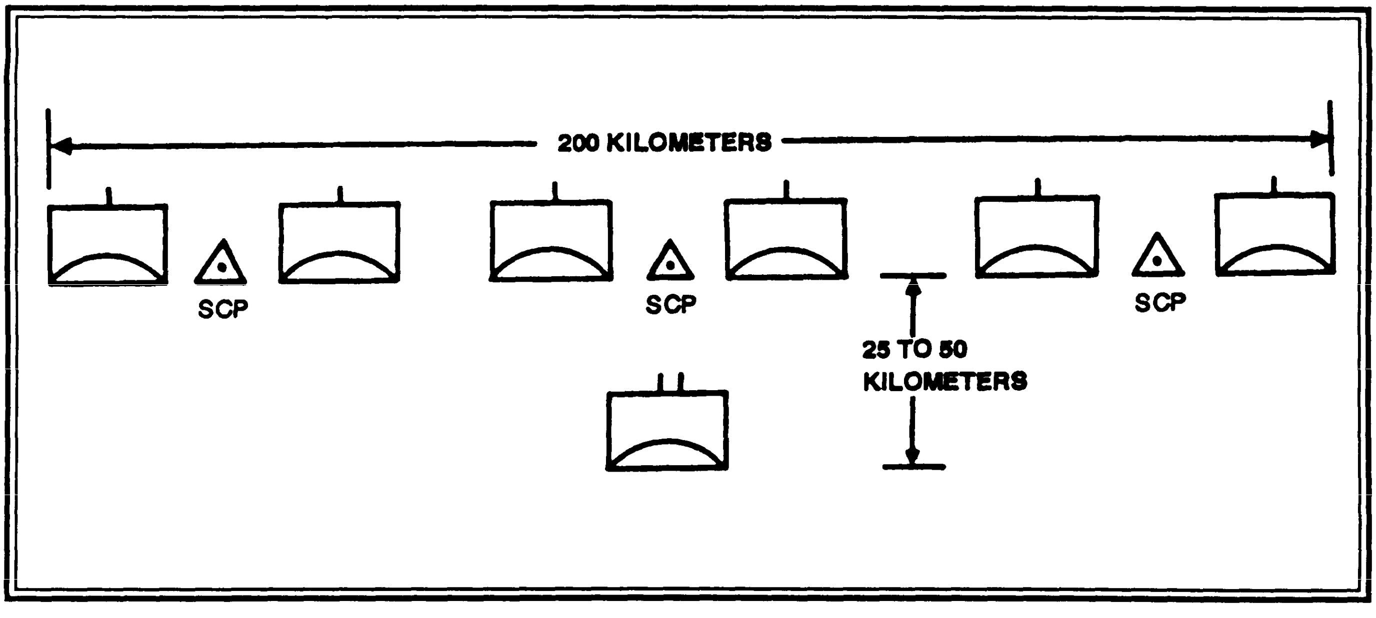
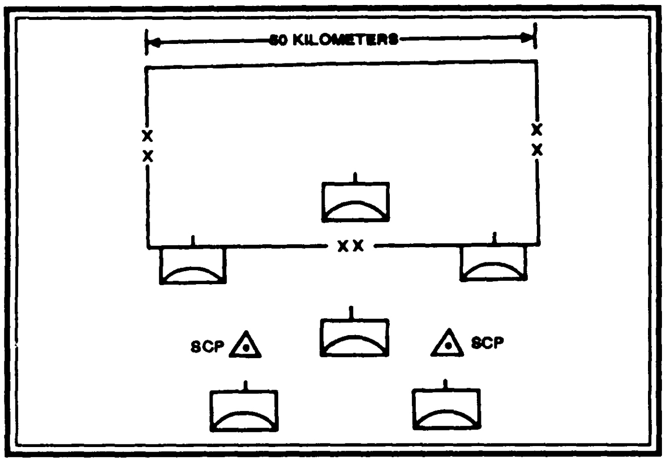


Figure 14-8. **Forward area defense engagement coverage**



c. Survey Requirements. The primary mission of the PADS survey parties is to provide the radar and launchers in each firing battery with timely survey control executed to prescribed accuracies. The required data are determined in the following order of priority:

- Orientation azimuth for the radar, north reference point (NREF), and azimuth mark.
- Coordinates and height of the radar.
- Coordinates, height, and orientation azimuth for the launchers.

(1) The primary missions of the SPCE are as follows:

- Collect, evaluate, and disseminate all available survey data that might be used by the battalion.
- Maintain maps and files of survey data for the battalion area of operation.
- Coordinate survey activities with higher, lower, and adjacent HQ.
- Train battery personnel in hasty survey techniques.

(2) Since the Patriot system uses true north as a reference and battery personnel will use grid azimuth to perform hasty surveys, both grid and true azimuths should be provided to the firing batteries. To ensure that survey data meet the required accuracy, the PADS teams will establish all surveys by performing 10-minute Z-VEL corrections.

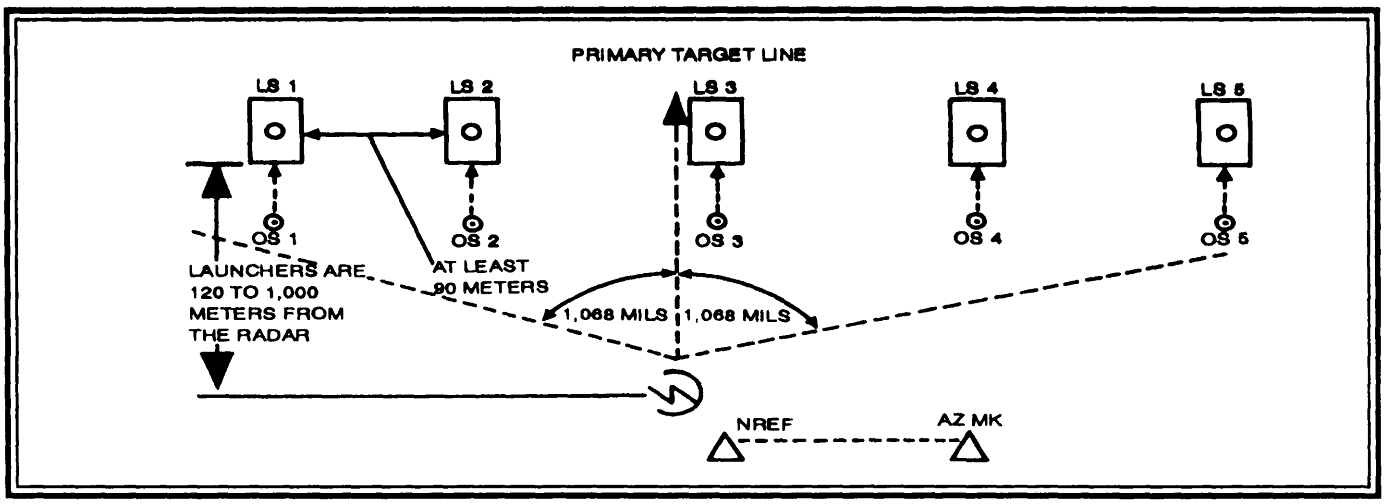
(3) On receipt of the battalion OPORD, usually 4 to 6 hours before the battery movement, the RSOP officer, RSO, or the chief surveyor will issue a warning order to the SPCE and the PADS teams. Because of the distance to be traveled, the PADS may be initialized before departing or initialization may be performed near the new position if survey control is available at the new position. The PADS teams should be included in the recon party so that the necessary survey operations can be started immediately after the new sites are selected.

(4) The survey will be performed in accordance with the battalion commander's guidance. In the absence of commander's guidance, the recommended methods of establishing the required survey control for the battalion, according to priority, are as follows:

- PADS performing two-position plumb bob or theodolite marks and using 10-minute Z-VEL corrections.
- Field artillery surveyors (PADS and SPCEpersonnel) using conventional survey methods.
- Patriot survey teams using hasty survey techniques and the aiming circle (FM 6-50).

★ **d. Survey Techniques.** The techniques to be used in surveying a Patriot battery (Figure 14-9) are discussed on the next page.

Figure 14-9. **Patriot battery area (five launchers)**



(1) Establish the NREF and azimuth mark by the two-position and azimuth mark method by using a plumb bob. If the NREF line must be less than 100 meters, establish the line by performing a position and azimuth mark with a theodolite.

(2) Establish the radar site by performing a position mark with a plumb bob or theodolite.

(3) In surveying the launcher sites (LSs) (Figure 14-10), establish the following for each launcher:

- An OS (located 10 to 12 meters behind the launcher position).
- OL from the OS to the launcher position.
- Location of the launcher position.

To do this, set up the theodolite over the launcher position and perform a position and azimuth mark by using the theodolite. After entering data, be sure to **apply 3,200 mils** to the azimuth displayed by the PADS (azimuth from launcher to OS) to get the azimuth from OS to launcher. The coordinates displayed will be to the launcher position and the height to ground level of the PADS.

(4) When time is critical, the PADS parties establish at least two SCPs with azimuth marks within each battery position. One will be near the radar site, and the other one will be the center launcher position. The azimuth mark for the SCP near the radar will serve as the NREF for the radar. (See Figure 14-11.) Battery personnel will extend survey control from these SCPs to the other four launchers by using conventional and hasty survey techniques.

(5) Whether the Patriot battalion is organized under the three-battery concept or the six-battery concept (Figure 14-12), the survey control required and the procedures for performing the survey are the same for each battery.

Figure 14-10. **Launcher site survey**

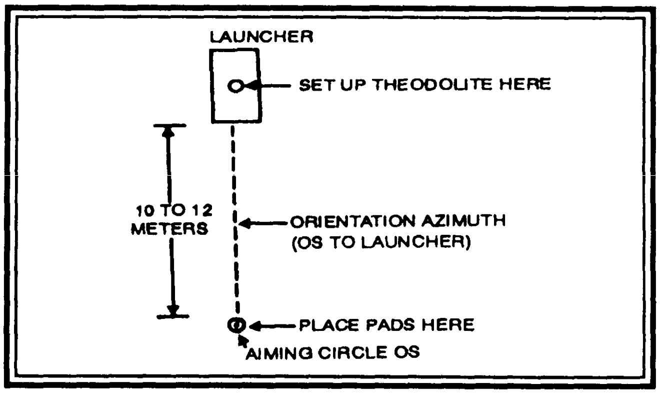


Figure 14-11. **Establishing two SCPs (time critical)**

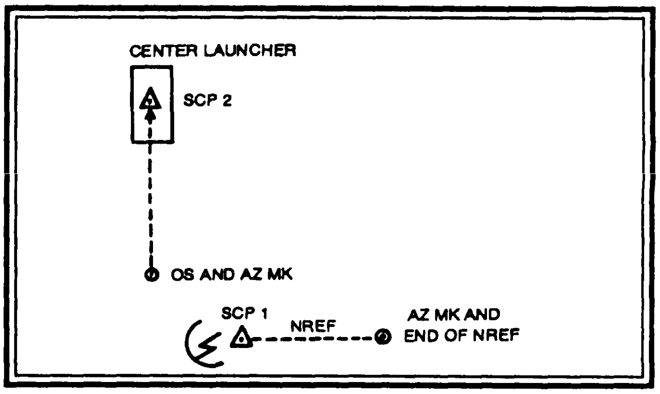
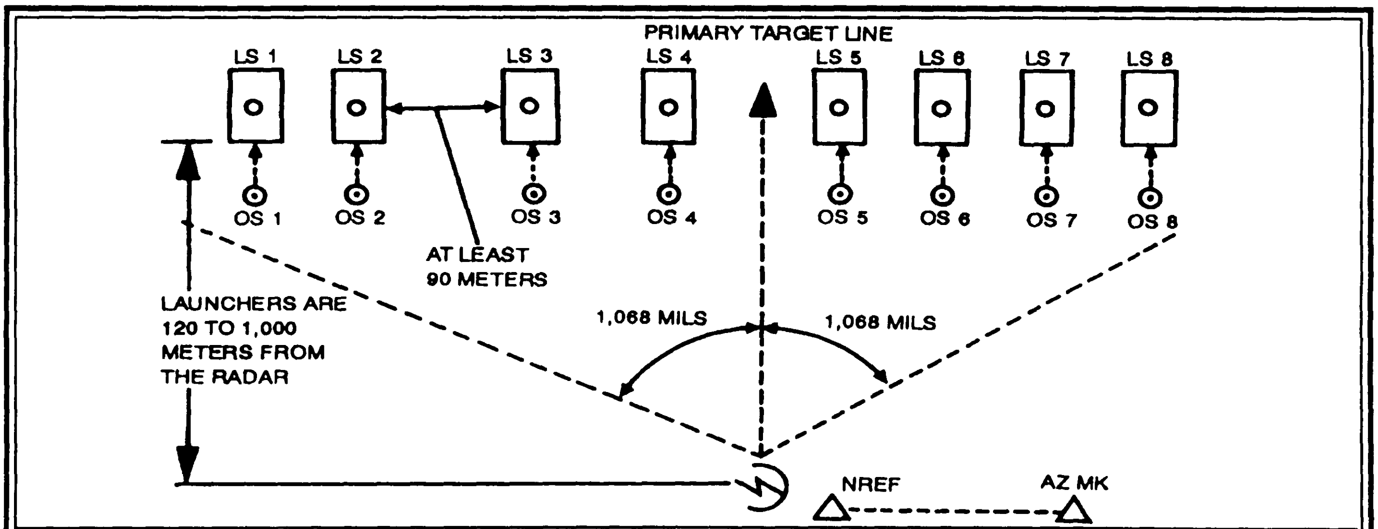


Figure 14-12. **Patriot battery area (eight launchers)**



Note. Estimated time of completion is 1.5 hours.

Section III

DIVISION ARTILLERY SURVEY

The primary mission of div arty survey is to establish battalion SCPs and an OL for assigned or attached firing and target-locating units. The div arty secondary mission is to recover and verify existing control, provide survey tie-in points to adjacent division areas, and help battalion surveyors whenever possible.

14-11. DIV ARTY SURVEY OFFICER

a. The div arty survey officer is the principal advisor to the div arty commander and his staff on survey matters. On the basis of the corps survey plan, he plans and supervises the div arty survey and has staff responsibility for all surveys performed by the div arty survey section.

b. The div arty survey officer must identify all units and elements requiring survey control and ensure that these requirements are met in his plan. Because of the number and variety of installations in the division requiring survey control, the div arty survey officer develops a survey plan that is based on the priorities established by the div arty commander.

c. Equal distribution of the survey workload increases the speed of execution. When the div arty survey officer tasks battalions and the TAB to perform surveys for various installations, he must ensure that these missions are within the capabilities of the battalion and/or TAB. The div arty survey officer must coordinate with lower echelon survey elements to avoid a duplication of effort.

d. The div arty survey officer must also maintain liaison with the aerial fire support observer (A FSO). He must determine the control requirements of the OH-58D aircraft with respect to specific mission planning. Landing areas collocated with the div arty TOC require surveyed initialization points. The div arty SPCE provides data from which the AFSO can get established control for planning way points for his mission.

14-12. DIV ARTY SURVEY SECTION

a. The div arty survey section starts from SCPs selected by the div arty survey officer. He selects these starting points from either existing trig lists or from SCPs established by engineer topo surveyors. If there is no existing control, the div arty survey officer or chief surveyor will assume starting data.

b. The div arty survey officer must use the survey section effectively. The PADS teams are his primary survey assets, but the survey team can be used to speed up survey operations. Once the PADS teams have brought control to the forward area by using 5-minute Z-VELs, the survey team using conventional methods can extend control from PADS points to nearby installations.

c. The preferred method for extending control from a PADS point is a traverse closed on the starting point by using a minimum number of traverse legs. The div arty SPCE helps the survey team if needed. If survey control is not provided and/or PADS cannot occupy existing control, the survey team uses conventional methods to provide the PADS teams with starting SCPs.

d. Div arty must operate on a 24-hour basis under the ALB concept. The mission of operating continuously and the long distances in the div arty survey mission creates a need for backup PADS teams. The survey section chief can schedule the survey team as an alternate PADS team to sustain the requirement of continuous operations. The div arty chief surveyor supervises the survey execution and helps coordinate between div arty, brigade SPCE, and other survey echelons.

e. If one div arty PADS becomes inoperative, the div arty survey officer distributes the workload between the remaining PADS and TAB PADS teams. The personnel from the team with the inoperative PADS combine with the survey team and perform as a five-man conventional survey party.

Section IV

TARGET ACQUISITION BATTERY AND DETACHMENT

The TAB survey section provides survey supped for the Firefinder radar (AN/TPQ-37) and, when tasked, for the IEW installations. The detachment PADS team is a corps asset that provides survey support for corps-assigned AN/TPQ-37 radars.

14-13. TARGET ACQUISITION BATTERY

a. The TAB survey section consists of one PADS team and a six-man survey party. Also located in the TAB is a survey HQ element.

b. Survey requirements of the TAB are discussed below.

(1) Provide the Firefinder radar (AN/TPQ-37) with azimuth, coordinates, height, vertical angle, and the distance from the site near stake to the far stake.

(2) Provide IEW installations with survey control when tasked by the div arty survey officer.

(3) Establish battalion SCPs when tasked by the div arty survey officer.

c. Although the AN/TPQ-37 radars are the TAB surveyors' standard mission, the div arty survey officer may direct the TAB survey section to perform any mission throughout the division area. To avoid duplication of the survey efforts, the TAB must closely coordinate its survey plan with the div arty survey officer.

d. When possible, the TAB survey will start from existing SCPs, as do all survey echelons. When existing survey control is not available, the TAB survey will start from an SCP provided by the div arty survey section. If the TAB has to assume starting control, they must close their survey back on the starting point and convert their data to div arty grid when available.

e. The TAB PADS team will use 5-minute Z-VEL corrections to ensure the necessary accuracy to establish battalion SCPs when directed. The PADS team can provide control, using resection and astro observation, if they have to go beyond the PADS limit of distance. The survey team can use short closed traverses anchor resections to establish starting control and update points for the PADS team. In addition to providing conventional support, the survey team will act as the relief PADS team during 24-hour continuous operations. In the event the PADS becomes inoperative, the HQ element will combine with the PADS team personnel to form a conventional team. The TAB will then operate with two conventional teams.

14-14. DETACHMENT

Detachments are corps assets in the form of a PADS team. Their sole function is to bring control to corps-assigned AN/TPQ-37s situated in the zone of operations.

Section V

SURVEY PLANNING AND COORDINATION ELEMENT (CORPS AND BRIGADE)

The corps artillery SPCE is the planning and control element for survey operations. The FA brigade SPCE may have a DS or general support reinforcing mission and is the controlling element for all survey operations within its area of responsibility.

14-15. CORPS ARTILLERY SPCE

The survey planning and coordination officer (SPCO) and the corps chief surveyor (SFC) plan and coordinate survey activities. Three survey computers (SGTs) are responsible for the functions discussed below.

a. Maintain maps and overlays which show completed surveys, surveys in progress, and planned surveys.

b. Keep a file of all SCPs and tie-in points established in adjacent corps areas by div arty and TAB survey sections.

c. Disseminate survey data via published trig lists and FM secure radio over the corps artillery survey net. (See Figure 14-13 for the field artillery survey radio net.)

14-16. FA BRIGADE SPCE

a. The FA brigade SPCE, consisting of four members, is the planning and coordination element that is the controlling element for all survey operations within its area of responsibility. The FA brigade may have a DS mission or general support reinforcing (GSR) mission. When assigned a DS mission, the FA brigade SPCE's mission is similar to that of the div arty SPCE, and it coordinates its survey requirement with the corps artillery. When assigned a GSR mission, the FA brigade coordinates its survey requirements with the div arty SPCE. Since the FA brigade does not have an organic survey section and to minimize duplication of the survey efforts, the SPCE must very closely coordinate its survey requirements with the higher HQ (corps and div arty SPCE).

b. The FA brigade SPCE mission requirements are discussed below.

(1) Ensure common grid throughout the brigade area of operation. This should be based on the grid provided by corps artillery or div arty SPCE.

(2) Coordinate survey operations with higher, lower, and adjacent units.

(3) Establish survey priority on the basis of the commander's intent.

(4) Request, through the corps artillery SPCE, external survey support and/or information from the corps engineer topo survey element.

(5) When required, request external survey support and/or information from the div arty SPCE.

(6) Disseminate survey information to its organic units.

(7) Gather, evaluate, and compile survey control established by its organic units.

(8) Maintain maps and overlays of completed surveys, surveys in progress, and planned surveys.

(9) Provide starting survey control data to its organic units and tie-in point data between adjacent units.

(10) Advise and help battalions plan, conduct, and evaluate survey training.

(11) Select sites for declination stations.

(12) Direct and coordinate tasked organizations of the FA brigade survey elements to best accomplish overall survey mission.

(13) Plan and provide survey control to other users (IEW, advanced helicopter improvement program [AHIP], mortars, and so on) when required.

(14) Direct and coordinate recovery of existing survey control points.

Figure 14-13. **FA survey radio net**

	RADIO NETS							
	Corps arty svy VHF-FM (V)	Corps arty cmd VHF-FM (V)	Div arty svy VHF-FM (V)	Div arty cmd VHF-FM (V)	FA bde svy VHF-FM (V)	FA bde cmd VHF-FM (V)	FA force svy VHF-FM (V)	FA/MLRS bn cmd VHF-FM (V)
Corps arty SPCE	N	X						
Topo svy	X							
MLRS bn SPCE							X	X
Div arty SPCE	X		N	X				
Div arty svy team			X	X				
Div arty PADS team			X					
MLRS PADS team			X					X
TAB svy team			X	X				
TAB PADS team			X					
FA bde SPCE					N	X	X	
FA bde svy team					X	X		
FA bde PADS team					X			
DS bn RSO			X					X
DS bn svy team			X					X
DS bn PADS team			X					
GS bn RSO					X			X
GS bn svy team					X			X
GS bn PADS team					X			

LEGEND:

bde	=	brigade	N	=	net control station	V	=	voice
cmd	=	command	FM	=	frequency modulated	VHF	=	very high frequency
D	=	digital	svy	=	survey	X	=	radio net

14-17. COLLECTION OF SURVEY INFORMATION

Information collected by the SPCE includes trig lists, reports by the FA section at corps HQ, div arty and TAB survey party reports, and FA battalion survey reports.

a. DMA Trig Lists. The SPCE obtains DMA trig lists as part of the initial map issue to the div arty. The SPCE retains one copy of each trig list as a reference record. Trig lists are considered allied support material to the map supply and are requisitioned through G2 channels. The areas of current operations and prospective interest are the basis of map supply to the div arty.

b. Reports by the FA Section at Corps Artillery Headquarters Battery. In static situations, the FA section at corps artillery HQ battery may periodically publish consolidated lists of fourth-order SCPs established by the survey parties from all division artilleries in the corps.

c. Div Arty and TAB Survey Party Reports. The div arty and TAB survey parties report their progress daily to the SPCE. Reports are accompanied by field notebooks and complete computations on all surveys performed. Members of the SPCE check and evaluate the data and enter the required information on DA Form 5075-R (Artillery Survey Control Point). (See Figures 14-14 and 14-15.) This form is completed in duplicate for each fourth-order SCP. One copy of the form is provided to the corps FA section, and one copy is filed as a reference record. (A reproducible copy of this form is included at the back of this book.)

d. FA Battalion Survey Party Reports. The survey parties periodically submit survey information to the div arty SPCE on DA Form 5075-R. Copies are retained as reference records. Only survey control that the div arty, SOP, or OPORD has directed the artillery battalions to establish are reported. The div arty survey officer designates the points to be established by battalions when the situation is such that the establishment of these control points would contribute materially to the expeditious delivery of FA fires. These survey control points are of particular value in cases in which FA battalions exchange position areas or when counterattack plans are implemented and an abundance of survey control is required in a general area to be occupied by the supporting field artillery. They are designated with a specific purpose in mind and then only when it is impractical to provide fourth-order survey control points.

Figure 14-14. **Front of DA Form 5075-R**

ARTILLERY SURVEY CONTROL POINT

For use of this form, see FM 6-2; the proponent agency is TRADOC

ANNEX A TO STANAG [illegible]

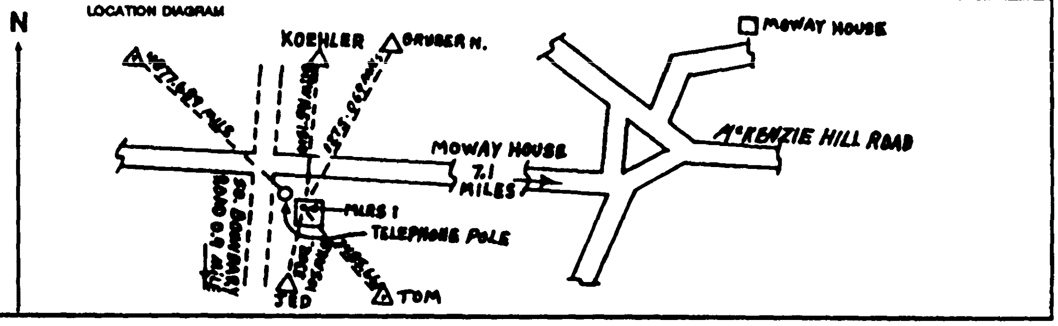
UTM ZONE	UTM SQUARE	STATION NAME		ACCURACY
14S	NP	MLRS 1		
		STATION NUMBER: 46		E - N: 1:5000
DATUM: NAD 27	ELLIPSOID: CLARKE 1886	MAP SERIES SHEET NO: 6253II		AZIMUTH: 1:3,000
HOW MARKED: DISK MARKED "MLRS 1" IN NW CORNER OF A 12.2 X 4.5 METER CONCRETE SLAB		E: 538548.11	N: 3834364.24	ALTITUDE: 1:3,000
		LONGITUDE: 98° 34' 46"	LATITUDE: 34° 39' 08"	ALTITUDE: 396.07 METERS

NOTES

WARNING:

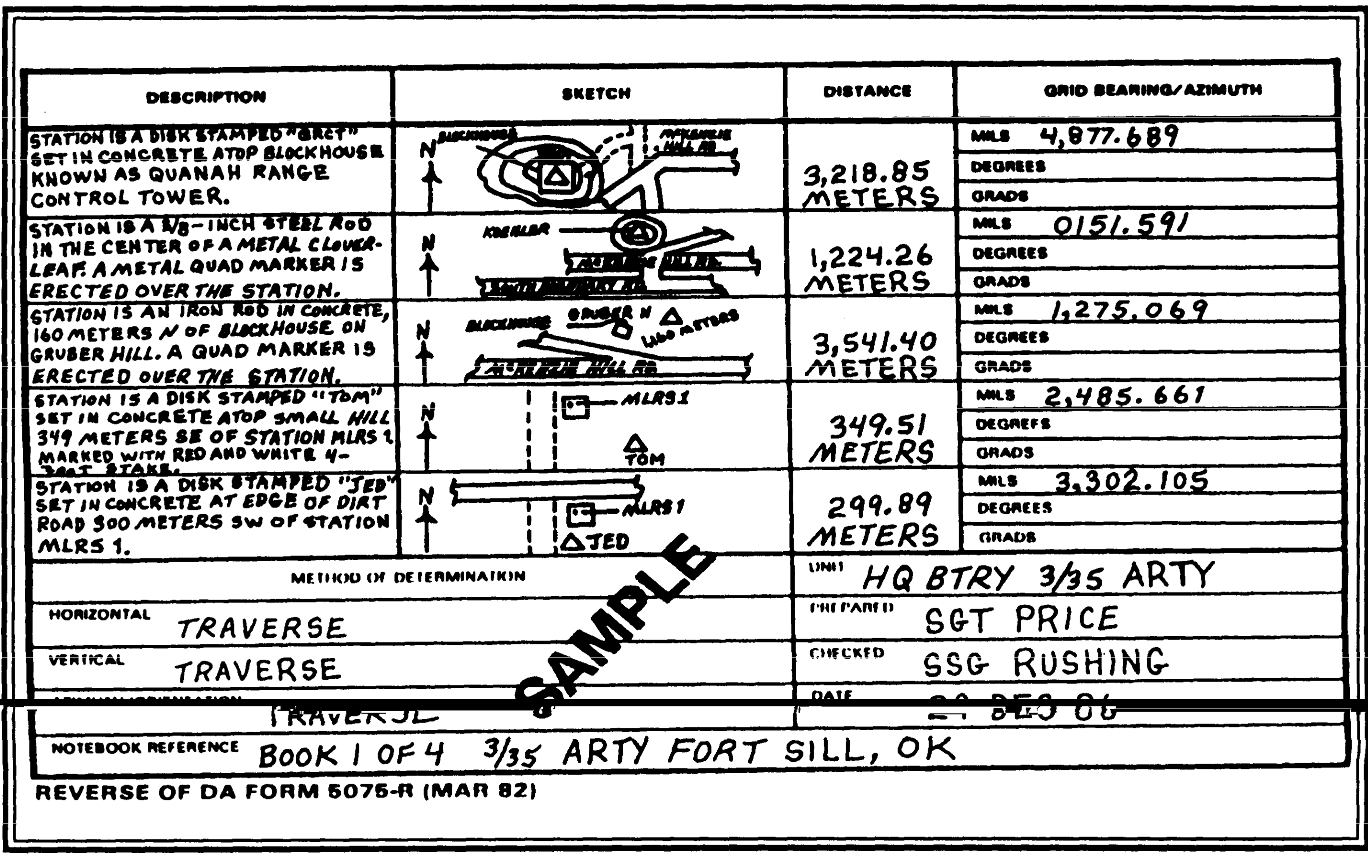
THERE ARE TWO DIFFERENT WAYS OF WRITING THE NUMBERS 1.7 AND 1.7

LOCATION DIAGRAM



DA FORM 5075-R (MAR 82)

Figure 14-15. **Reverse of DA Form 5075-R**



DESCRIPTION	SKETCH	DISTANCE	GRID BEARING/AZIMUTH
STATION IS A DISK STAMPED "GRCT" SET IN CONCRETE ATOP BLOCKHOUSE KNOWN AS QUANAH RANGE CONTROL TOWER.		3,218.85 METERS	MILS 4,877.689 / DEGREES / GRADS
STATION IS A 3/8-INCH STEEL ROD IN THE CENTER OF A METAL CLOVERLEAF. A METAL QUAD MARKER IS ERECTED OVER THE STATION.		1,224.26 METERS	MILS 0151.591 / DEGREES / GRADS
STATION IS AN IRON ROD IN CONCRETE, 160 METERS N OF BLOCKHOUSE ON GRUBER HILL. A QUAD MARKER IS ERECTED OVER THE STATION.		3,541.40 METERS	MILS 1,275.069 / DEGREES / GRADS
STATION IS A DISK STAMPED "TOM" SET IN CONCRETE ATOP SMALL HILL 349 METERS SE OF STATION MLRS 1. MARKED WITH RED AND WHITE 4-FOOT STAKE.		349.51 METERS	MILS 2,485.661 / DEGREES / GRADS
STATION IS A DISK STAMPED "JED" SET IN CONCRETE AT EDGE OF DIRT ROAD 300 METERS SW OF STATION MLRS 1.		299.89 METERS	MILS 3,302.105 / DEGREES / GRADS

METHOD OF DETERMINATION	
HORIZONTAL TRAVERSE	UNIT HQ BTRY 3/35 ARTY
VERTICAL TRAVERSE	PREPARED SGT PRICE
	CHECKED SSG RUSHING
TRAVERSE	DATE DEC 86
NOTEBOOK REFERENCE BOOK 1 OF 4 3/35 ARTY FORT SILL, OK	

REVERSE OF DA FORM 5075-R (MAR 82)

SAMPLE

14-18. MAINTENANCE OF SURVEY INFORMATION

The SPCE must maintain the information it has collected in a usable form. A survey information map with overlays and a survey information file are prepared to allow information to be used.

a. Information Map and Overlays. The SPCE maintains an information map showing all SCPs in the division area and adjacent division areas located to fourth-order accuracy or higher. In addition, overlays to the map show the locations of artillery units, possible position areas, surveys in progress, proposed surveys, and other information required by unit SOP. These maps and overlays should show the following information:

- Survey control points in black.
- Completed surveys in brown.
- TAB installations in blue.
- Proposed surveys in green. When possible, surveys proposed by div arty and TAB are included.
- Present (solid-line symbols) and proposed (broken-line symbols) artillery positions in the division area in brown.
- The friendly situation and the enemy situation when it might affect the planning or performance of survey in the division area.

b. Information File. The SPCE maintains a survey information file of trig lists and extracts of trig lists prepared and issued by DMA and the Corps of Engineers. A record is maintained of field notes and computations on control points established by the div arty and TAB survey sections. The SPCE submits periodic reports on surveys in progress to adjacent div arty SPCEs and to artillery units operating in the division area.

c. TACFIRE or AFATDS SCP Data Base. The SPCE must ensure that known control points are entered into the tactical fire direction system (TACFIRE) or advanced field artillery tactical data system (AFATDS) SCP data base. SCPs in the division area of interest and in the supported unit areas of influence should be entered and updated. The SCP data base must be kept current to decrease the possibility of duplicate surveys and to rapidly exchange survey data automatically.

This paragraph implements STANAG 2934.

d. DA Form 5075-R. DA Form 5075-R is used to permit quick identification of survey control points. Figures 14-14 and 14-15 show the use of DA Form 5075-R. The front of the form (Figure 14-14) provides blocks for the following:

- Control point name and number.
- Map sheet and series number.
- Grid and geographic coordinates.
- Altitude.
- UTM zone and UTM square.
- Marking method.
- Accuracy of the data.
- Notes.
- Location diagram.

The reverse side of DA Form 5075-R (Figure 14-15) provides blocks for the following:

- Description of reference points.
- Sketch of reference points.
- Distance to reference points.
- Grid bearing or azimuth to reference point.
- Methods used in determining horizontal, vertical, and azimuth control.
- Verification information (unit, preparer, checker, date, and notebook reference).

14-19. EVALUATION OF SURVEY INFORMATION

a. The div arty SPCE must check the field records and computations of the div arty and TAB survey sections. A survey team operating in the field maintains a field notebook containing a complete record of all fieldwork performed and all DA forms on which computations are performed. On completion of the survey, the field notebook, computation forms, and results of the survey are forwarded to the SPCE for checking, adjusting, and recording.

b. The evaluation process is designed to verify the validity of the surveys and consists of procedure checks, computation comparison checks, closure checks, and map verification.

(1) Procedure check. All computations and values recorded in the field notebook are checked to ensure that proper procedures, specifications, and techniques were used to complete the survey fieldwork to the required accuracy.

(2) Computation comparison check. The computations performed by the computers are compared to ensure that both sets of computations agree.

(3) Closure check. A check is made to ensure that the survey has been properly closed within fourth-order accuracy.

(4) Map verification. If the survey data pass the procedure check, computation check, and closure check, the data are plotted on the largest-scale map available to check both the validity of the survey and the accuracy of the map. If the map plots verify the recorder's field notebook description, the survey is accepted. If the map plots do not verify the recorder's field notebook description, the data are subjected to a complete computation check. If necessary, additional fieldwork is prescribed to determine whether the map or the survey is in error. Any map errors detected by survey personnel performing fieldwork should be noted in the remarks column of the field notebook and reported to higher HQ through G2 channels.

c. In addition to performing the functions just discussed, SPCE personnel are equipped and trained to make the following checks and computations:

- Traverse, triangulation, intersection, resection, and astro computations.
- Adjustment of all surveys to distribute minor errors in distance and direction throughout all stations occupied in the survey. Before adjustment, all surveys must meet the minimum fourth-order closure requirements.
- Swinging and sliding operation to convert survey data from one grid to another.
- Transformation of coordinates and grid azimuths between UTM zones.
- Conversion of geographic coordinates to grid coordinates and grid coordinates to geographic coordinates.

14-20. DISSEMINATION OF SURVEY INFORMATION

Timely dissemination of survey information is equally as important as maintaining a complete and accurate survey information file. The SPCE maintains survey information maps and overlays to aid in the rapid dissemination of survey information to units and to aid the div arty survey officer in preparing the division survey plan. In the div arty, survey information is disseminated by personal visits by battalion survey personnel, coordination and liaison visits by the div arty survey officer, command and control systems, radio and telephone, and field liaison between survey sections.

a. Battalion and TAB RSOs or their representatives should visit the SPCE often to keep abreast of div arty survey plans and to obtain survey control (trig lists) available in their prospective areas of interest.

b. The div arty survey officer should visit the FA battalions and the TAB often to coordinate and discuss survey operations and requirements. During these visits, he should ensure that the RSOs are aware of available control.

c. Survey data can be stored and rapidly trasmitted by using command and control systems such as TACFIRE and AFATDS. Unit SOP will dictate the procedures used to access, store, update, and disseminate survey information between echelons.

d. Survey information may be disseminated by radio or telephone. However, security requirements outlined in the unit signal operation instructions (SOI) must be observed. Radio or telephone communication is the least desirable method of disseminating survey information because of possible errors in transmitting and because of problems in orally describing the survey station sketches shown on DA Form 5075-R.

e. In the div arty, survey information usually is not disseminated until it has been evaluated and adjusted. During fast-moving situations in areas where limited survey control is available, there may be exceptions. The div arty survey section in the field may disseminate survey data directly to the battalion sections as the data are determined. In this case, the chief of the div arty survey section disseminating the survey data will ensure that the battalion and TAB survey officers are informed that the data provided are unchecked and unadjusted. When the survey data are turned in to the SPCE, the chief of the survey section will report which data he has disseminated and to whom. The SPCE will then ensure that the user gets the adjusted data when they become available.

Section VI

SURVEY IN SPECIAL ENVIRONMENTS

Survey operations must proceed regardless of environmental factors, such as climate and terrain. Therefore, the type of environment must be considered. This section discusses some of the problems that may affect surveyors in arctic, desert, jungle, and urban areas.

14-21. ARCTIC AREAS

a. Survey Operations. Normally, peacetime surveys are planned to take advantage of the warmer months of the year to avoid working under the varying terrain and climate conditions found in the upper latitudes. In wartime, however, survey operations are executed when and where needed and cannot wait for ideal climate conditions. The summer season has the advantage of better visibility, greater body comfort, and fewer equipment malfunctions. The winter season reduces transportation difficulties in river, lake, and tundra regions. Survey control can be extended easily along riverbanks; over the nearly level, treeless plains of the arctic tundra; or across large bodies of water. When committing survey elements to field operations in arctic regions or under arctic conditions that are seasonal in the middle latitudes, commanders must consider the effects of ice movement, snowfall, prevailing wind, light refraction, and other peculiarities. The proper use of authorized cold weather equipment and field expedients will overcome most problems caused by the cold. For detailed instructions on cold weather operations, refer to FMs 31-70 and 31-71.

b. PADS Operation. The PADS operates without performance degradation at temperature extremes between -50°F (-45°C) and 125°F (50°C). It may be stored without damage between -50°F and 160°F (71°C). Initialization, which normally takes about 30 minutes, will take longer at temperatures below -5°F (-20°C) or when wind blows into the IMU heat exchanger. Using a vehicle enclosure, parking behind a windbreak, or placing a blanket or an article of clothing over the heat exchanger exhaust will improve reaction time. Keep the batteries warm at temperatures below -20°F (-29°C). Use the vehicle heater during operation. Store batteries in a warm area when they are not being used.

> **WARNING**
>
> **Contact with power supply fins may cause skin bums at high ambient temperatures. Lead-acid batteries that are not fully charged may freeze and burst. Handle batteries as prescribed in TM 9-6140-200-14.**

c. Other Field Operations. Survey accuracy depends largely on factors that can be controlled in the field by the survey officer, the chief surveyor, and the chief of the survey section. These include instrument handling, equipment care, and aids to maintaining body comfort. Surveying in the arctic or under arctic conditions requires a lot of professional judgement and common sense. All survey methods may be employed subject to terrain and weather conditions in the area of operation. Warmup time for electronic equipment will be increased.

(1) Setting up instruments under bad weather conditions, especially in snow, requires the use of field expedients. Brief setups in snow can be accomplished by firming up a snow base. Tamping will suffice for routine operations. Other procedures are discussed below.

(a) Clear away the snow to reach the frozen but solid earth.

(b) Drive stakes to form a trivet-like base for tripod shoes.

(c) Use long tripod legs for setting up in deep snow.

(d) Use sharply pointed tripod shoes to facilitate setting upon icy surfaces.

(e) Protect the instrument from wind, or accurate readings will be difficult

(2) Proper daily care ensures against equipment failure and delays in the field. Extreme changes in temperature may induce internal stresses within an instrument. Instruments should be kept outside overnight or in unheated shelters for short periods of nonuse. When transporting instruments in the field, make some arrangement for the instrument to be carried outside the vehicle or in an unheated cargo compartment. Tripods also should be left outside when not in use. The BUCS (with batteries removed) can be stored in temperatures down to -40°F, but it cannot operate below 32°F (O°C). The proper lubricant for arctic use is grease, artillery and automotive, military specification MIL-G-10924, or an equivalent.

(3) Body comfort depends mainly on the protection offered by issue clothing. The survey chief can improve conditions by directing the digging of pits, erecting windshields, or building up snowbanks to reduce the intensity of exposure over extended periods. Utility stoves should be used for heating nourishing liquids and keeping the fingers warm. An instrument can be modified by providing enlarged nonmetallic operating knobs or by wrapping standard knobs with adhesive tape. This facilitates manipulation of the instrument and helps keep the fingers from being injured. Head and hand coverings become a problem for the instrument operator and the recorder. Layer gloves and layer head coverings provide a practical combination of warmth and maneuverability. An easily removed hood over an ear-covering headpiece is practical for most conditions. Safety precautions are discussed below.

(a) Do not touch metal with any part of the bare skin.

(b) Make use of equipment furnished for protection of the eyes against wind and glare.

(c) Always use the buddy system in surveying. Do not go out alone.

(d) Always carry a first aid kit.

(e) Practice personal hygiene as coveredin FM31-70.

d. Survey Control. In most arctic areas, especially on the tundra or in heavily forested regions and away from centers of civilization, preestablished control will be minimal. Survey control that does exist will be difficult to locate in areas of heavy snowfall and high winds. Topo support is essential to establish the common grid. Map spottings, when maps are available, are almost impossible because of the lack of definable natural and man-made objects. The most probable solution for the extension of survey control (if topo support cannot be provided) is for the div arty survey officer to assume position control; use the PADS, astro observation, or the SIAGL (latitude of operation permitting) for direction; and start the common grid there. Each installation or unit will then convert to common control as it enters the divisional survey net.

14-22. DESERT AREAS

Field artillery survey in a desert environment lends itself to some major problems in equipment, methods, and operations. Problems not experienced in other environments are prevalent during desert operations. Initially, desert operations seem to be perfect for survey w ith long lines of sight, clear traverse lines, and cloudless skies for celestial observations. However, the desert is no utopia for the surveyor. Some of the problems encountered are described below.

a. Equipment. Optical instruments operated in extreme heat can have some major interior and exterior physical problems. Experience has shown that at 100°F, the survey instrument leveling vials increase about 2 graduations past the true center. Therefore, at 120°F, the instrument operator may not be able to level the instrument because of bubble expansion. To counter this, instruments should always be shaded. The direct rays of the sun can and will cause optical distortion and internal stress. Before moving to a desert environment, operators and supervisors must ensure that proper maintenance is performed and lubricants are applied to and maintained in the instruments. The scoring effects of sand and grit on the instrument optics require that the instrument lens covers be in place when the instruments are not being used. The major problems in desert operations are caused by heat waves. Distances between stations are severely limited because of heat wave distortions. Consistent readings at occupied stations are nearly impossible to achieve.

Operator eye fatigue is common and necessitates frequent operator changes. Beause of heat wave distortion, conventional survey operations and PADS operations requiring optical transfer should be avoided. The BUCS can be stored in temperatures up to 140°F (with batteries removed), but it cannot operate above 113°F (45°C). If absolutely necessary, conventional survey operations will have to be conducted during the hours of darkness or during early morning and late afternoon.

b. Survey Control. Survey control in the desert is very fleeting in nature. The lack of definable natural and man-made objects increases the problem of permanent control. Topo surveyors must make every effort to provide starting control for the division survey section. Established survey control dates from the desert colonial periods and, although scarce, it is accurate. However, control that can be identified and located one day may be obscured by sand the next. If these control points are constructed of anything valuable (for example, metallic substances of any kind), local civilians will dig up and carry off the station markers. In establishing control, efforts must be made to camouflage or immobilize control points. Use of the existing road networks and road junctions is another way of ensuring that control is available when it is required. Burned-out armored vehicles and destroyed fortifications also can be used as control points. When operating in the desert, the survey officer should ensure that all control possible within the zone of operations is recovered and verified. It should be understood that control in the desert is, at best, only temporary in nature.

c. Techniques of Conventional Desert Survey. Conventional surveys conducted in a desert environment require special considerations. In any other area, the primary means of extending control is traverse. However, in the desert, the distance involved and the lack of control indicate the primary means of extending control will be triangulation. If traverse has to be used, night traverses will be common. If night surveys are required, parties will have to be augmented with additional personnel. Light discipline will be of great importance because lights can be seen in the desert to distances of about 8 miles. Trig traverse is an excellent means of extending control in desert operations. The use of astro observation, simultaneous observations, and the SIAGL to start and extend directional control will be of critical importance to the surveyors.

d. Personnel. Personnel acclimatization is an important factor in desert operations. It can be assumed that if our current deployment policy does not change, there will be no time for acclimatization. Surveyors will be deployed from the continental United States (CONUS) right into a desert environment. Care should be taken to ensure that all personnel who might possibly be employed in this type of environment are trained in survival techniques.

14-23. JUNGLE AREAS

a. Survey Operations. Survey operations in the jungle pose many problems not encountered in other environments. Some of these are the foreboding appearance of the jungle, the oppressive humidity and heat, the unfamiliar noises, and the loneliness one feels in the jungle. In addition to the physical and psychological effects of working in the jungle, the FA surveyor will be aware immediately of the lack of adequate maps. The maps that are available often are inaccurate except for locations of coastlines and principal rivers. For a more detailed discussion of jungle operations, refer to FM 90-5.

b. Survey Control. Because of the inaccessibility of jungle areas and since adequate maps do not exist for most areas, the establishment of survey control and the common grid is a primary consideration of the commander.

(1) The extension of survey control should not depend on preestablished control, which in most jungle areas is minimal and at best difficult to recover and identify. One solution is for the div arty or battalion survey officer, using available maps or map products, to assume control; to use the PADS, astro observation, the SIAGL, or simultaneous observation for direction; and to initiate the common grid. Each unit will convert to common control when it ties into the division survey control net. Map spottings with available maps or photomaps may have to suffice for position control at firing unit locations.

(2) Normally, FA firing positions are in natural clearings. This usually will permit a position area survey to tie in the firing batteries relative to each other. Direction can be obtained as described in (1) above. One possible solution for the extension of the common grid is the use of gridded mosaics or other photomap products.

c. Conventional Methods. Survey control maybe extended through the jungle by pursuing traverse procedures. It will be difficult and time consuming and normally will require that a security force go with the surveyors. Using triangulation and resection techniques is most difficult, since line of sight is extremely short or nonexistent. Target area survey and connection survey usually are very restricted or impossible. In any case, survey in the jungle requires the imagination and initiative of all survey personnel.

14-24. URBAN AREAS

a. In most military operations, the type of terrain is a prime factor in planning, coordinating, and executing a unit mission. This is especially true for survey operations conducted in and around villages, towns, cities, and other built-up areas. The presence of buildings and man-made changes to the landscape greatly affect conventional survey operations and also must be considered during PADS operations.

b. The tactical situation is a strong influence on survey operations in built-up areas. The enemy can be well hidden by using roofs and upper stories of buildings, sewer systems, subways, and other underground structures. Enemy obstacles (barricades, booby traps, and minefield) may deny the use of certain terrain needed as routes for extension of survey control. Communication between survey assets may be hampered by the limited range of FM radios within built-up areas.

c. Line of sight limitations in urban areas and the possibility of widespread weapon positions will increase the number of survey stations. Required OPs must be located on rooftops, towers, or other high structures. Also, more OPs may be needed to observe all areas of concern and to ensure accurate target locations.

d. Targets of opportunity generally will be exposed to observes for brief periods. Also, political and tactical considerations will demand pinpoint accuracy in locating and destroying targets. Destroying key facilities and creating severe obstacles to friendly troops must be weighed. For a detailed discussion of urban operations, see FM 90-10.

CHAPTER 15

SURVEY PLANNING

The purpose of artillery survey is to provide firing and target-locating assets with a common grid. Common survey control allows the commander to tactically employ his units with a guarantee of accurate and timely fire support. This allows him to mass fires of subordinate units, to store and transfer target locations for future attacks, and to limit vulnerability of firing units. Planning for artillery surveys is based primarily on the planned positioning of firing units and TA assets and the commander's accuracy requirements.

15-1. CONDUCT OF PLANNING

a. Surveys are planned to ensure that all required control is provided in the correct place and at the time required. The plan distributes work evenly among teams and eliminates duplicate work. Planning is based on meeting as many survey requirements as possible under the given conditions and always providing the best available survey control to using units. Direction is the most important element of survey control. Therefore, when time is critical, the plan must reflect the requirement to rapidly extend direction throughout the area of operation and later extend coordinates and height.

b. Survey planning is conducted at all echelons at the same time. Provisions should be made to link together all surveys conducted in the area. Normally, the surveyors of div arty HHB provide survey control points to all assigned and attached battalions or separate batteries. Thus, they tie together the surveys of the division firing and locating elements. The TAB and battalion surveyors survey their organic and attached elements and help other units as directed. The degree of accuracy, speed of execution, and priority of work are given in the commander's guidance or are set by the S3 from the commander's guidance.

c. Artillery units at all levels start survey operations before occupation of position. They do not wait for higher-echelon survey control to be established in the area. Firing and target-locating units must work from the best available data and improve the data as higher-order survey becomes available.

d. Fourth-order survey sections are organic to the div arty HHB and TAB to provide survey control for assigned and attached units of the division. Each artillery battalion has an organic fifth-order survey section. These sections are organized into survey teams and equipped according to the modification tables of organization and equipment (MTOE) for the unit. The concept of employment of these sections is based on the guidelines below.

(1) *Div arty.* Provide all organic, attached, and reinforcing artillery battalions, TA assets, and separate batteries with common direction, coordinates, and height.

(2) *TAB.* Provide common direction, coordinates, and height for the TA assets of the battery. Provide SCPs for other units as directed by the TAB commander.

(3) *Battalion.* Provide common direction coordinates, and height for all firing batteries and targeting devices that are assigned or attached to or reinforcing the battalion and mortars.

e. For the purpose of planning a survey, installations may be separated into groups according to the accuracy of survey required. Requirements and position considerations are shown in Table 15-1.

(1) Fourth order. Fourth-order survey control is required at firing battalion and separate battery SCPs.

Table 15-1. **Survey installations**

TYPE OF SURVEY	INSTALLATION	REQUIREMENT	REMARKS
Fourth-order (PADS must use 5-minute Z-VEL corrections.)	Battalion SCP	Azimuth, coordinates, and height	Bn SCP within 2 km of center of battalion position area
	Battery SCP	Azimuth, coordinates, and height (azimuth not required for MLRS)	SCP within 2 km of center of battery position area
Fifth-order (PADS must use 10-minute Z-VEL corrections.)	Cannon battery (non-Paladin)	Azimuth from OS to EOL. Coordinates and height of battery center or OS	Orienting line part of main scheme if traverse is used
	Paladin howitzer	Coordinates and height to platoon area SCPs. Azimuth from SCP to an azimuth mark	Howitzer update points needed every 16 miles
	Patriot missile system	Orientation azimuth for radar, NREF. Coordinates and height of radar and launchers. Orientation azimuth for launchers	Perform two-position plumb bob or theodolite marks by using 10-minute Z-VEL or fifth-order conventional survey
	OH-58D (AHIP)	Coordinates and height of initialization and update points	Requires update every 15 minutes or 15 nautical miles
	MLRS	Coordinates and height of platoon area SCP	Update points needed every 6 to 8 km
	AN/TPQ-37 radar	Azimuth and distance from OS to azimuth mark	Azimuth accuracy ±0.4 mil (PE)
		Coordinates and height of radar position	
	AN/TPQ-36 radar	Azimuth, distance, and vertical angle from OS to azimuth mark	Azimuth accuracy ±0.4 mil (PE)
		Coordinates and height of radar position	
	Ground-based signal intercept radio direction-finding systems—Trail Blazer and Teammates	Coordinates and elevation for OS and EOL with azimuth	PADS uses 10 Z-VEL or fifth-order conventional survey

(2) Fire order. Fifth-order survey control is required by firing and target-locating installations. Some installations require 0.4-mil or 0.5-mil accuracy for direction. Care must be used in selecting a method to establish direction for these installations. The requirements for CEWI sites should be addressed by local SOP or coordinated by the div arty survey officer.

(3) Hasty survey. All firing and target-locating elements requiring survey must be able to use hasty survey techniques to provide the best available survey control rapidly. The hasty survey techniques preferred for a particular system are covered in the applicable field manual. For example, FM 6-50 prescribes hasty survey techniques for FA cannon batteries.

15-2. SURVEY PLANNERS

Survey planning is performed by many individuals at many levels. Some of these planners are discussed below.

a. Artillery commander or FSCOORD. The maneuver commander initiates the requirement for survey planning when he issues guidance to the FSCOORD. He does so by stating his scheme of maneuver, rate of movement, anticipated enemy threat, and critics) phases of the battle. The FSCOORD analyzes the commander's guidance to determine the need for passing of target information, first-round fire-for-effect accuracy, and massing of fires. He weighs his analysis against the ability to adjust fires, fire registration missions, and rapidly engage targets from new position areas. The concept for a survey plan to provide common survey control is thus begun.

(1) The FSCOORD then must extract from the maneuver commander's guidance information that will allow him to visualize the survey requirements for fire support (FS) assets. The FSCOORD can gain most of the information by reviewing the scheme of maneuver, rate of movement, effects required on high-payoff targets, and accuracy requirements for TA sensors. He must also determine whether it is more important to have survey at the guns or TA assets first.

(2) Each artillery commander is responsible for establishing common control throughout his area of operations. The FSCOORD must disseminate to the appropriate artillery battalion HQ the established accuracy requirements in survey terms. Additional requirements or guidance derived by the FSCOORD must also be **communicated.** This should either be done through face-to-face coordination or through the S3. The survey officer must be included in this coordination. He should advise the FSCOORD and/or S3 on his current survey capabilities and limitations. Figure 15-1 is a checklist for use by the FSCOORD as an aid in determining survey requirements. This checklist is not inclusive and should be modifed to meet situations) requirements.

b. Corps Artillery SPCO. The responsibilities of the SPCO associated with the corps survey effort are discussed below.

Figure 15-1. **FSCOORD checklist**

1. Select primary, alternate, and supplementary position areas for the following:
   - Weapons:
   - FA battalions.
     - Missiles.
     - Rockets.
     - Mortars.
   - TA systems:
     - Radars.
     - CEWI.
     - Observers.
2. Select times as follows:
   - Time survey to be completed.
   - Time to start fieldwork.
   - Time to start reconnaissance.
   - Time to start planning.
3. Determine accuracies (hasty survey or fifth-order survey) for the following:
   - FA battalions.
   - Observers.
   - Target locators.
4. Determine the priorities for the weapons and TA systems of each of the following:
   - DS battalion.
   - Reinforcing (R) battalion.
   - GS battalion.
   - GSR battalion.
   - Mortars.

   TA systems include the following:
   - Radars:
     - AN/TPQ-36.
     - AN/TPQ-37.
   - Observers:
     - COLTs.
     - OPs.
   - Other:
     - CEWI.
     - Elevated target acquisition systems (ETASs).
5. Coordinates as follows:
   - To determine locations of the third-, fourth-, and fifth-order SCPs.
   - To determine when SCPs will be established.
   - To determine additional survey requirements from higher echelons.
   - To establish liaison with higher, lower, and adjacent units.

(1) Know the survey requirements of all crops units (Figure 15-2) and the survey capability of those units.

(2) Coordinate with the corps G2 to get intelligence estimates of the proposed work areas to include the following:

- Enemy activity.
- Friendly forces.
- Other optional connstraints.

(3) Coordinate with the crops G3 plans to get the following:

- Current and planned positions of corps artillery units.
- Unit movement plans.
- Dates and times of movement.
- Priority of unit movement.

This information used in planning and coordinating includes IEW systems requiring survey in support of corps missions. (Refer to Figures 15-3 and 15-4 for corps survey plan—in progress and future surveys overlay.)

(4) Make contact with the survey company of the engineer topo battalion and obtain necessary details from the commander (for example, attached platoon, location of company SPCE, and names of points of contact). The engineer topo battalions' survey company supports the field artillery and sir defense artillery with third-order horizontal and vertical control points and azimuth marks for EAC down to division and separate artillery brigades on a 24-hour basis. Topo survey augments FA survey requirements with the following:

- EAC—two SCPs per Patriot battalion.
- Corps area-eight SCPs each 24-hour period and one SCP per div arty or separate brigade each 24-hour period.
- PADS—starting and closing SCPs are provided at a maximum interval of 25 km.
- MLRS—stsrdng and closing SCPs are provided at a maximum interval of 30 km.

Figure 15-2. **Units requiring survey within a corps**

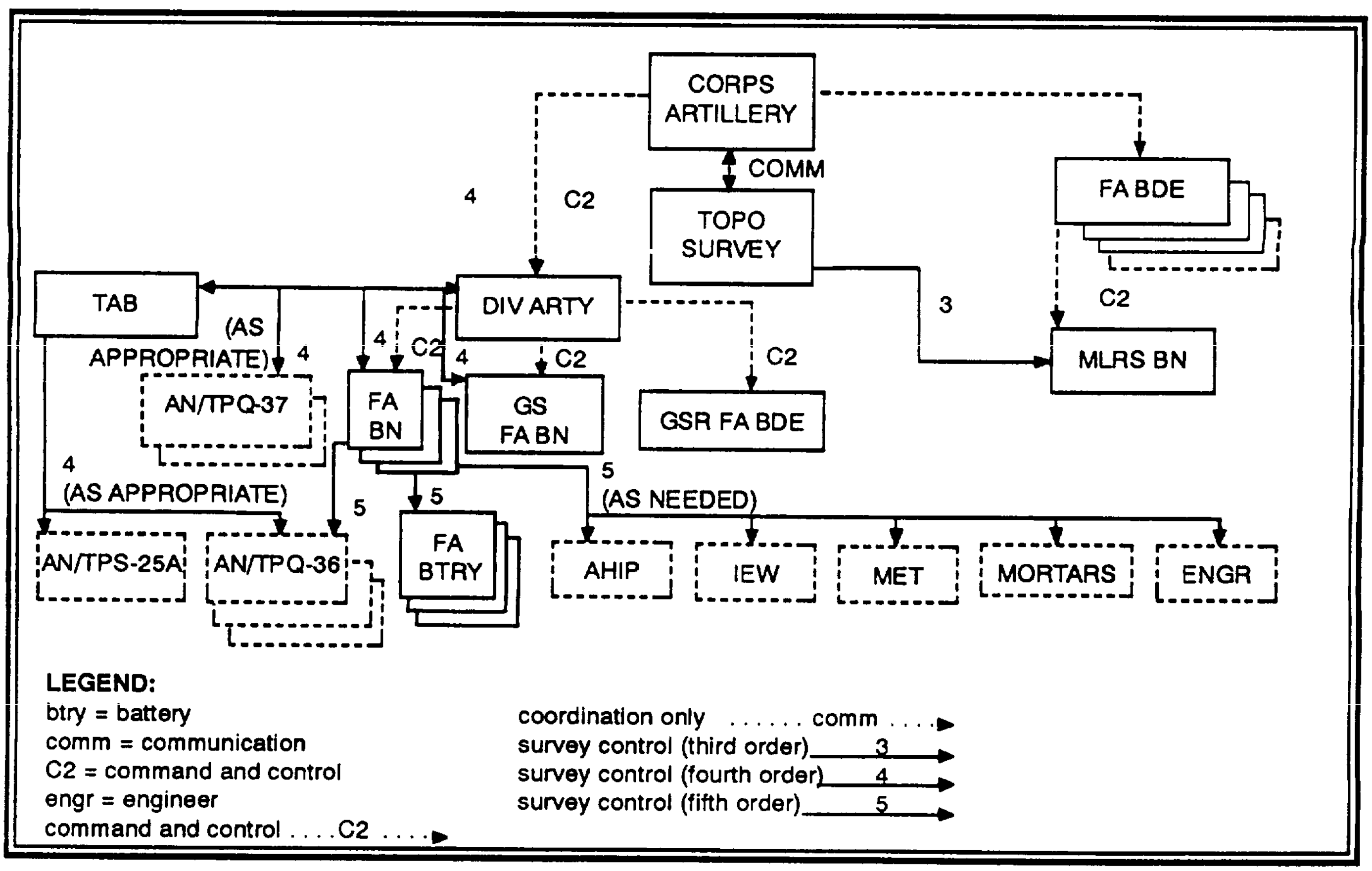


Figure 15-3. **Corps survey plan—in progress**

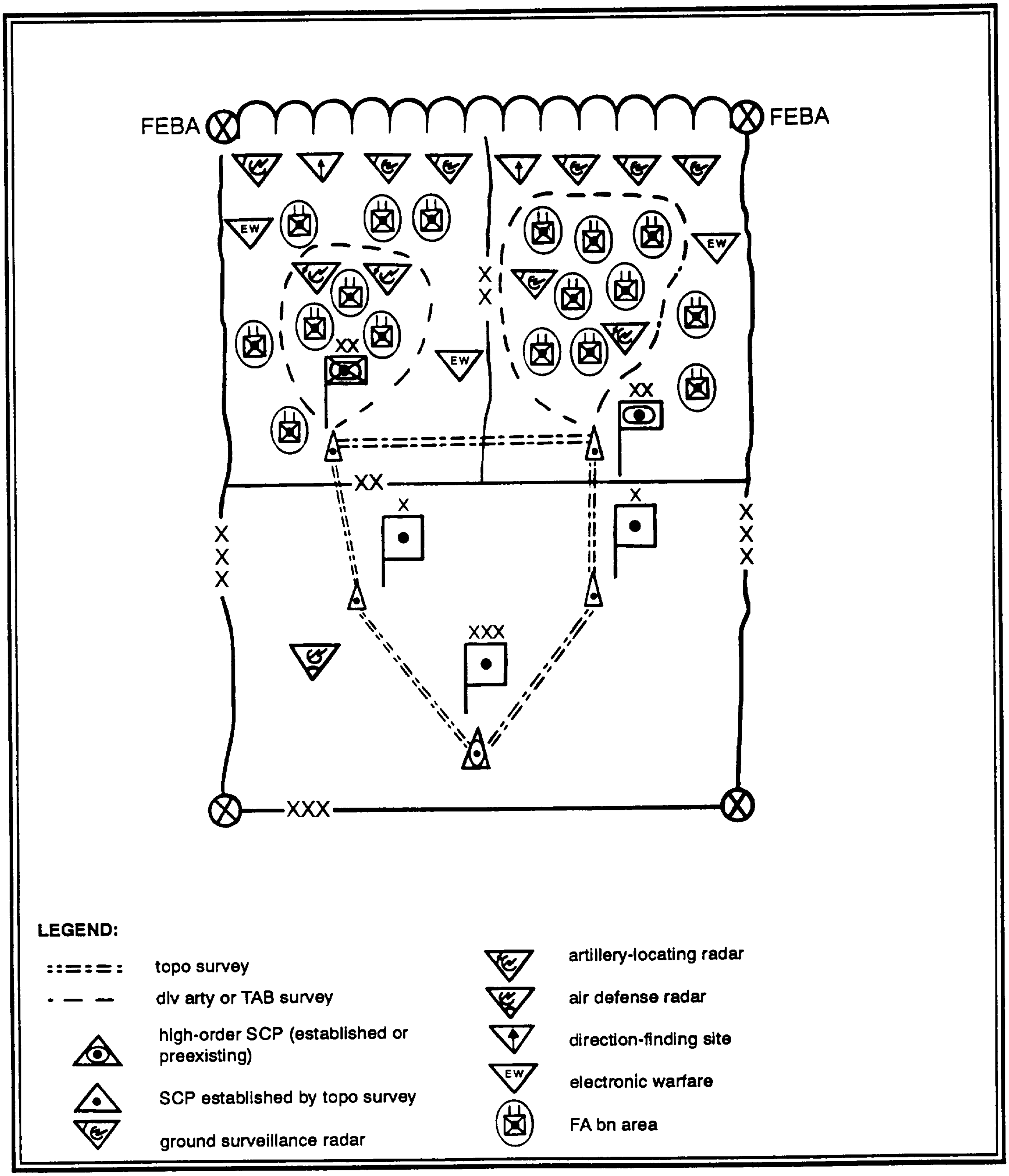
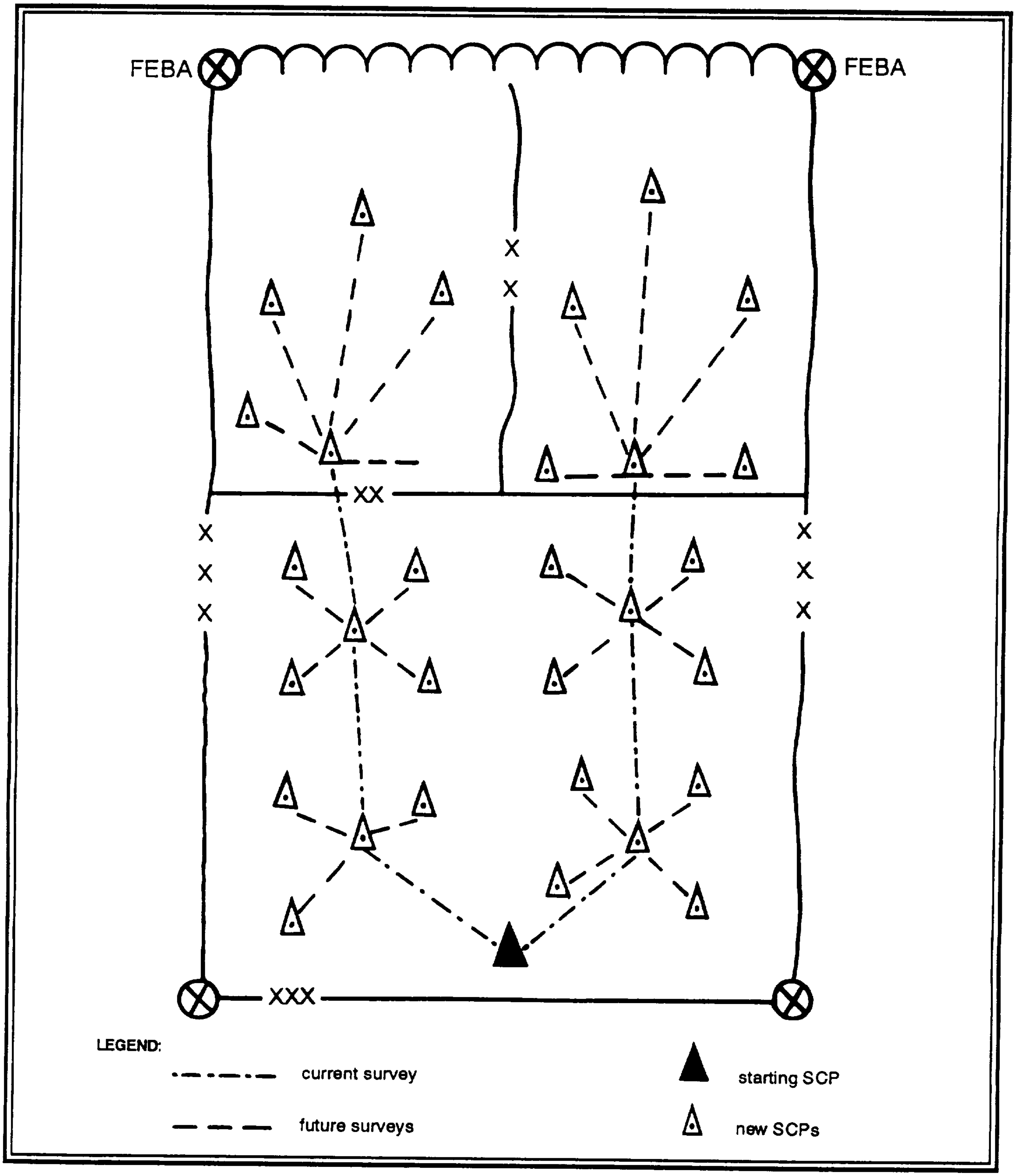


Figure 15-4. **Corps survey plan—future surveys overlay**



(5) Make necessary arrangements with headquarters and headquarters company (HHC), corps for administrative and logistical support of the topo survey platoon.

(6) Arrange and coordinate with the corps aviation company for aviation support if requested by the survey platoon leader of the engineer topo survey company.

(7) Maintain a close working relationship with the topo survey platoon leader or survey technician, the survey officers of corps artillery units, and the div arty survey officers. This coordination will ensure timely three-way flow of information concerning survey operations and data collection. It will also enhance timely completion of the survey mission.

c. Div Arty Survey Officer. The div arty survey officer is the survey platoon leader of div arty HHB. As such, he initiates tactical survey planning. He is responsible to the div arty commander for the execution of the survey plan to establish common survey control (the common grid) throughout the division area. He coordinates all artillery survey operations in the division to ensure effectiveness and to reduce duplication of effort. This includes the activities of the div arty SPCE, which is vital to the coordination of the survey effort. The div arty survey officer requests external survey support as required. He plans the employment of all organic fourth-order sections in the division. His plan is in accordance with the commander's guidance as interpreted by the S3. The locations of division tie-in points must be coordinated with adjacent div arty survey officers for establishment of a corps common grid. As the coordinator of div arty survey resources, the survey officer must advise the commander and staff on all matters pertaining to the following:

- Survey requirements.
- Techniques.
- Capabilities.
- Problem areas.

d. Div Arty Chief Surveyor. The div arty chief surveyor is the technical expert on surveying in the div arty. His primary duty is to advise the div arty survey officer. He must have wide experience in the employment of FA surveyors in support of all systems requiring survey data. He must—

- Be prepared to assume the duties of the survey officer.
- Brief the staff on survey and recon matters.
- Formulate, implement, and supervise the execution of the survey plan.
- Train surveyors in proper survey procedures.

He works closely with the TAB and battalion chief surveyors to ensure complete undemanding of the div arty survey concept. He also supervises the div arty SPCE to ensure effective collection, evaluation, and dissemination of survey data.

e. TAB Survey Officer. The TAB survey officer is primarily concerned with extending survey control to organic TA assets requiring survey control. He receives a survey order from div arty survey officer and plans the employment of his section to accomplish the mission. The TAB survey officer must be ready to assume the duties of the div arty survey officer when directed. In coordinating the div arty survey effort, the TAB survey section may be assigned responsibility for other installations (for example, battalion SCPs) and may also assume SPCE functions.

f. TAB Chief Surveyor. In planning the TAB survey, the chief surveyor must work closely with other section leaders of the TAB in determining the locations of the required positions. Since the TAB will be required to help establish the common grid, the TAB chief surveyor must have a thorough knowledge of the div arty plan and be prepared to help in its implementation.

g. Battalion RSO. The battalion RSO is responsible for placing organic and attached firing TA elements on a common grid. His first priority is to establish common directional control. Other priorities are listed in the commander's guidance or are derived by the S3. The RSO coordinates the placement of the battalion SCPs with the div arty survey officer. He also coordinates with the RSO of any R artillery unit to ensure that units are on a common grid. The use of a common grid allows accurate transfer of target data between units. When required, the RSO and his HQ element (chief surveyor and driver) combine with the survey section to speed up operations such as setting up reflectors and computing data. The battalion RSO performs reconnaissance for the battalion to include selection of routes and evaluation of positions within the position area. He works with the S2 and S3 to determine areas requiring reconnaissance and helps the battalion commander in his reconnaissance. The RSO, as the technical advisor for survey in the battalion must monitor an effective hasty survey training program. The ability of the firing units to provide themselves with some form of survey greatly improves their effectiveness and allows the commander to mass fires of his subordinate units sooner.

h. Battalion Chief Surveyor. Responsibilities of the battalion chief surveyor parallel those of the div arty and TAB chief surveyors. He must advise and perform technical planning and coordinate the work of the survey team. He must be prepared to perform the duties of the battalion RSO and advise the battalion staff on survey and recon matters.

15-3. ESSENTIALS OF A GOOD SURVEY PLAN

In formulating the survey plan, the survey planner must remember and strive to meet certain essentials. The survey plan must meet the essentials discussed below.

a. Provide Required Control. The plan must provide survey control within the required accuracy to all installations that require survey.

b. Provide for Checks. Whenever possible, the plan must provide for cheeks; for example, closed surveys and alternate bases. Each member of the survey team continuously makes checks as a matter of standard practice.

c. Be Simple. The plan must be understood by all survey personnel. Work that is unnecessary or that exceeds the required accuracy must be avoided.

d. Be Timely. The plan must be capable of execution in the time allotted.

e. Be Flexible. The plan must be capable of being changed if the situation warrants.

f. Be Adaptable. The plan must be adaptable to the following:

- Terrain.
- Situation.
- Personnel available.
- Weather.
- Equipment.

15-4. FACTORS AFFECTING SURVEY PLANNING

In formulating the plans by which the survey mission is to be accomplished, the survey planner must consider the factors of mission, enemy, terrain and weather, troops and time available (METT-T). The factors of METT-T cannot be considered independently because each is related to the other.

a. Mission. The tactical mission of the unit determines the time available, the area to be surveyed, the accuracy, and priority of the survey effort. It is the basis of the survey mission and determines the influence other factors have on the survey.

(1) Starting control. The location of existing survey control or the establishment of control by a higher echelon of survey affects the time required to extend control. Survey operations are concurrent at all echelons. When starting control is not available, the starting data must be assumed. The necessary survey operations are started immediately. More extensive survey planning is required in areas where survey control is limited.

(2) *Priority.* The priority of work assigned is either listed in the mission or commander's guidance or derived from the mission by the S3. The priority of work affects the order in which the plan is executed or the type of survey performed.

(3) Number of installations. The number and locations of installations to be surveyed must be considered primarily with respect to time and troops available. The survey operations required to locate a few widely scattered installations often take more time and/or personnel than would be required for many closely grouped installations. In the survey plan, the survey tasks should be allocated so that the various survey teams complete their portion most expeditiously.

b. Enemy. The enemy situation has a strong influence on survey operations, since the disposition of troops may interfere with or restrict the movement of survey personnel and their equipment. Restrictions on communications, such as radio silence and enemy jamming, can greatly reduce the effectiveness of survey teams. The ability of the enemy to interfere with survey operations by denying use of terrain or routes is of prime importance. When survey operations are restricted, the commander should give priority of survey to those units supporting the main attack. FA surveyors must be able to implement suppressive fire immediately if they receive enemy fire. Terrain and cover must be used as much as possible. Unit SOP should provide for actions to be taken by survey teams that came under fire.

c. Terrain and Weather. The terrain and weather through which survey control must be extended are a primary factor in determining the methods of survey to be used. The survey planner must be so familiar with the effects of terrain and weather on survey operations that he can promptly and properly advise his commander on the time and personnel requirements. Adverse weather greatly reduces the capability of survey teams. Fog, rain, snow, heat or dust can reduce visibility to the extent that observation through an optical instrument is impossible. When visibility is poor, the commander may choose to put his survey effort on accurately locating his radar so that it can locate his firing units. In this case, the SIAGL would be used to establish common direction. Extreme heat or cold can also reduce survey team efficiency and increase the time needed to complete the survey.

d. Troops. The survey personnel and equipment available to perform the survey mission greatly affect the plan. The status of training determines the methods available and time required to perform survey, The availability and operability of survey equipment dictate the methods used in the plan.

e. Time. The time available to complete the survey operation is the most critical factor in planning. Survey planners must use the survey techniques necessary to provide the best survey data within the prescribed time. A trade-off between accuracy and time may have to be made, depending on the tactical situation. The commander makes the decision to allow decreased accuracy before the survey starts or to accept decreased accuracy on completion of the survey.

15-5. METHODS OF SURVEY

In addition to being able to evaluate the factors that will affect the survey, the survey planner must know the methods of survey that might be used and the advantages and disadvantages of each. The method chosen to provide survey control depends on the factors of METT-T. PADS survey supplemented by conventional methods is the primary means of executing the survey order.

a. PADS Surveys. The main advantage of the PADS over conventional methods is its speed. Disadvantages of the PADS include the following:

- Reliance on the availability of survey control.
- Mode and route of travel.
- Restrictions on mission time and radial distance from the update point.

These are the main considerations in planning PADS operations. The time and distance factors used for planning PADS missions are shown in Table 15-2.

Table 15-2. **Time and distance factors—PADS mission**

Average speeds:	
-Cross-country	10 km per hour
-Unimproved road	25 km per hour
-Improved road	50 km per hour
Maximum speed (improved road)	70 km per hour
Initialization (including PMCS)	30 to 45 minutes
Mark coordinates of station	5 minutes
Two-position azimuth	10 minutes
Theodolite marks	10 minutes
Maximum mission time between updates	7 hours
Maximum radial distance from update point	55 km

EXAMPLES

Time computations for a div arty PADS mission requiring 80 km road travel to establish four battalion SCPs are as follows:

Initialization (45 minutes)	0.8 hour
Average travel time (80 km at 25 km per hour)	3.2 hours
Four bn SCPs x 10 minutes (40 minutes)	0.7 hour
Estimated mission time	4.7 hours

Time computations for a cannon battalion PADS mission requiring 40 km road travel to establish eight battery positions are as follows:

Initialization (45 minutes)	0.8 hour
Average travel time (40 km at 25 km per hour)	1.6 hours
Eight battery positions x 10 minutes (80 minutes)	1.4 hours
Estimated mission time	3.8 hours

b. Conventional Survey Methods. Conventional methods of survey may be used-exclusively to extend or establish survey control if the PADS is not available. When the PADS is available, conventional methods are used to supplement PADS operations. Conventional teams provide update points for the PADS teams as required. This reduces the need to backtrack to close the PADS survey. Required installations along the route taken by conventional teams in establishing update points are surveyed to save time. Simultaneous observation is used to quickly establish direction before PADS teams arrive at installations. The conventional survey team gives the survey plainer flexibility. This allows the plan to be tailored to fit the factors of METT-T and allows sustained PADS operation by rotation of survey personnel. Conventional survey methods are as follows:

- Traverse.
- Triangulation.
- Intersection.
- Resection.

(1) Traverse. Traverse is the most suitable conventional method for most survey operations. It is a rapid and flexible means of extending control. Traverse does not require es much reconnaissance as triangulation and is extremely easy to control in the field. Traverse is ideally suited for survey in gently rolling or flat terrain or for extending control along roads and trails. For planning purposes, a well-trained traverse team can extend control over open and gently rolling or flat terrain at a rate of about 2 km per hour with the SEDME-MR or 1 km per hour with a 30-meter steel tape.

The use of offset legs to locate radar positions and other points can reduce the time required for the traverse. Offset traverse legs are not used to carry control, and an error made during the offset leg fieldwork will not affect traverse closure. Therefore, the fieldwork must be carefully checked.

(2) *Triangulation.* Triangulation is a means of extending control over long distances. It is ideally suited for survey in difficult terrain and for crossing obstacles. The primary disadvantage of triangulation is the amount of time required for reconnaissance. For planning purposes, triangulation requires about 30 minutes per station plus time for reconnaissance and travel between stations. Triangulation schemes are not as flexible as traverse schemes, since all stations in a triangle must be intervisible. Reconnaissance for triangulation generally requires as much time as the fieldwork, especially in extensive triangulation schemes. If the distance-measuring equipment is operational, traverse is preferred because it requires less time and fewer personnel.

(3) Intersection. Intersection is a method of triangulation in which only two angles in a triangle are measured. It is used to locate critical points, to establish update points for the PADS, and to survey firing and target-locating elements. When control is extended from a point established by intersection, the survey must be closed on another known point. The only exception to this is when intersection is used to locate 01 and 02 of the target area base.

(4) Resection. Resection is a method of obtaining control from distant points of known control that can be seen but not occupied. Resection is used to—

- Locate firing and target-locating elements.
- Establish update points for the PADS.
- Locate 01 and 02 of the target area base.
- Close a survey.
- Check a location established by some other method of survey.

If a point located by resection is used to extend control, the survey must be closed on another known point. The only exception to this is when resection is used to locate 01 and 02 of the target area base.

15-6. STEPS IN SURVEY PLANNING

The steps in planning a survey are generally the same as the normal small-unit troop-leading steps. They are the procedures by which a commander issues instructions to his subordinates so that he can accomplish his mission. The lower the echelon, the more simple, direct, and rapid the process. Once the battle starts, orders and responses must be fast, effective, and simple. This requires teamwork. Troop-leading steps should be an instructive and automatic way of thinking for section leaders and commanders. Without detailed instructions, commanders must turn a mission order into actions to support the plan of the next higher commander. Elaborate troop-leading procedures are useless if they slow the response of the force. The eight troop-leading steps are as follows:

- Receive the mission.
- Issue a warning order.
- Make a tentative plan that will accomplish the mission.
- Start the necessary movement.
- Reconnoiter.
- Complete the plan.
- Issue the order.
- Supervise.

Troop-leading steps are not rigid. They can be changed to fit the mission and the situation. Often, some steps are taken at the same time while others are considered continuously throughout the operation. When there is a lack of time, certain steps may be left out. The troop-leading steps as they apply to survey operations are discussed below.

a. Receive the Mission. Leaders receive a mission in either an oral or written OPORD or fragmentary order (FRAGO). Upon receiving the order, the leader analyzes the mission and plans the use of available time. The FSCOORD or S3 gives the survey officer a mission. It may consist of general areas to be surveyed or specific locations for battalion SCPs, platoon area SCPs, molar positions, and such.

b. Issue a Warning Order. The leader issues a warning order that gives his subordinates the mission and the time it starts. He issues it early enough for the section to plan and prepare. Normally, warning orders are issued through the chain of command. In that way, all personnel are kept informed of what they must do and why they must do it. The warning order should include the location of a nearby SCP or prominent landmark. Preoperation checks of vehicles and equipment are completed.

c. Make a Tentative Plan. The survey always connects required control with known control. The first step in formulating a survey plan is to gather information on the area, enemy situation, and any usable known control. A map reconnaissance is made to tentatively determine the methods of survey.

(1) Gather information. From the commander's briefing, the survey officer gathers vital information that influences the planning of his survey. This information should pertain to—

- The situation to include the following:
  - Mission of the units.
  - Status of registration.
  - Time available.
  - Zones of fire.
  - Friendly positions.
- Routes, communications, minefield, contaminated areas, and restrictions on modes of travel.
- Support to R units, to allies, or to priority units.

(2) Make map reconnaissance. After attending the commander's briefing and issuing a warning order to alert his personnel, the survey officer, using any suitable map or map substitute, makes a thorough map reconnaissance. In doing this, he follows a specific procedure to ensure that full consideration is given to all factors. This procedure, in order, is discussed below.

(a) Map-spot installations. Known control and those installations requiring survey control are plotted on the map. Restricted areas and other information relative to the area of operations are also plotted.

(b) Select a tentative plan. All the factors that affect survey (METT-T) are fully considered, methods are chosen, and a tentative plan is made. Particular attention is placed on the accessibility of installations.

(c) Consider time. An estimate of the time required to execute the tentative plan is made. If the survey mission cannot be performed within the allotted time, the plan is modified or an appropriate recommendation is made to the commander. The planner may recommend the following

- Extra personnel be made available.
- Div arty support be requested.
- More time be allowed for survey.
- Location of certain installations be delayed.
- Accuracy for certain installations be relaxed.

(d) Determine critical areas. Areas that require detailed ground reconnaissance are identified.

d. Start Necessary Movement. The survey planner must now make good use of the time available so that the section will be in the area to be surveyed at the required time. If the section must move a long distance, it should start the move immediately on the basis of first rough plans.

e. Reconnoiter. After the map reconnaissance, the survey planner must make a ground reconnaissance as detailed as time permits. The tentative plan selected during the map study is changed as required by the terrain. Particular emphasis should be placed on critical areas. If necessary, indications are made to other survey planners or team chiefs at points where tentative plans may need revision or close coordination. A scale sketch of the survey is an easy way to summarize information determined from the ground reconnaissance. Since a PADS team can provide survey data as it reconnoiters, greater emphasis must be placed on efficiency of movement through the area.

f. Complete the Plan. Reconnaissance may not change the plan, but it certainly adds detail. The plan must be modified to fit all the information gained from the ground reconnaissance.

g. Issue the Order. A verbal survey order is issued, if possible, from a vantage point overlooking the area to be surveyed. The survey order follows the standard five-paragraph OPORD format. Continuing operations may require the use of a FRAGO.

h. Supervise. A leader must continually supervise the preparation for and execution of the mission. Constant supervision is as important as issuing the order. Along with supervising, the survey HQ element must help the conventional team as required. This help will supplement PADS operations and speed up the survey mission.

15-7. THE SURVEY ORDER

The survey order contains detailed instructions to each survey team not covered by local SOP. It gives general information needed for the efficient accomplishment of the survey mission. The survey order is written or issued orally. It generally follows the same sequence as the OPORD. Often, because of the tactical situation and wide dispersal of units, parts of this order may be issued by radio or wire or both.

a. The format for a five-paragraph survey order is shown in the example on page 15-12.

b. FRAGOs include the information in paragraphs 2 and 3 of the survey order and anything else that has changed since the last order.

EXAMPLE

* * * * * * *

1. SITUATION

Items in this paragraph are addressed only if they have a bearing on the execution of the survey mission.

a. Enemy Forces. This subparagraph contains information from the S2 on enemy forces that may affect the survey mission.

b. Friendly Forces. This subparagraph contains information on higher, adjacent, and supporting units that may affect the survey mission.

c. Attachments and Detachments. This subparagraph lists sections attached or detached for a particular mission, such as an infantry squad for security.

2. MISSION

This paragraph is a clear, concise statement of the task to be done by the section. It includes those tasks specified by the S3. Also, it may include implied tasks determined by the survey officer from his mission analysis. Normally, it describes who, what, when, where, and as appropriate, why. This paragraph has no subparagraphs.

3. EXECUTION

a. Concept of Operation. This subparagraph briefly describes the survey methods to be used. It answers the question, Generally, how will the survey be done?

(The intermediate subparagraphs of paragraph 3 [b, c, d, e, and so forth] are specific missions of subordinate survey sections or teams. These missions tell the subordinate leader what he must do but not how he must do it [unless rigid centralized control must be maintained]. The mission of each subordinate team is addressed in its own paragraph, which contains instructions for that team only.)

f. Coordinating Instructions. The last subparagraph contains instructions common to two or more units. These instructions are designed to keep the subordinate units working together. Instructions such as primary methods of determining azimuths and distances are appropriate as coordinating instructions.

4. SERVICE SUPPORT

This paragraph lists those logistical considerations that may concern the surveyors. It lists food, ammunition, POL, location of corpsmen and aid stations, handling of enemy prisoners of war, and nonorganic transportation. These considerations are addressed only as they affect the particular survey. Local SOP items need not be addressed.

5. COMMAND AND SIGNAL

a. Command. This subparagraph gives the locations of the CP, survey officer, chief surveyor, and team chiefs.

EXAMPLE (CONTINUED)

b. Signal. This subparagraph lists nonstandard hand-and-arm signals, pyrotechnics, radio frequencies, call signs, and electronic counter-countermeasures (ECCM).

* * * * * * *

15-8. PRINCIPLES OF A SURVEY SOP

a. An SOP standardizes procedures for those phases of operation the commander wants to make routine. These procedures are to be followed in the absence of specific instructions. The SOP of a battalion or higher-level HQ should contain a section on survey. The SOP for each level must conform to the SOP of the next higher level. Therefore, the survey portion of the SOP at each FA level should include only those survey procedures the commander wants to make standard throughout his command. Survey items the commander wishes to make standard only for the survey section of his HQ should be in the SOP for that particular section. A survey SOP does the following:

- Simplifies the transmission of the survey plan.
- Helps perfect the training of survey personnel.
- Promotes teamwork through understanding.
- Expedites survey operations.

(1) Simplify the transmission of survey plans. Instructions included in an SOP need not be restated in the survey plan. Many details on operations, measurements, or methods of survey may be outlined in the SOP. This eliminates the need for a lengthy and bulky survey plan or order. However, inclusion of instruction in the SOP does not prevent the survey officer from restating these instructions in the survey plan for emphasis.

(2) Simplify and perfect the training of survey personnel. Establishment of standard procedures for survey operations ensures uniform training and minimizes the need for special instructions. Through the continued use of standard procedures, survey personnel become more proficient in their operations.

(3) Promote teamwork and understanding. Standing operating procedures ensure uniform performance of survey operations and minimize the time and effort required for coordination. This is particularly true in those units that use more than one survey team.

(4) Expedite survey operations. When personnel become familiar with and use standard signals, techniques, and procedures, they will do their tasks in minimum time. Furthermore, the use of standard procedures reduces confusion and eliminates unnecessary survey operations.

b. To be effective, a survey SOP must be brief and must conform to established doctrine. If the SOP is too long and detailed, it loses its value as an instrument of ready reference. It must be flexible, since it cannot cover every possible survey situation or method. The SOP should give survey personnel enough latitude to adapt survey requirements to different situations rather than specify various types of problems that may or may not exist in the field. The SOP must conform to the doctrine and policy in the SOP of the higher HQ so that trained personnel reassigned from one unit to another will have no difficulty or be no less proficient. As a minimum, the SOP for survey operations should contain the information and instructions discussed below.

(1) Principal duties of key personnel. This survey SOP should define the principal duties of key personnel. The key personnel include the following:

- Survey officer of the echelon at which the SOP is prepared.
- Chief surveyor.
- Survey team chiefs.
- Team members.
- Survey officers of subordinate commands, assigned or attached.

(2) Acceptable methods of survey. The survey SOP should include the methods of survey acceptable for various survey tasks. The methods will depend on the type of instruments available, time available, and status of training of survey personnel.

(3) Specifications and techniques. The survey SOP should contain specifications and techniques for fieldwork and computations. These include such items as the following:

- Minimum closures for angles and triangles.
- Manner of measuring angles.
- Allowable errors.
- Station marking techniques.
- Recording techniques.
- Required degrees of accuracy.

(4) Supply and maintenance information. The survey SOP should include pertinent information on supply procedures, stock levels, and maintenance responsibilities for all survey personnel.

(5) Communications. The survey SOP should include information pertaining to the use of radios, telephones, visual signals, and ECCM.

15-9. SURVEY PLANNER'S GUIDELINES

The guidance below is provided to help the survey planner prepare a survey plan. Use the guidelines to ensure that none of the important considerations are omitted.

a. Preparing the Survey Plan.

(1) Enemy forces.

- Have all the intelligence data pertaining to the tactical situation been considered?
- HOW will NBC hazards affect survey operations?

(2) Friendly forces. Have all the friendly forces in the area of operation been identified, and can they provide logistical support if needed?

(3) Attachments and detachments. Are reinforcing units needing survey control in the area of operations?

(4) Number of installations.

- Have all elements requiring survey control been identified?
- Which installations can provide their own survey control?
- Are there survey requirements from the higher echelon?

(5) *Priority of installations.*

- What priorities must be established to support the commander's guidance and the maneuver forces?
- What method of survey should be used to meet the priority requirements?

(6) *Accuracy requirements.*

- Can the accuracy requirements be met with the equipment available?
- Where can accuracy requirements be relaxed until accurate data are available?
- Does the plan Provide for common control throughout?

(7) Time requirements.

- Can time requirements be met on the basis of time available, accuracies required, and survey assets available?
- Is additional survey support required, and where is it available?

Ž Dots the plan incorporate time lines that consider response time for units or systems to meet the operational times in support of the attack?

(8) *Coordination requirements.*

Ž *Where is the* SPCE located?

Ž What survey control is available?

Ž Are trig lists available?

Ž What maps are required?

Ž At what locations is control from higher or lower echelon required?

(9) *Assets (equipment and/or personnel).*

Ž Is all survey equipment operational?

Ž Are all survey personnel available?

Ž Can survey equipment be effectively used in existing terrain and weather?

Ž Does the survey plan provide for continuous operations?

Ž Does the response time require the survey HQ element to help the conventional team with survey fieldwork?

(10) Alternatives to the survey plan. Is the survey plan flexible enough to support maneuver forces under changing situations?

(11) Command and control.

Ž Is the command and control portion of the survey plan adequate?

Ž Does the survey plan allow for alternate communications during intense jamming?

(12) Supply and logistics.

Ž Does the survey section have enough rations for the first 72 hours of operation?

Ž Does the survey section have enough expendable supplies (such as hubs, stakes, and batteries) for the number of positions required?

Ž Do survey operations have to be interrupted for refueling vehicles, or can the survey vehicles be resupplied on the move?

Ž Where are DS maintenance units located for repair or exchange of equipment?

Ž Does DS maintenance have PADS units or line replaceable parts available?

Ž Are helicopters available to help the survey effort if needed?

Ž Does the survey section have its basic load of ammunition?

(13) Allied requirements.

Ž Does the plan include allied forces?

Ž Is survey support required for any allied units operating in the-of operations?

Ž What are the survey requirements for the allied units or systems?

b. Executing the Survey Plan.

(1) Disseminate trig lists, maps, and other pertinent survey information.

(2) Ensure that survey control is provided—

Ž To prescribed accuracies.

Ž On time.

Ž When needed.

(3) Ensure priorities are met.

(4) Maintain the goal of common control with the higher echelon.

(5) Maintain continuous communications with all echelons.

(6) Be prepared to modify the survey plan and execute changes rapidly.

(7) Inform the commander of the following:

Ž Delay in providing survey control and actions to be taken to correct this deficiency.

Ž Degraded accuracy caused by lack of time.

Ž Projected time when survey data will be upgraded.

Ž Any deviation from previous guidance.

APPENDIX A
STANDARDIZED PROCEDURES

The following standardized procedures relevant to survey operations are denoted in text by a large asterisk (*).

Subject	Location
BUCS	Chapter 12
Field notes	Chapter 4
Station marking	Paragraph 5-4b
SEDME-MR	Chapter 2, Section II
Duties of survey personnel	Paragraph 1-8
Orders of survey accuracy	Appendix B
Survey forms	Appendix D

★ APPENDIX B

SURVEY STANDARDS AND SPECIFICATIONS

★ This appendix implements STANAG 2934 and QSTAG 269.

The US government makes nationwide surveys, maps, and charts of various kinds that must be referenced to national datums. These are necessary for the conduct of public business, for national defense, and for development of the country.

B-1. GEODETIC CONTROL SURVEYS

a. Geodetic surveys, executed with high precision, are used to control mapping and charting operations and engineering projects. The terms *geodetic survey* and *control survey* are almost interchangeable.

b. Control surveys are of two types-horizontal and vertical. Horizontal control surveys determine latitudes and longitudes referenced to a national datum and provide the basis for rectangular coordinate systems. Horizontal geodetic surveys are adjusted to the mathematical figure of the earth applicable to the national datum. Vertical control surveys determine elevations to a national datum that has been referenced to tidal measurements. Vertical geodetic surveys are adjusted with respect to the geoid. These surveys provide permanently marked and properly described stations.

c. Horizontal control is established by triangulation, trilateration, and traverse procedures. Vertical control is established by leveling of a high order of accuracy.

d. The classifications and standards of geodetic control surveys in the United States are issued by the Federal Geodetic Control Committee (FGCC) under the authority of the Office of Management and Budget (OMB). The specifications are published in a document titled *Classification Standards of Accuracy and General Specifications of Geodetic Control Surveys* and in a supporting document titled *Specifications to Support Classifications, Standards of Accuracy, and General Specifications of Geodetic Control Surveys.* Both documents are published by and can be obtained from the National Geodetic Survey Division, National Oceanic and Atmospheric Administration (NOAA), Rockville, Maryland 20852.

B-2. FIELD ARTILLERY CONTROL SURVEYS

a. Field artillery control surveys are performed to fourth- and fifth-order specifications as described below.

(1) Fourth-order survey is FA survey performed to an accuracy of 1 unit of error in 3,000 similar units of survey. It usually is written 1:3,000.

(2) Fourth-order astro azimuth is an FA azimuth established by astronomical methods, the probable error of the result of which does not exceed 0.060 mil. The considered accuracy for FA survey is 0.150 mil.

(3) Fourth-order azimuth is an azimuth of a line used in the extension of fourth-order survey that, from its point of origin at a fourth-order astro azimuth line or higher-order direction, has depreciated in accuracy by a PE value of 0,030 mil per main scheme angle; or it is the azimuth of a line determined by computation between a fourth-order SCP and an SCP of equal or higher order. In the latter case, considered accuracy for FA survey is 0,300 mil.

(4) Fifth-order survey is FA survey performed to an accuracy of a maximum of 1 unit of error in 1,000 similar units of survey. It usually is written 1:1,000.

(5) Fifth-order astro azimuth is an FA azimuth established by astronomical methods, the probable error of the result of which does not exceed 0.12 mil. The considered accuracy for FA survey is 0.300 mil.

(6) Fifth-order azimuth is an azimuth of a line used in the extension of fifth-order survey which, from its point of origin, has depreciated in accuracy by a PE value of 0,09 mil per main scheme angle. A fifth-order azimuth cannot be obtained by computation between a fifth-order SCP and an SCP of equal or higher order.

b. The specifications presented in Tables B-1, B-2, and B-3 are the permissible tolerances allowed to ensure that the overall standards for fourth- and fifth-order surveys are achieved. The specifications apply for determining a 1:500 azimuth. If direction is not extended from the line established by observation, the rejection limit can be relaxed to 1.0 mil with a considered accuracy of 1.0 mil, In the tables, D/R means direct/reverse. In Tables B-1 and B-2, N represents the number of main scheme angles used to carry azimuth. In Table B-1, K represents the total main scheme distance surveyed to the nearest 0.1 kilometer. In Table B-2, K is the sum of the sides used to compute coordinates. When a computer or calculator is used, angles and distances may be used in computations to the nearest 0.001.

Table B-1. **Traverse survey specification.**

REQUIREMENT	FOURTH ORDER	FIFTH ORDER
Adjusted	Yes	No
Position closure:		
• If length of traverse is less than 9,000 meters	1:3,000	1:1,000
• If length of traverse is 9,000 meters or more	$\sqrt{K}$	1:1,000
Height:		
• If length of traverse is less than 4,000 meters	$\sqrt{K}$	±2 meters
• If length of traverse is 4,000 meters or more	$\sqrt{K}$	$1.2 \times \sqrt{K}$
Azimuth (when compared with astronomic, gyroscopic, or preestablished azimuths):		
• Six or fewer stations	0.04 X N	0.1 X N
• Seven or more stations	$0.1 \times \sqrt{N}$	0.1 X N
Azimuth carried to	0.001 mil	0.1 mil
Number of stations between azimuth checks	25	20
Horizontal angles:		
• Measured	One position	One position
• Recorded to	0.001 mil	0.1
Vertical angles:		
• Measured	1 D/R	1 D/R
• Recorded to	0.001 mil	0.1 mil
• Used in computations to	0.001 mil	0.1 mil
Distance:		
• Tape	Double taped to a comparative accuracy of 1:5,000	Single taped, checked by pacing
• SEDME-MR	Mean of three measurements after application of rejection limit of 0.01 from the mean	Mean of three measurements after application of rejection limit of 0.01 from the mean
Easting and northing coordinates computed to	0.01 meter	0.1 meter
Height computed to	0.1 meter	0.1 meter

Table B-2. **Triangulation survey specifications**

REQUIREMENT	FOURTH ORDER	FIFTH ORDER
Position closure:		
• If sum of the sides used to compute coordinates is less than 9,000 meters	1:3,000	1:1,000
• If sum of the sides used to compute coordinates is 9,000 meters or more	$\sqrt{K}$	1:1,000
Baseline check:		
• Comparative accuracy of check base	1:3,000	1:1,000
• Strength of figure between bases, maximum	200	200
• Maximum number of triangles between bases	5	5
Azimuth (when compared with astronomic, gyroscopic, or preestablished azimuths):		
• Six or fewer stations	0.04 X N	0.1 X N
• Seven or more stations	$0.1 \times \sqrt{N}$	0.1 X N
Azimuth carried to	0.001 mil	0.1 mil
Azimuth check (normally with baseline check):		
• Strength of figure between checks, maximum	200	200
• Maximum number of triangles between checks	5	5
Base determination:		
• Known coordinates	See paragraph 6-5c(1)	See paragraph 6-5c(1)
• Tape	Double-tape to a comparative accuracy of 1:7,000	Double-tape to a comparative accuracy of 1:3,000
• SEDME	Mean of three measurements after application of rejection limit of 0.010 of the mean	Mean of three measurements after application of rejection limit of 0.010 of the mean
Horizontal angles:		
• Measured	Two positions (rejection limit between two positions ±0.050 mil)	One position
• Recorded to	0.001	0.1
Vertical angles:		
• Measured	1 D/R	1 D/R
• Recorded to	0.001 mil	0.1 mil
Minimum distance angle	400 mils	400 mils
Triangle closure:		
• Per single triangle	0.060 mil	0.3 mil
• Average per scheme	0.050 mil (closure per single triangle within scheme cannot exceed 0.060 mil)	0.3 mil

Table B-3. **Astronomic azimuth survey specifications**

REQUIREMENT	FOURTH ORDER	FIFTH ORDER
Minimum number of sets observed	3	3
Rejection limit	0.150 mil	0.3 mil
Minimum number of sets remaining after rejection	2	2
Horizontal angles:		
• Measured	One position	One position
• Recorded to	0.001 mil	0.1 mil
Vertical angles:		
• Measured	1 D/R	1 D/R
• Recorded to	0.001 mil	0.1 mil
Considered accuracy	0.150 mil	0.3 mil

APPENDIX C

TRAINING THE FIELD ARTILLERY SURVEYOR, MOS 82C

The purpose of this appendix is to help the survey officer or chief surveyor conduct a more effective training program. It suggests a program for training the survey platoon and/or section. There is no single "best" method of training. What is important is that the training approach used should be determined in advance and planned in detail.

C-1 . TRAINING PHILOSOPHY

The key to effective performance on the battlefield is a training program based on planning, conduct (execution), and evaluation.

a. Planning. Planning is the keystone to interesting, worthwhile, and effective training. The planning must ensure that each member of the survey section understands his role in accomplishing the survey mission of his unit, whether the unit is a battalion, TAB, or div arty.

b. Conduct. Conduct is the action phase of the training program. In this phase, the individual surveyor, survey party, or survey section participates in classroom instruction, operation of survey instruments, field exercises, and practice Army training and evaluation programs (ARTEPs).

c. Evaluation. Evaluation is controlled feedback. The survey officer or chief surveyor must examine the entire learning process to ensure that the members of the survey section can successfully accomplish the survey methods, techniques, and procedures that they have been taught. The survey officer or chief surveyor conducting the training must receive controlled feedback after the conduct of an exercise so that success can be reinforced and mistakes can be identified and corrected.

C-2. TRAINING THE TRAINER

a. The survey officer is responsible for developing a training program, for conducting training, and for keeping abreast of training doctrine. The survey officer uses FMs 25-100 and 25-101 as a guide for planning, conducting, and evaluating a training program. He uses Soldier Training Publication (STP) 6-82C 14-SM-TG, and applicable ARTEPs to determine individual and team qualifications. The trainer's guide (STP 6-82C14-SM-TG) lists the critical tasks of MOS 82C, identifies the tasks to be performed at each skill level, and indicates for each task where the soldier is to be trained. Used together, these documents become the foundation for the training program.

★ **b.** Supervised on-the-job training (SOJT) may also be used to train surveyors in the unit. Correspondence subcourses are excellent for individual and common educational needs, combined study, and joint discussions and critiques. Available subcourses and instructions for requesting correspondence course material are included in DA Pam 351-20.

c. The trainer should ensure that every member of the survey section has a copy of the soldier's manual applicable to his grade. This document outlines performance standards and gives the soldier a "road map" for progression.

C-3. TRAINING THE SURVEYOR

The trainer must ensure that the individual surveyor is trained to perform his required tasks. If the individual surveyor has not attended a service school for his initial survey training, he must be trained in the unit through various methods, such as one-on-one instruction, Army correspondence course lessons, unit school, SOJT, or a combination of these methods. A unit evaluation of individual knowledge, primarily through the use of the self-development test (SDT), will determine if the individual surveyor is knowledgeable in his skill level and can perform effectively as a member of a survey party.

C-4. TRAINING THE SURVEY PARTY OR SECTION

When the individual surveyors have attained the desired level of proficiency, party or section training can be started with the goal of molding an efficient working team capable of performing its mission. First, each survey party should complete miniature field exercises involving position area survey, target area survey, and connection survey until the party performs surveys efficiently and with minimum supervision. The survey parties, operating together as a survey section, should complete miniature field exercises until the section can operate efficiently and with minimum supervision. One type of miniature field exercise is depicted in Figure C-1. The miniature problem shows each member of the survey party how his job relates to the party function as a whole. It facilitates supervision; provides savings in motor vehicle maintenance, fuel, and time; and requires no special training area. Full-scale survey operations should be conducted with an ARTEP as often as necessary to gain and maintain the required collective proficiency. Figure C-2 depicts a miniature field exercise for use by the TAB survey section. Figure C-3 is an example of a miniature exercise for the div arty survey section.

C-5. SURVEY PARTY OR SECTION MINIATURE FIELD EXERCISE

a. Before the start of a field exercise, the survey officer or chief surveyor should draw up the survey plan based on assumed or real guidance from the commander. If at all possible, the survey of target area bases, targets, attached radars, and CEWI sites that normally would be located in the unit zone of operation should be completed before the exercise ends.

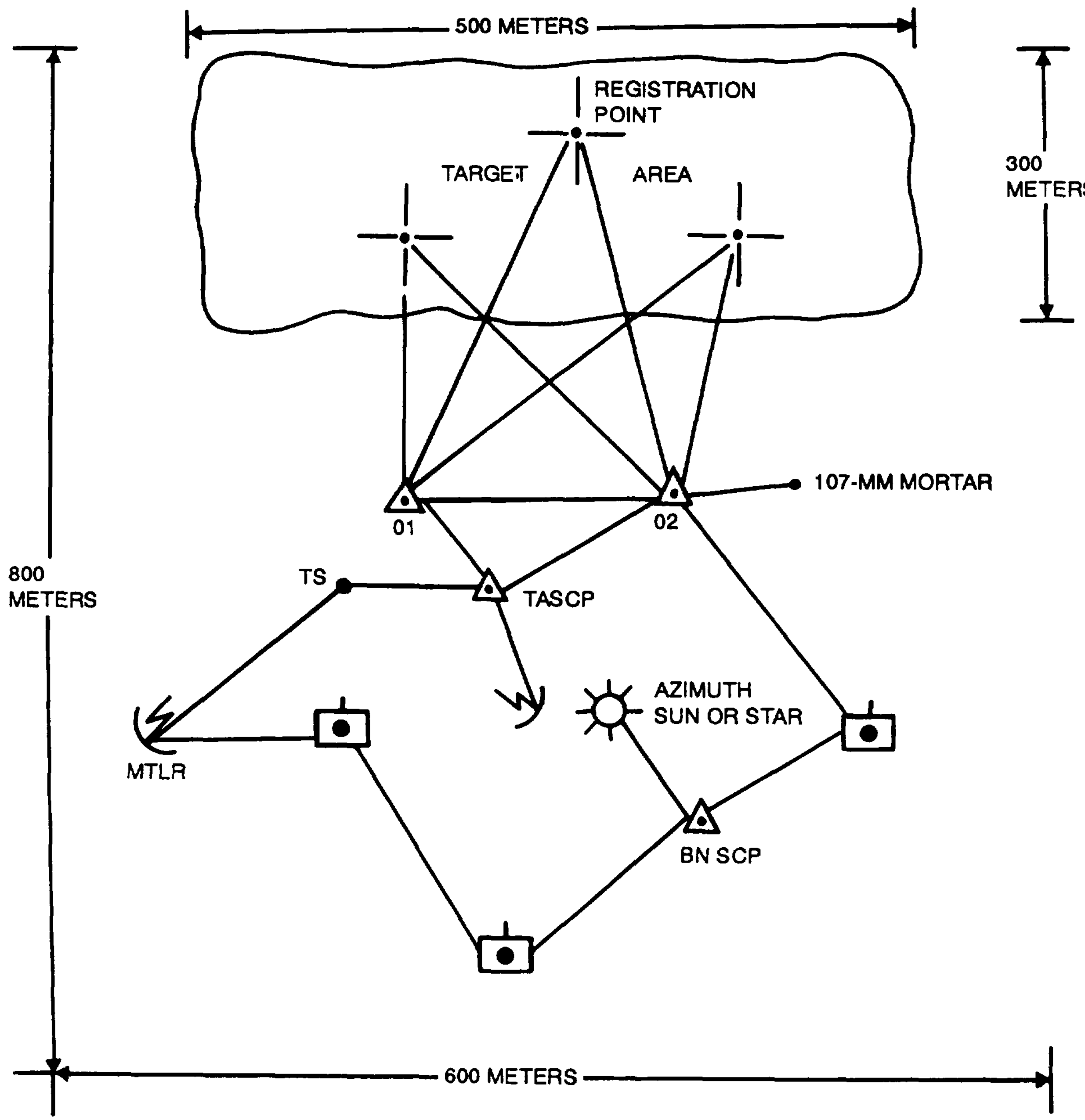
b. Even though short distances are involved in a miniature exercise, the SEDME-MR will be exercised adequately.

c. For the purpose of the exercise, true or assumed control may be used. When assumed control is used, the party or section should practice conversion to common control.

d. Priority should be given to establishing the essential survey control in the fastest manner possible on the basis of guidance from the commander. After this survey is completed, the party or section could receive additional training in miniature triangulation schemes.

e. The survey of the battery OLs, attached radars, CEWI sites, and target area bases must be to the accuracy required for cannon battalion survey.

Figure C-1. **Typical FA battalion miniature survey exercise**



LEGEND:
MTLR = moving-target-locating radar

Figure C-2. **Typical TAB miniature survey exercise**

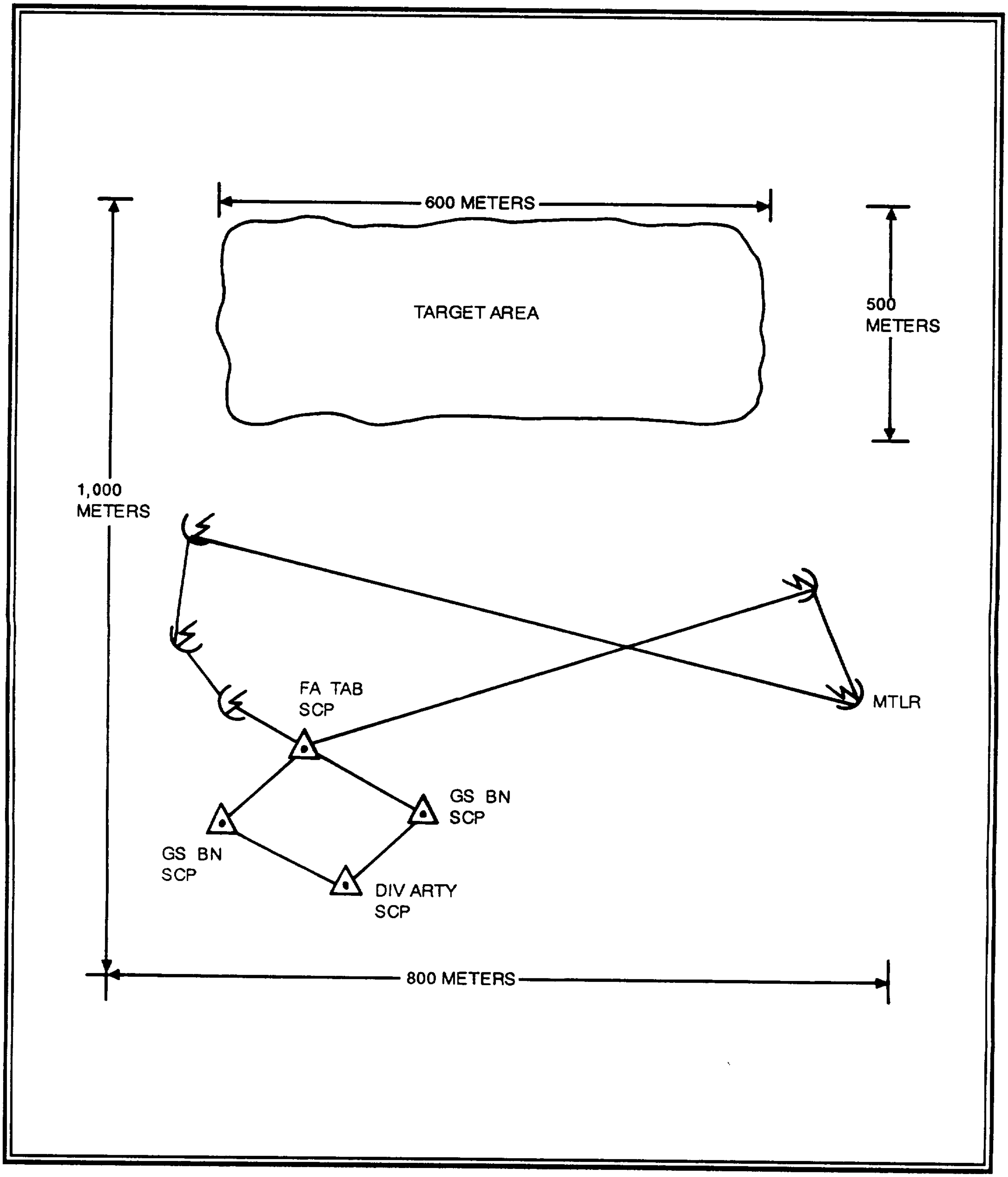
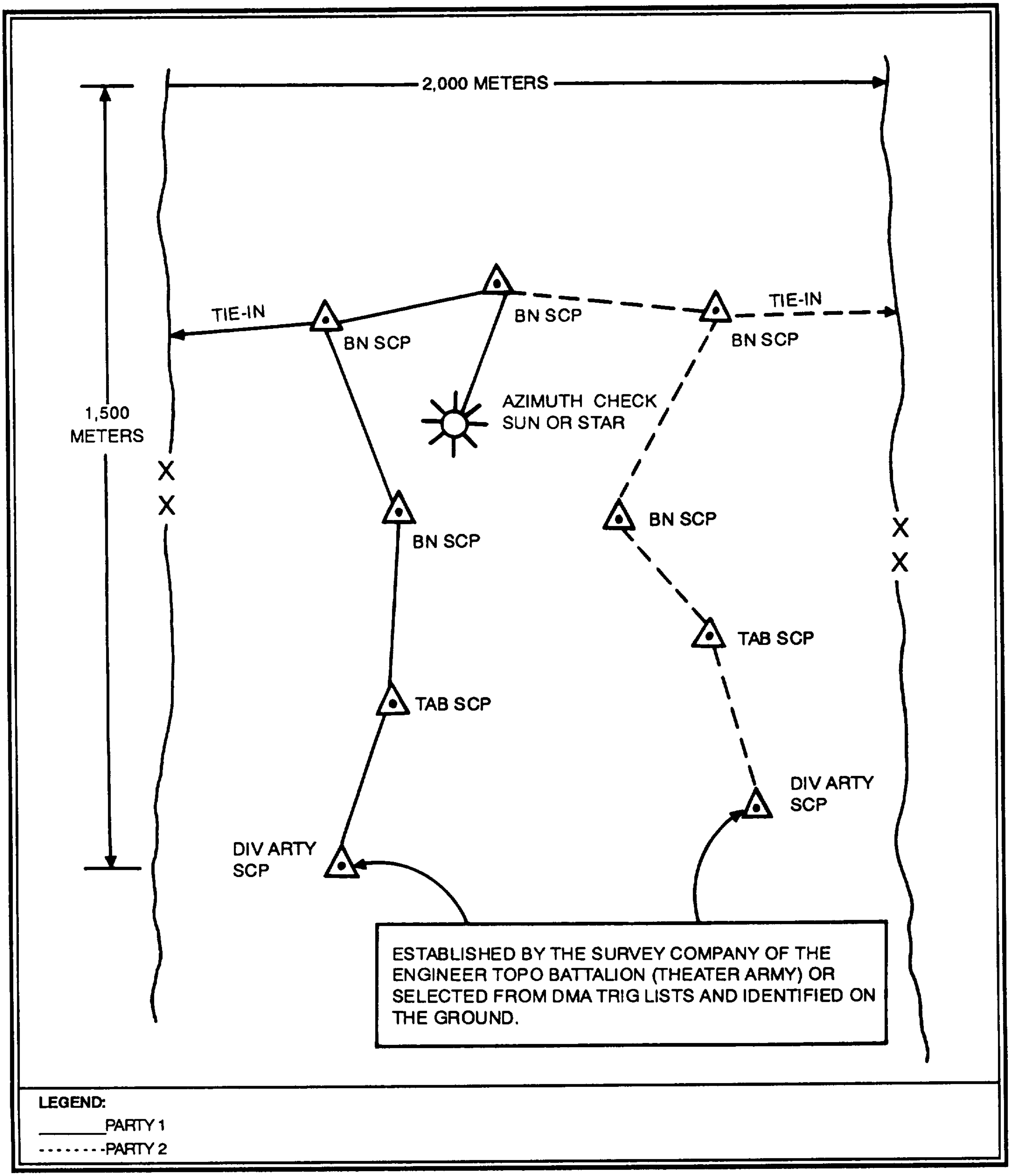


Figure C-3. **Typical div arty miniature survey exercise**



C-6. DESIRABLE TRAINING FACILITIES

The following basic training facilities are desirable for the conduct of comprehensive training:

- TOE of the unit survey section or party.
- Beseler Cue/See projectors.
- Movie projector (16-mm) with screen.
- Classroom.
- Outside training area with survey control.

*APPENDIX D
REPRODUCIBLE FORMS

This appendix provides a list of the reproducible forms shown at the back of this book. These forms are not available through publications supply channels. You may reproduce them locally.

DA Form 5075-R	*Artillery Survey Control Point*
DA Form 5590-R	*Computation of Azimuth and/or Distance From Coordinates (BUCS)*
DA Form 5591-R	*Computation of Coordinates and Height From Azimuth, Distance, and Vertical Angle (BUCS)*
DA Form 5592-R	*Computation of Plane Triangle Coordinates and Height From One Side, Three Angles, and Vertical Angles (BUCS)*
DA Form 5593-R	*Computation of Coordinates and Height by Three-Point Resection (BUCS)*
DA Form 5594-R	*Computation of Astronomic Azimuth by Altitude Method Sun (BUCS)*
DA Form 5595-R	*Computation of Astronomic Azimuth by Altitude Method Star (BUCS)*
DA Form 5598-R	*Computation of Astronomic Azimuth by Polaris Tabular Method (BUCS)*
DA Form 5599-R	*Computation—Convergence of True Azimuth to Grid Azimuth (BUCS)*
DA Form 5600-R	*Computation—Conversion of Geographic Coordinates to UTM Coordinates (BUCS)*
DA Form 5601 -R	*Computation—Conversion of UTM Coordinates to Geographic Coordinates (BUCS)*
DA Form 5604-R	*Computation—Zone-to-Zone Transformation— UTM Grid Coordinates and UTM Grid Azimuth (BUCS)*
DA Form 7284-R	*Computation of Trig Traverse/Subtense (BUCS)*
DA Form 7285-R	*Computation of Coordinates and Height by Intersection (BUCS)*
DA Form 7286-R	*Computation of Star Identification (BUCS)*
DA Form 7287-R	*Computation of Arty Astro (BUCS)*
DA Form 7288-R	*Computation of Hasty Astro (BUCS)*
DA Form 5602-R	*Computation of Datum-to-Datum Coordinate Transformation (Program 14—Listed Datums) (BUCS)*
DA Form 5603-R	*Computation of Datum-to-Datum Coordinate Transformation (Program 15—Gauss-Kruger [GK]) (BUCS)*
DA Form 7289-R	*Computation of BUCS Datum-to-Datum Coordinate Transformation (Program 16—User-Defined) (BUCS)*
★ DA Form 7356-R	*Computation of Azimuth and Distance From Coordinates (FED MSR)*
★ DA Form 7357-R	*Computation of Coordinates and Height From Azimuth, Distance, and Vertical Angle (FED MSR)*
★ DA Form 7358-R	*Computation of Plane Triangle Coordinates and Height From One Side, Three Angles, and Vertical Angle (FED MSR)*
★ DA Form 7359-R	*Computation of Coordinates and Height by Three-Point Resection (FED MSR)*

★ DA Form 7360-R *Computation of Astronomic Azimuth by Altitude Method (FED MSR)*

★ DA Form 7361-R *Computation of Astronomic Azimuth by the Hasty Astro Method (FED MSR)*

★ DA Form 7362-R *Computation of Azimuth and Vertical Angle to Selected Star (Star ID) (FED MSR)*

★ DA Form 7363-R *Computation of Astronomic Azimuth by Polaris Tabular Method (FED MSR)*

★ DA Form 7364-R *Computation--Convergence of True Azimuth to Grid Azimuth (FED MSR)*

★ DA Form 7365-R *Computation of Trig-Traverse (FED MSR)*

★ DA Form 7366-R *Computation of Coordinates and Height by Intersection (FED MSR)*

★ DA Form 7367-R *Computation of Astronomic Azimuth by the Arty Astro Method (FED MSR)*

★ DA Form 7368-R *Computation--Conversion UTM to GEO Coordinate, GEO to UTM Coordinate, Zone-To-Zone Transformation (FED MSR)*

★ DA Form 7369-R *Computation--Datum- To-Datum Coordinate Transformation Listed Datums (FED MSR)*

★ DA Form 7370-R *Computation--Datum- To-Datum Coordinate Transformation Gauss Kruger (GK) Datums (FED MSR)*

★ DA Form 7371-R *Computation--Datum- To-Datum Coordinate Transformation User-Defined Datums (FED MSR)*

★ APPENDIX E

ELLIPSOIDS AND DATUMS

The PADS Core (Version 8), PADS Solid State (Version 4), BUCS Survey (Rev 1), BUCS DDCT (Rev 0), MADTRAN (Edition 2), MADTRAN (Edition 4), PLGR (Version 04.62), and FED MSR systems contain a data base that stores the relevant constants and parameters for the ellipsoids listed in Table E-2.

LOCATION OF DATUM TRANSFORMATION TABLES

E-1. REFERENCES

a. The following references were used to compile the information found in this appendix:

(1) DMA TM 8358.1 (September 1990).

(2) DMA TR 8350.2 Second Edition (1 September 1991) with Insert 1 (9 December 1993).

(3) National Geodetic Survey, Geodetic Glossary (September 1986).

(4) DoD Glossary of Mapping, Charting, and Geodetic Terms (1991).

(5) MADTRAN, Edition 2 and 4 (DMA program referencing DMA TR 8350.2 above).

(6) Mercator (DMA program referencing DMA TM 8358.2 (dated September 1989).

(7) TM 08837A-12/1A (28 October 1988) with Change 3 (9 September 1992) PADS.

b. When the information in the references above conflicted, DMA TR 8350.2 was considered the senior publication.

c. The numbers in front of the references above correspond to the reference numbers in the tables of this appendix. Reference 8 was used to determine the PADS ellipsoid code; Reference 4 was used to determine the BUCS DDCT (Rev 0) code.

E-2. TABLES

a. Ellipsoids.

(1) Table E-1 is a list of all ellipsoids and their parameters as published in the references above.

(a) This is not a list of all ellipsoids; however, it is the most complete one-table list of ellipsoids and their parameters available to artillery surveyors.

(b) The semimajor axis (a), semiminor axis (b), and flattening (l/f) are listed when available. Semiminor axes not listed were not available from the references and must be computed by the user with the formula **b = a (l - f).**

(2) Table E-2 is a list of the ellipsoids in Table E-1 cross-referenced with current survey applications.

b. Datums.

(1) The datum transformation parameters are listed corresponding to the ellipsoid to which they are referenced. The

transformation parameters are from the local geodetic datum to WGS-84; therefore, a datum table with WGS-84 will not be published. Also, datum tables for ellipsoids in Table E-1 with no listed datums are not published.

(2) Differences in data published in the above references are explained in the notes section at the end of this appendix.

E-3. WORLD GEODETIC SYSTEM

a. Because of the large amount of mapping, charting, geodetic, gravimetric, and digital products produced by DMA for DoD, it became apparent that a signle geocentric coordinate system was needed to ensure accuracy and user interface. This system must support the widest range of applications. A geocentric system provides a basic reference for the mathematical figure of the earth. It also provides a means for establishing various geodetic datums to an earth-centered, earth-fixed (ECEF) coordinate system. This system is termed *World Geodetic System* (WGS).

b. Previously, DoD has adopted three such systems: WGS-60, WGS-66, and WGS-72. With each system proving more accurate than the last, WGS-72 can still be used for some applications. It does, however, have several shortcomings. For example, the WGS-72 Earth Gravitational Model and Geoid are obsolete. Also, more accurate datum shifts from local geodetic datums to a WGS were needed. Several other factors contributed to the need to replace WGS-72. These included the replacement of NAD 27 with NAD 83 and the development of the Australian Geodetic Datum 84. Also, a large increase in data and more advanced types of data (satellite ranging for example) were now available. WGS-84 was developed as the replacement for WGS-72.

c. In determining the WGS-84 ellipsoid and its associated parmeters, the WGS-84 Development Committee closely followed the procedures used by the International Union of Geodesy and Geophysics (IUGG) who hd lready developed the Geodetic Reference System 1980 (GRS-80). Four parmeters were used to develop WGS-84: the semimajor axis (a), the earth's gravitational constant (GM), the normalized second degree zonal gravitational constant ($\bar{C}_{20}$), and the angular velocity(ω) of the earth. All are identical to GRS-80 except that the second degree zonal used is that of the WGS-84 gravitational model instead of the notation J_2 used for GRS-80. As a result of that difference, the ellipsoid parmeters differ slightly between GRS-80 and WGS-84. These differences are insignificant from a practical application standpoint; therefore, it has been accepted that GRS-80 and WGS-84 are the same and their associated datums are based on the same ellipsoid. Even so, it must be understood that WGS-84 is datum within the WGS-84 ellipsoid, and NAD-83 is a datum referenced to the GRS-80 ellipsoid.

d. DMA has designated WGS-84 as the preferred ellipsoid and datum for all mapping, charting, and geodetic products. Some areas of the world can still be covered by other systems.

Figure E-1. **World Geodetic System 1984**

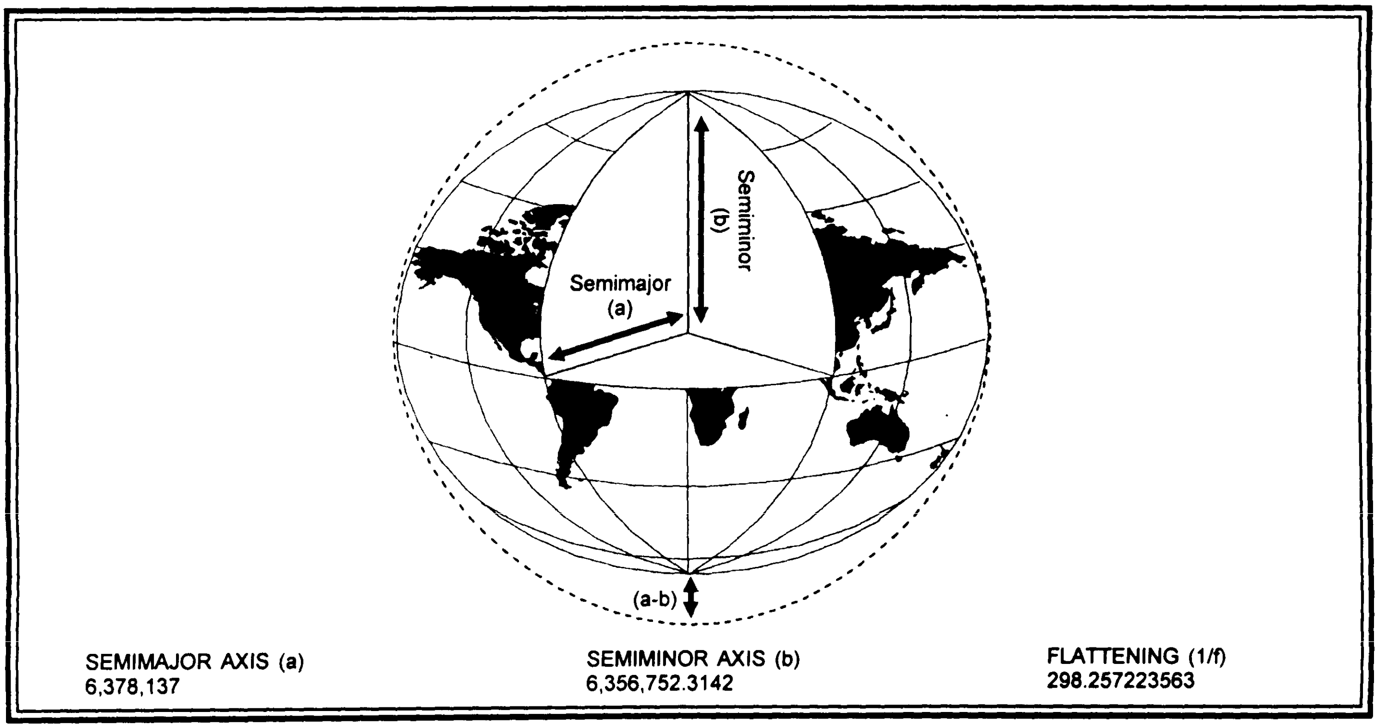


Table E-1. **Ellipsoid parameters**

Ref	Ellipsoid	Datum	Semimajor Axis	Semiminor Axis	Flattening (1/f)	PADS
1	Airy		6,377,563.396	6,356,256.910	299.32496 46	10
1	Modified Airy		6,377,340.189	6,356,034.446	299.32496 46	11
3	Airy 1830		6,377,563.541	6,356,257.053	293.325	
1	Australian National [1]		6,378,160	6,356,774.7192	298.25	8
1	Bessel 1841		6,377,397.155	6,356,078.9629	299.15281 28	5
2	Bessel 1841	Namibia	6,377,483.865		299.15281 28	
3	Clarke 1858		6,378,361	6,356,685	294.26	
1	Clarke 1866		6,378,206.4	6,356,583.8	294.97869 82	1
1	Clarke 1880 [2]		6,378,249.145	6,356,514.8696	293.465	3
1/4	Clarke 1880 French [2]	Carthage Voirol Merchich	6,378,249.2	6,356,515.0	293.46598	
7	Clarke 1880 Mod. [2]		6,378,249.145		293.46630 7656	
7	Clarke 1880 Palistine [2]	Indian	6,378,300.790		293.46630 7656	
1	Clarke 1880 [2]	ARC 1950	6,378,249.14532 6	6,356,514.966721	293.46630 76	
7	Danish		6,377,104.430		300.0000	
7	Delambre		6,376,523.300		308.640	
2	Everest (Pakistan)		6,377,309.613		300.8017	
1	Everest 1830		6,377,276.34518	6,356,075.41511	300.8017	4
3	Everest 1847					
2	Everest 1948	Timbalai 1948	6,3777,298.556		300.8017	
1	Mod. Everest 1948 [3]	Kertau 1948	6,377,304.063	6,356,103.039	300.8017	12
2	Everest 1956	Indian	6,377,301.243		300.8017	
2	Everest 1969		6,377,295.664		300.8017	
3/5	Fischer 1960	Mercury	6,378,166.0		298.3	
2/3	Mod. Fischer 1960	S. Asia	6,378,155.0		298.3	
5	Fischer 1968	Mercury	6,378,150		298.3	
3	GRS-1967 [1]		6,378,160		298.247	8
2	GRS-80		6,378,137	6,356,752.3141	298.25722 2101	9
1	GRS-80 China		6,378,140		298.247	
3/6	Hayford 1909		6,378,388.0	6,356,909.0	297.00	
2	Helmert 1906		6,378,200		298.3	
2	Hough 1960		6,378,270		297	14
2	Indonesian 1974		6,378,160.0		298.247	
1	International 1924		6,378,388	6,356,911.9462	297	2
2	Krassovsky 1940		6,378,245		298.3	
7	Plessis		6,376,523.3		308.640	
3	Schott 1900		6,378,157		304.5	
1	South American 1969 [1]		6,378,160	6,356,774.7192	298.25	8
5	SGS-85		6,378,136		298.257	
7	Struve		6,378,298.3		294.730	
1	War Office 1924		6,378,300.58		296	
5	WGS-60		6,378,165		298.3	
5	WGS-66		6,378,145		298.25	
1	WGS-72		6,378,135	6,356,750.5	298.26	13
1	WGS-84		6,378,137	6,356,752.3142	298.25722 3563	9

[1] See Note 5 on page E-38.
[2] See Note 1 on page E-38.
[3] Also known as Malayan ellipsoid.

Table E-3. **Survey system to ellipsoid cross-reference**

ELLIPSOID	PADS CORE V.8	PADS SOLID STATE V.4	BUCS SURVEY REV 1	BUCS DDCT REV 0	MADTRAN ED. 2	MADTRAN ED. 4	PLGR VER. V04b.2	FED MSR
Airy		X		X	X	X	X	X
Modified Airy		X		X	X	X	X	X
Airy 1830								
Australian National [3]	X	X	X	X	X	X	X	X
Bessel 1841	X	X	X	X	X	X	X	X
Bessel 1841 (Namibia)					X	X		
Clarke 1858								
Clarke 1866	X	X	X	X	X	X	X	X
Clarke 1880 [2]	X	X	X	X	X	X	X	X
Clarke 1880 French [2]							X	
Clarke 1880 Mod. [2]								
Clarke 1880 Palistine [2]								
Clarke 1880 (Arc 1950) [2]								
Danish								
Delambre								
Everest (Pakistan)						X		
Everest 1830	X	X	X	X	X	X	X	X
Everest 1847								
Everest 1948					X	X		
Mod. Everest 1948 [1]	X	X	X	X	X	X	X	X
Everest 1956					X	X	X	
Everest 1969					X	X		
Fischer 1960					X			
Mod. Fischer 1960				X	X	X		X
Fischer 1968					X		X	X
GRS-1967 [3]	X	X	X	X	X	X	X	X
GRS-80		X	X	X	X	X	X	X
GRS-80 China								
Hayford 1909								
Helmert 1906				X	X	X	X	
Hough 1960		X		X	X	X		
Indonesian 1974						X		
International 1924	X	X	X	X	X	X	X	X
Krassovsky 1940				X	X	X		X
Plessis								
Schott 1900								
South American 1969 [3]	X	X	X	X	X	X	X	X
SGS-85					X			
Struve								
War Office 1924								
WGS-60					X			
WGS-66					X			
WGS-72		X	X	X	X	X	X	X
WGS-84		X	X	X	X	X	X	X

NOTES:

1. An X indicates the ellipsoid listed in the column to the left is available in the system listed at the top.
2. A [1] indicates that this ellipsoid is also known as Malaysian.
3. A [2] refers to Note 1 on page E-38.
4. A [3] refers to Note 5 on page E-38.

E-4. DATUM TRANSFORMATION TABLES

a. A datum transformation table (Figure E-2) includes the following information:

- Ellipsoid name, semimajor axis (a), semiminor axis (b), and flattening (l/f) as listed in Table E-1.
- Δa, which is the difference between the semimajor axes of the local reference ellipsoid and WGS-84.
- $\Delta f x\ 10^7$, which is the difference between the flattenings of the local reference ellipsoid and WGS-84 multiplied by 10^7.

Note. Both Δa and $\Delta f\ x\ 10^7$ are necessary for the user-defined option in the AN/PSN-11 (PLGR) Version V04b.2.

- PADS code as listed in TM 08837A-12/1A. In cases where two or more ellipsoids have the same parameters, the same PADS code was listed for each even when not listed in the reference. For example, Australian National and South American 1969 can both use code 8. **These codes are for Version 4 PADS.** If a PADS code is not listed, the user-defined option should be used.
- Local geodetic datum. The datum name as it appears in DMA TR 8350.2. In cases where a datum has more than one name, the second name is listed in parentheses.
- Country/area. This information is mostly as it appears in DMA TR 8350.2. The only variations from the reference are listings of states and countries published under mean solutions.
- Transformation parameters (shifts in X, Y, and Z axes) as listed in DMA TR 8350.2. These parameters are from the local datum to WGS-84.
- Datum code. The codes in the DATUM CODE column match the programmed datum codes from the AN/PSN-11 (PLGR) Version V04b.2. The datum codes listed in this column that are not a programmed option of the PLGR must be selected as user-defined. All datum codes published in this table are from DMA TR 8350.2.
- DDCT code. This is the datum code from the BUCS DDCT Rev 0.

b. Tables E-3 through E-25 are datum transformation tables. A quick reference to the location of specific tables is on page E-1.

Figure E-2. **Datum transformation table**

AIRY a: 6377563.396 Δa: +573.604		b: 6356256.910		1/f: 299.32496 46 $\Delta fx\ 10^7$: +119.600		PADS CODE: 10	
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	**COUNTRY/ AREA**	**TRANSFORMATION PARAMETERS** ΔX	ΔY	ΔZ	**DATUM CODE**	**DDCT CODE**	**REF**
Ordnance Survey of Great Britain 1936					OGB		2
	Mean Solution (England, Isle of Man, Scotland, Shetland Islands)	375	-111	431	OGB-M	76	2

Table E-3. **Airy**

AIRY

a: 6377563.396 b: 6356256.910 1/f: 299.32496 46 PADS

Δa: +573.604 Δfx 10^7: +119.600 CODE: 10

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Ordnance Survey of Great Britain 1936					OGB		2
	Mean Solution (England, Isle of Man, Scotland, Shetland Islands)	375	-111	431	OGB-M	76	2
	England	371	-112	434	OGB-A		2
	England, Isle of Man, and Wales	371	-111	434	OGB-B		2
	Scotland and the Shetland Islands	384	-111	425	OGB-C		2
	Wales	370	-108	434	OGB-D		2

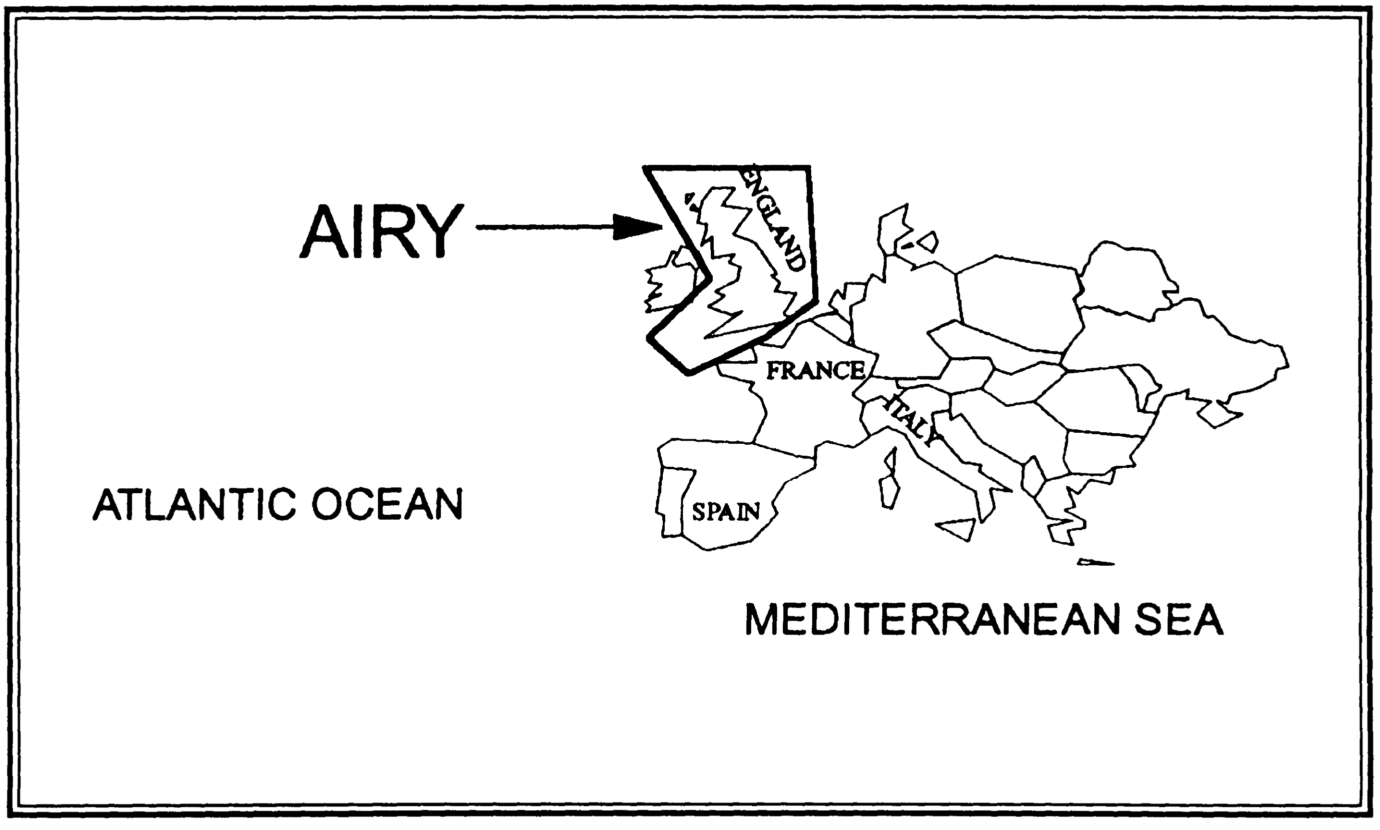


Table E-4. **Modified Airy**

MODIFIED AIRY							
a: 6377340.189	b: 6356034.446		1/f: 299.32496 46		PADS		
Δ*a*: +796.811			Δ*f*x 10⁷: +119.600		CODE: 11		
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Ireland 1965	Ireland	506	-122	611	IRL	38	2

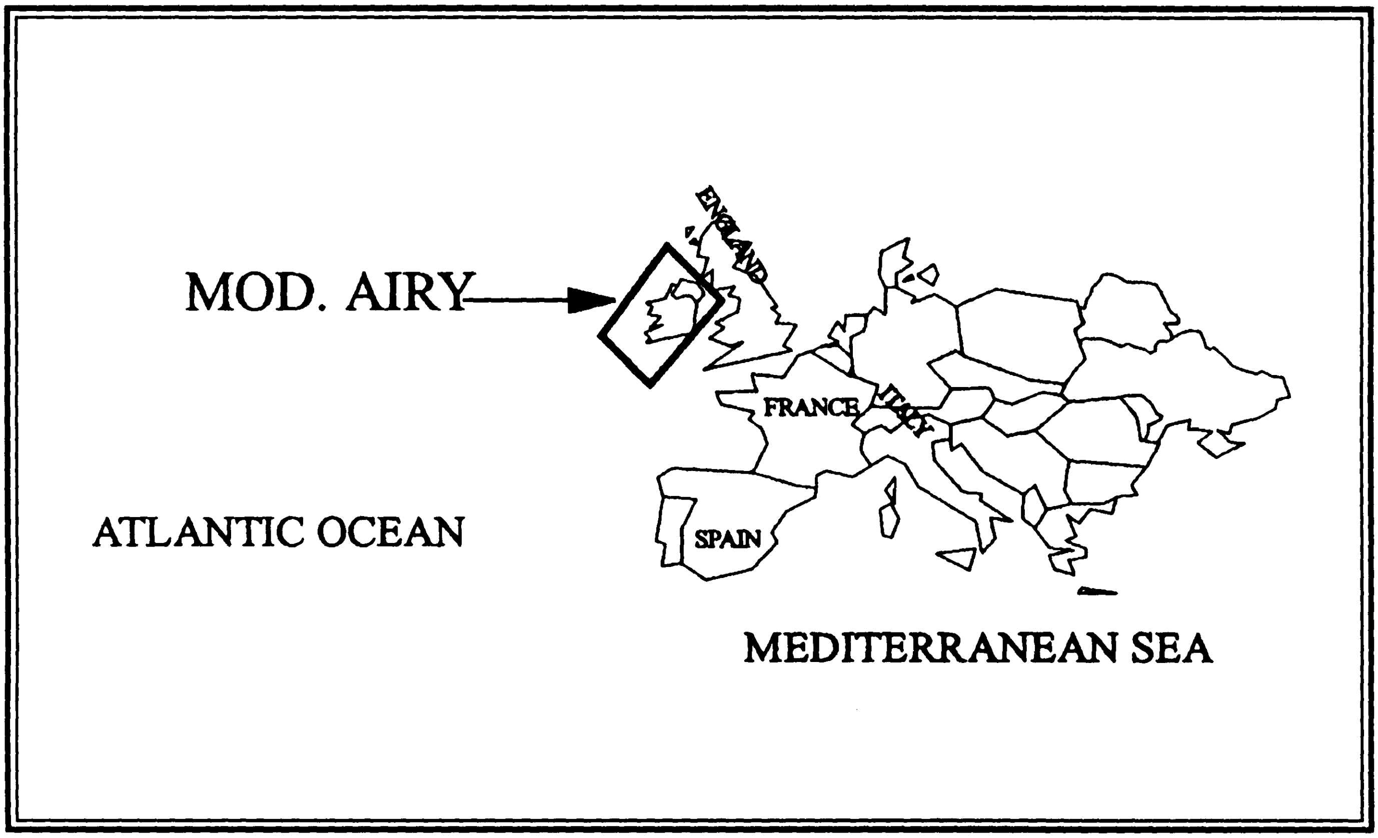


Table E-5. **Australian National**

AUSTRALIAN NATIONAL (SEE NOTE FIVE)

a: 6378160 | b: 6356774.7192 | 1/f: 298.25 | PADS
Δa: -023.000 | $\Delta f \times 10^7$: -000.812 | CODE: 8

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
		DATUM TRANSFORMATION PARAMETERS — LOCAL DATUM TO WGS-84					
Anna 1 Astro 1965	Cocos Islands	-491	-22	435	ANO	4	2
Australian Geodetic 1966	Australia and Tasmania	-133	-48	148	AUA	12	2
Australian Geodetic 1984	Australia and Tasmania	-134	-48	149	AUG	13	2

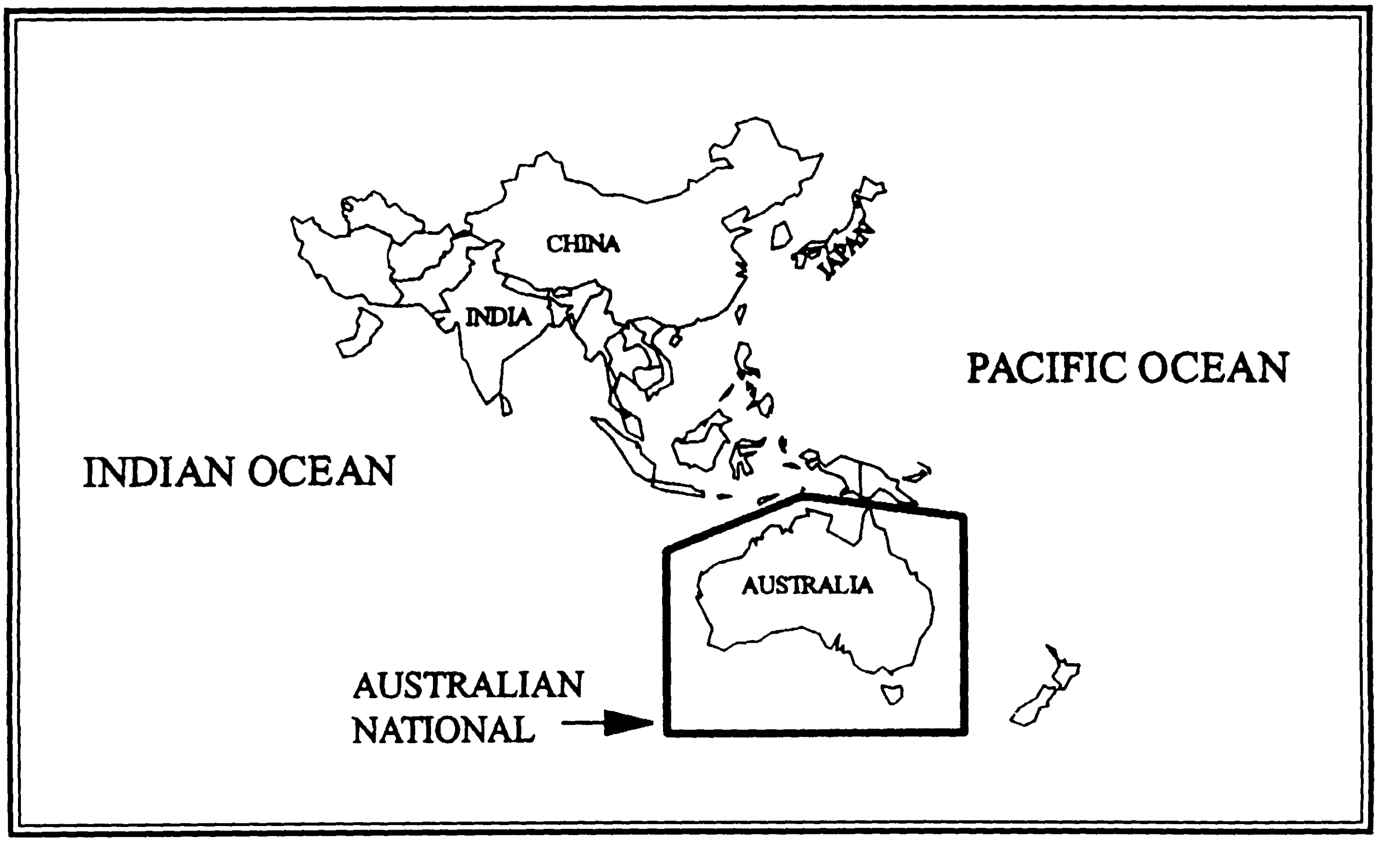


Table E-6. **Bessel 1841**

BESSEL 1841

a: 6377397.155 b: 6356078.9629 1/f: 299.15281 28 PADS

Δa: +739.845 $\Delta f \times 10^7$: +100.375 CODE: 5

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Bukit Rimpah	Indonesia (Bangka and Belitung Islands)	-384	664	-48	BUR		2
Djakarta (Batavia)	Indonesia (Sumatra)	-377	681	-50	BAT		2
Gunung Segara	Indonesia (Kalimantan)	-403	684	41	GSE		2
Massawa	Ethiopia (Eritrea)	639	405	60	MAS		2
Potsdam (See Note four)	Germany						4
S-JTSK	Czechoslovakia (Prior to 1 Jan 93)	589	76	480	CCD		2
TOKYO					TOY		2
	Mean Solution (Japan, Okinawa, and South Korea)	-148	507	685	TOY-M		2
	Japan	-148	507	685	TOY-A		2
	Okinawa	-158	507	676	TOY-C		2
	South Korea	-146	507	687	TOY-B		2

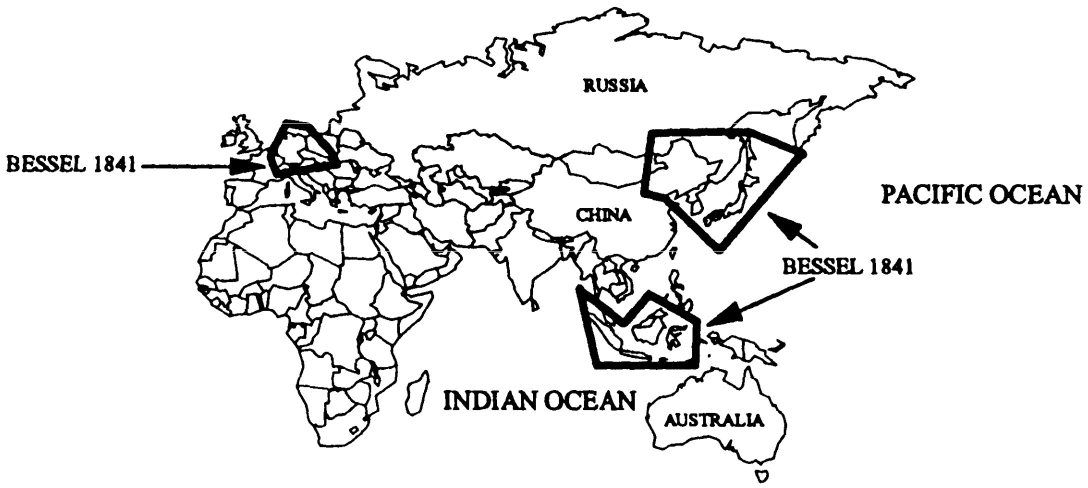


Table E-7. **Bessel 1841 (Namibia)**

BESSEL 1841 (Namibia)							
a: 6377483.865	b:		1/f: 299.15281 28			PADS	
Δ*a*: +653.135			Δ*f*x 10⁷: +100.375			CODE:	
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Schwarzeck	Namibia	616	97	-251	SCK		2

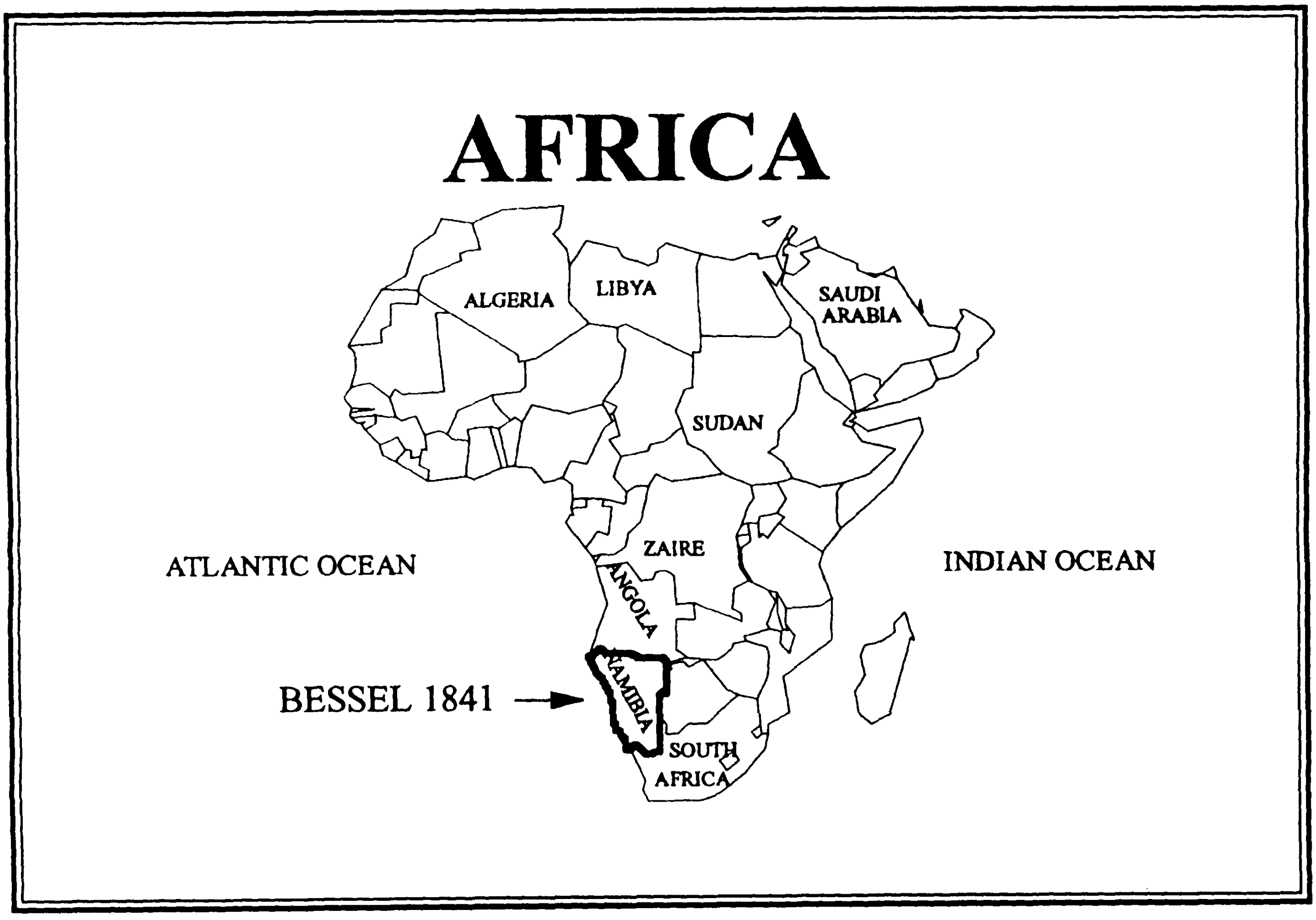


Table E-8. **Clarke 1866**

CLARKE 1866
a: 6378206.4 b: 6356583.8 1/f: 294.97869 82 PADS
Δa: -069.400 Δfx 10^7: -372.646 CODE: 1

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
American Samoa 1962	US Samoan Islands	-115	118	426	AMA		2
Bermuda 1957	Bermuda Island	-73	213	296	BER	15	2
Cape Canaveral	Mean Solution (Bahamas and Florida)	-2	151	181	CAC		2
Guam 1963	Guam	-100	-248	259	GUA	32	2
LC 5 Astro 1961	Cayman Brac Island	42	124	147	LCF	45	2
Luzon					LUZ		2
	Philippines (Excluding Mindanao Island)	-133	-77	-51	LUZ-A	47	2
	Mindanao Island	-133	-79	-72	LUZ-B	48	2
North American 1927 United States					NAS		2
	Mean Solution (CONUS)	-8	160	176	NAS-C	60	2
	Eastern US	-9	161	179	NAS-A		2
	Western US	-8	159	175	NAS-B		2
	Alaska (Excluding the Aleutian Islands)	-5	135	172	NAS-D	61	2
	Aleutian Islands						
	East of 180° West	-2	152	149	NAS-V		2
	West of 180° West	2	204	105	NAS-W		2

Table E-8. **Clarke 1866 (Continued)**

CLARKE 1866 Continued

a: 6378206.4 b: 6356583.8 1/f: 294.97869 82 PADS

Δa: -069.400 Δfx 10^7: -372.646 CODE: 1

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
North American 1927 Canada					NAS		2
	Mean Solution (Canada, including Newfoundland)	-10	158	187	NAS-E	64	2
	Alberta and British Columbia	-7	162	188	NAS-F		2
	Eastern Canada (Newfoundland, New Brunswick, Nova Scotia, and Quebec)	-22	160	190	NAS-G		2
	Manitoba and Ontario	-9	157	184	NAS-H		2
	Northwest Territories and Saskatchewan	4	159	188	NAS-I		2
	Yukon	-7	139	181	NAS-J		2
North American 1927 Other than US & Canada							
	Bahamas (Excluding San Salvador Island)	-4	154	178	NAS-Q	62	2
	Canal Zone	0	125	201	NAS-O	65	2
	Caribbean	-3	142	183	NAS-P	66	2
	Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua	0	125	194	NAS-N	67	2
	Cuba	-9	152	178	NAS-T	68	2

Table E-8. **Clarke 1866 (Continued)**

CLARKE 1866 Continued

a: 6378206.4 b: 6356583.8 1/f: 294.97869 82 PADS

Δa: -069.400 Δfx 10⁷: -372.646 CODE: 1

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
North American 1927					NAS		2
	Greenland (Hayes Peninsula)	11	114	195	NAS-U	69	2
	Mexico	-12	130	190	NAS-L	70	2
	San Salvador Island	1	140	165	NAS-R	63	2
	Manitoba and Ontario	-9	157	184	NAS-H		2
Old Hawaiian					OHA		
	Mean Solution	61	-285	-181	OHA-M	74	2
	Hawaii	89	-279	-183	OHA-A		2
	Kauai	45	-290	-172	OHA-B		2
	Maui	65	-290	-190	OHA-C		2
	Oahu	58	-283	-182	OHA-D		2
Puerto Rico	Puerto Rico and Virgin Islands	11	72	-101	PUR	81	2

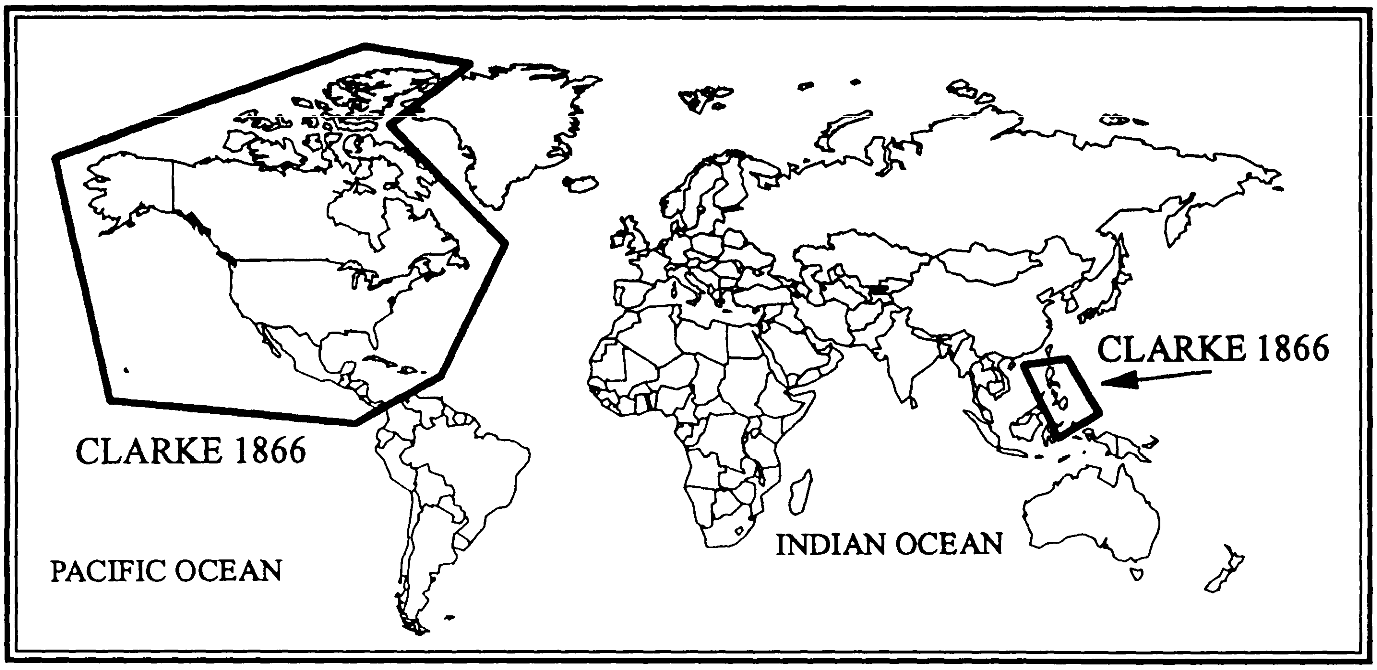


Table E-9. **Clarke 1880**

CLARKE 1880 (SEE NOTE ONE)
a: 6378249.145 b: 6356514.8696 1/f: 293.465 PADS
Δa: -112.145 Δf x 10⁷: -547.507 CODE: 2

DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Adindan					ADI		2
	Mean Solution (Ethiopia and Sudan)	-166	-15	204	ADI-M	1	2
	Burkina FASO	-118	-14	218	ADI-E		2
	Cameroon	-134	-2	210	ADI-F		2
	Ethiopia	-165	-11	206	ADI-A		2
	Mali	-123	-20	220	ADI-C		2
	Senegal	-128	-18	224	ADI-D		2
	Sudan	-161	-14	205	ADI-B		2
Antigua Island Astro 1943							2
	Antigua and Leeward Islands	-270	13	62	AIA		2
Arc 1950 (See Note one)					ARF		2
	Mean Solution (Botswana, Lesotho, Malawi, Swaziland, Zaire, Zambia, and Zimbabwe	-143	-90	-294	ARF-M	5	2
	Botswana	-138	-105	-289	ARF-A		2
	Burundi	-153	-5	-292	ARF-H		2

Table E-9. **Clarke 1880 (Continued)**

CLARKE 1880 Continued (SEE NOTE ONE)

a: 6378249.145 b: 6356514.8696 1/f: 293.465 PADS
Δa: -112.145 Δfx 10^7: -547.507 CODE: 2

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Arc 1950 continued (See Note one)					ARF		2
	Lesotho	-125	-108	-295	ARF-B		2
	Malawi	-161	-73	-317	ARF-C		2
	Swaziland	-134	-105	-295	ARF-D		2
	Zaire	-169	-19	-278	ARF-E		2
	Zambia	-147	-74	-283	ARF-F		2
	Zimbabwe	-142	-96	-293	ARF-G		2
Arc 1960	Mean Solution (Kenya and Tanzania)	-160	-6	-302	ARS	6	2
Ayabelle Lighthouse	Djibouti	-79	-129	145	PHA		2
Cape	South Africa	-136	-108	-292	CAP	19	2
Carthage (See Note one)	Tunisia	-263	6	431	CGE		2
Dabola	Guinea	-83	37	124	DAL		2
Deception Island	Deception Island, Antarctica	260	12	-147	DID		2

Table E-9. **Clarke 1880 (Continued)**

CLARKE 1880 Continued (SEE NOTE ONE)
a: 6378249.145 b: 6356514.8696 1/f: 293.465 PADS
Δa: -112.145 Δfx 10[7]: -547.507 CODE: 2

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Fort Thomas 1955	Nevis and St. Kittis (Leeward Islands)	-7	215	225	FOT		2
Leigon	Ghana	-130	29	364	LEH		2
Liberia 1964	Liberia	-90	40	88	LIB	46	2
Mahe 1971	Mahe Island	41	-220	-134	MIK	49	2
Merchich (See Note one)	Morocco	31	146	47	MER		2
Minna					MIN		
	Cameroon	-81	-84	115	MIN-A		2
	Nigeria	-92	-93	122	MIN-B	54	2
Montserrat Island Astro 1958	Montserrat (Leeward Islands)	174	359	365	ASM		2
M'Poraloko	Gabon	-74	-130	42	MPO		2
Nahrwan					NAH		
	Masirah Island (Oman)	-247	-148	369	NAH-A	55	2
	Saudi Arabia	-243	-192	477	NAH-C		2
	United Arab Emirates	-249	-156	381	NAH-B	56	2

Table E-9. **Clarke 1880 (Continued)**

CLARKE 1880 Continued (SEE NOTE ONE)
a: 6378249.145 b: 6356514.8696 1/f: 293.465 PADS
Δa: -112.145 Δf x 10[7]: -547.507 CODE: 2

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
North Sahara 1959	Algeria	-186	-93	310	NSD		2
Oman	Oman	-346	-1	224	FAH	75	2
Point 58	Mean Solution (Burkino FASO and Niger)	-106	-129	165	PTB		2
Pointe Noire 1948	Congo	-148	51	-291	PTN		2
Viti Levu 1916	Viti Levu Island (Fiji Islands)	51	391	-36	MVS	95	2
Voirol 1960 (See Note one)	Algeria	-123	-206	219	VOR		2

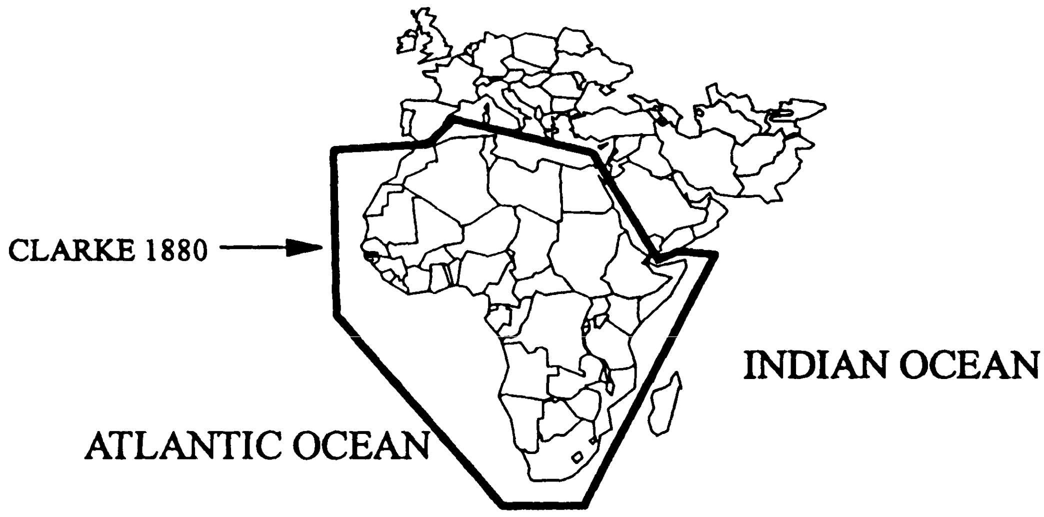


Table E-10. **Everest 1830**

EVEREST 1830

a: 6377276.34518 b: 6356075.41511 1/f: 300.8017 PADS

Δa: +860.655 Δfx 10[7]: +283.614 CODE: 4

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Indian	Bangladesh	282	726	254	IND-B		2
Indian 1954	Thailand	217	823	299	INF-A		2
Indian 1960					ING		2
	Con Son Island (Vietnam)	182	915	344	ING-B		2
	Vietnam (near 16⁰ north)	198	881	317	ING-A		2
					INH		
Indian 1975	Thailand	209	818	290	INH-A		2
Kandawala	Sri Lanka	-97	787	86	KAN	41	2

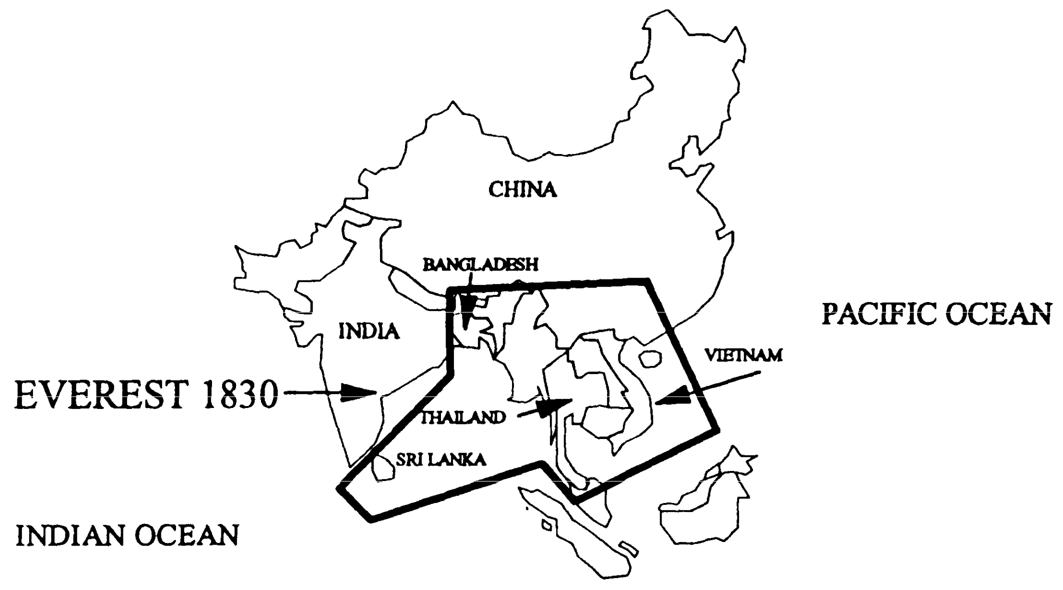


Figure E-11. **Everest 1948**

EVEREST 1948								
a: 6377298.556 Δa: +838.444	b:	1/f: 300.8017 Δf x 10[7]: +283.614				PADS CODE:		
DATUM TRANSFORMATION PARAMETERS								
LOCAL DATUM TO WGS-84								
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF	
Timbalai 1948	Brunei and East Malaysia (Sarawak and Sabah)	-679	669	-48	TIL		2	

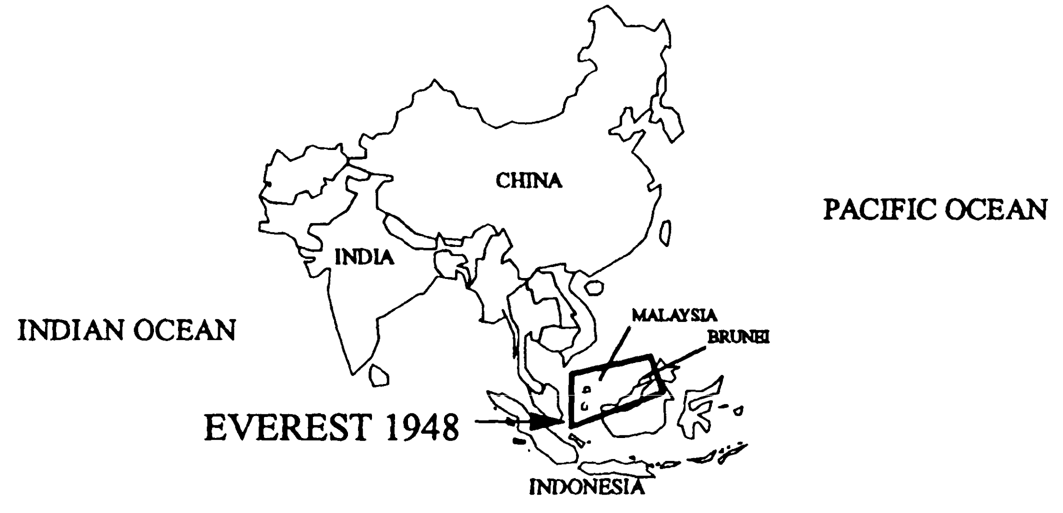


Table E-12. **Modified Everest 1948**

MOD. EVEREST 1948							
a: 6377304.063	b: 6356103.039	1/f: 300.8017				PADS	
Δa: +832.937		Δfx 10^7: +283.614				CODE: 12	
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Kertau 1948	West Malaysia and Singapore	-11	851	5	KEA	43	2

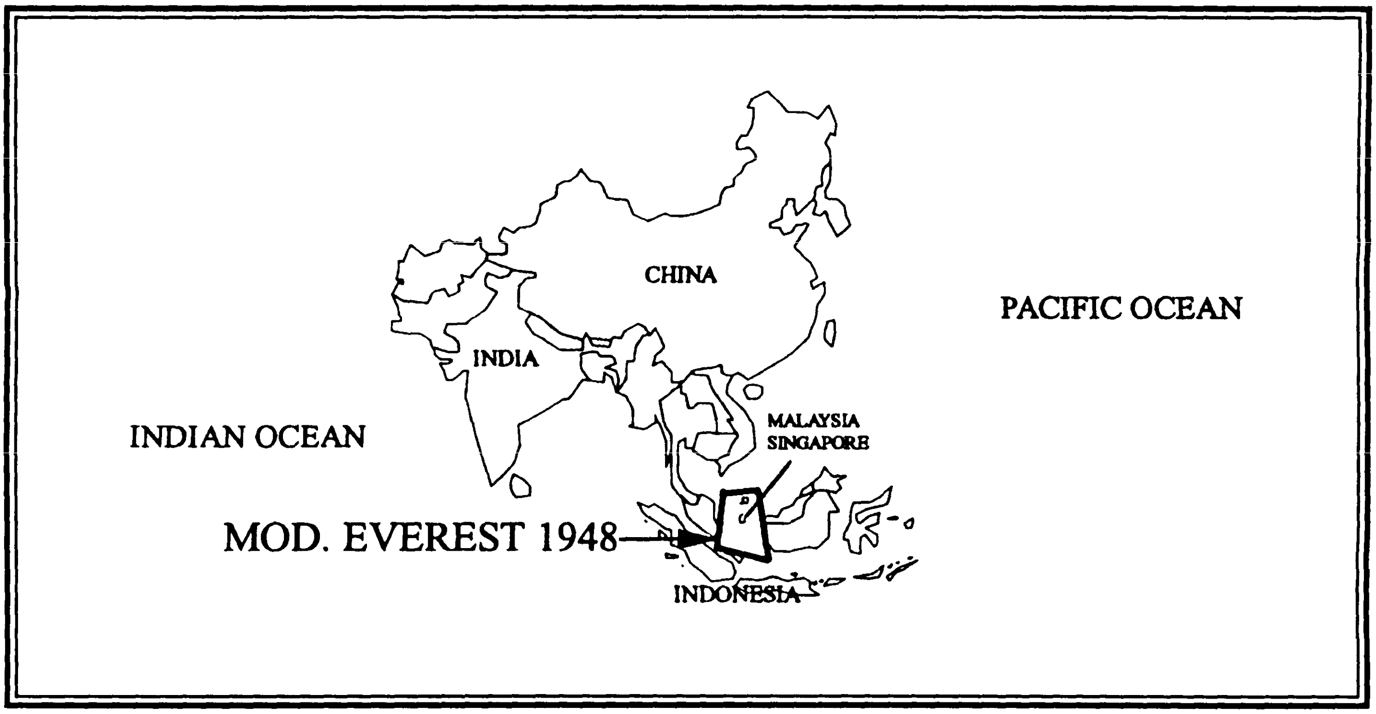


Table E-13. **Everest 1956**

EVEREST 1956 a: 6377301.243 Δ*a*: +835.757	b:	1/f: 300.8017 Δ*f*x 10^7: +283.614				PADS CODE:		
DATUM TRANSFORMATION PARAMETERS								
LOCAL DATUM TO WGS-84								
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF	
Indian	India and Nepal	295	736	257	IND-I		2	

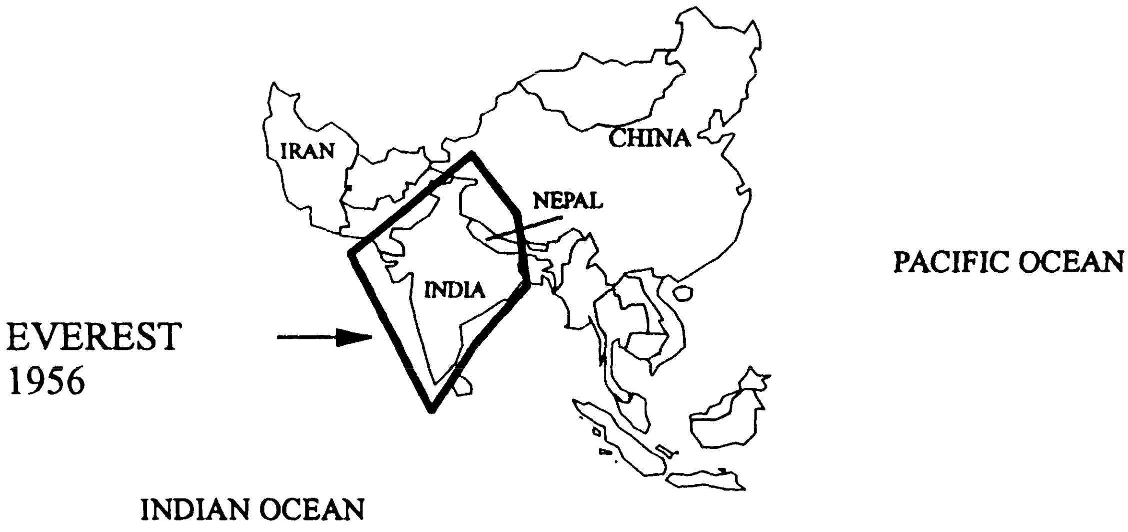


Table E-14. **Everest (Pakistan)**

EVEREST (PAKISTAN)							
a: 6377309.613 b:		1/f: 300.8017				PADS	
Δa: +827.387		$\Delta f \times 10^7$: +283.614				CODE:	
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Indian	Pakistan	283	682	231	IND-P		2

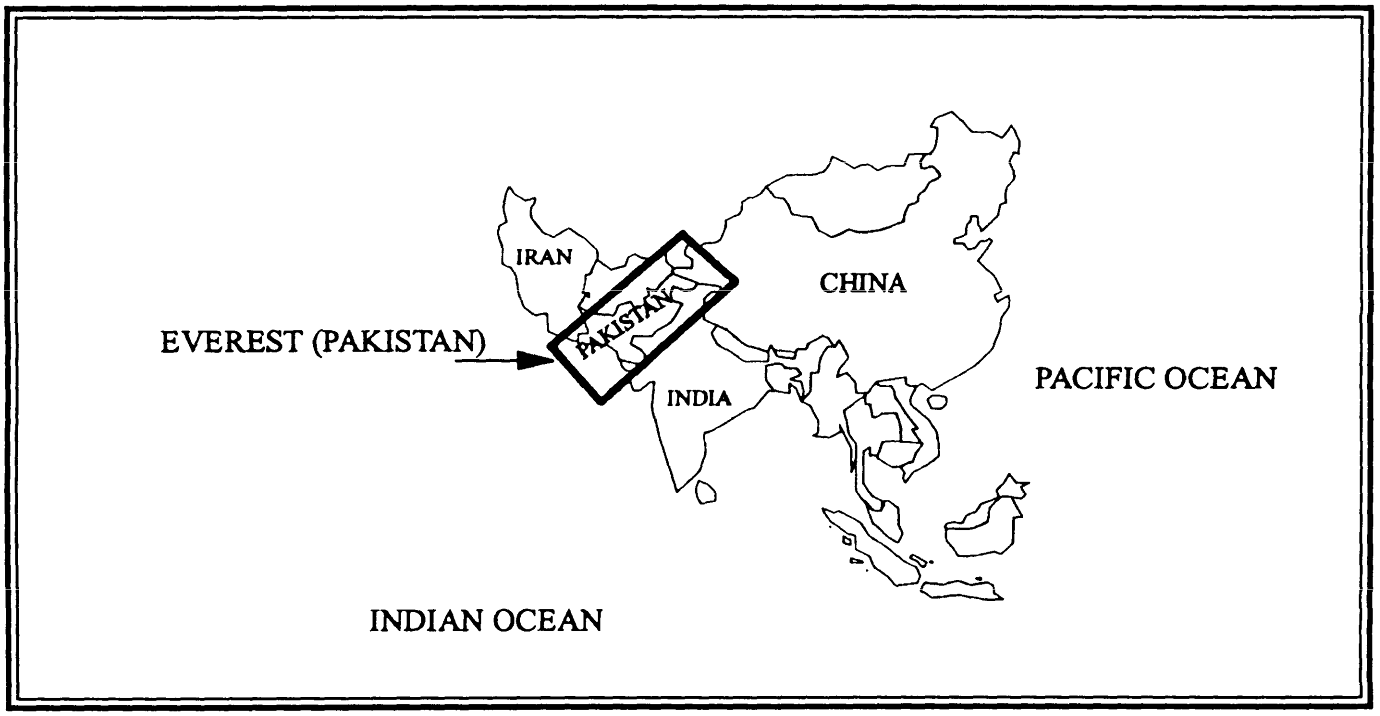


Table E-15. **Modfied Fischer 1960**

MODIFIED FISCHER 1960							
a: 6378155.0	b:		1/f: 298.3			PADS	
Δ*a*: -018.000			Δ*f*x 10[7]: +004.808			CODE:	
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
South Asia	Singapore	7	-10	-26	SOA	89	2

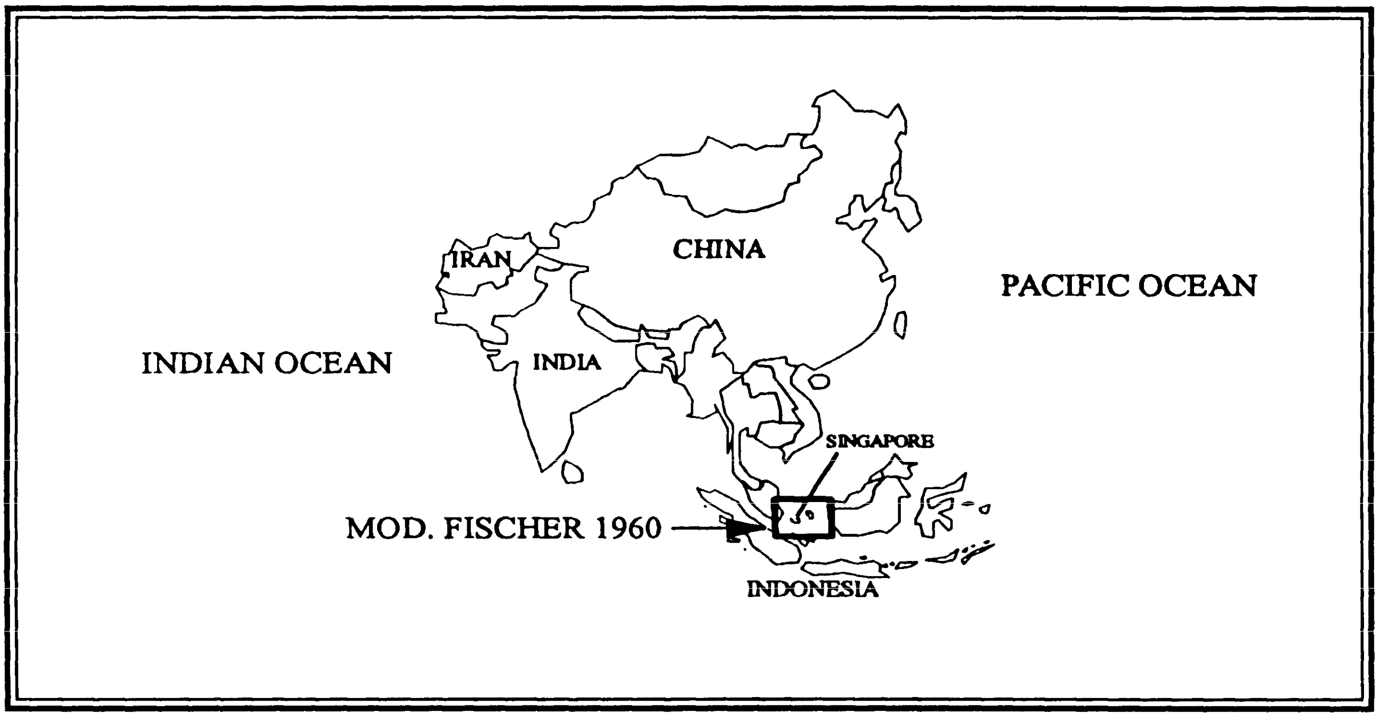


Table E-16. **Geodetic Reference System 1980**

GEODETIC REFERENCE SYSTEM 1980							
a: 6378137	b: 6356752.3141	1/f: 298.25722 2101			PADS		
Δ*a*: 000.000		Δ*fx* 10^7: 000.000			CODE: 9		
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
North American 1983					NAR		2
	Alaska (Excluding the Aleutian Islands)	0	0	0	NAR-A	71	2
	Aleutian Islands	-2	0	4	NAR-E		2
	Canada	0	0	0	NAR-B	71	2
	CONUS	0	0	0	NAR-C	71	2
	Hawaii	1	1	-1	NAR-H		2
	Mexico and Central America	0	0	0	NAR-D	71	2

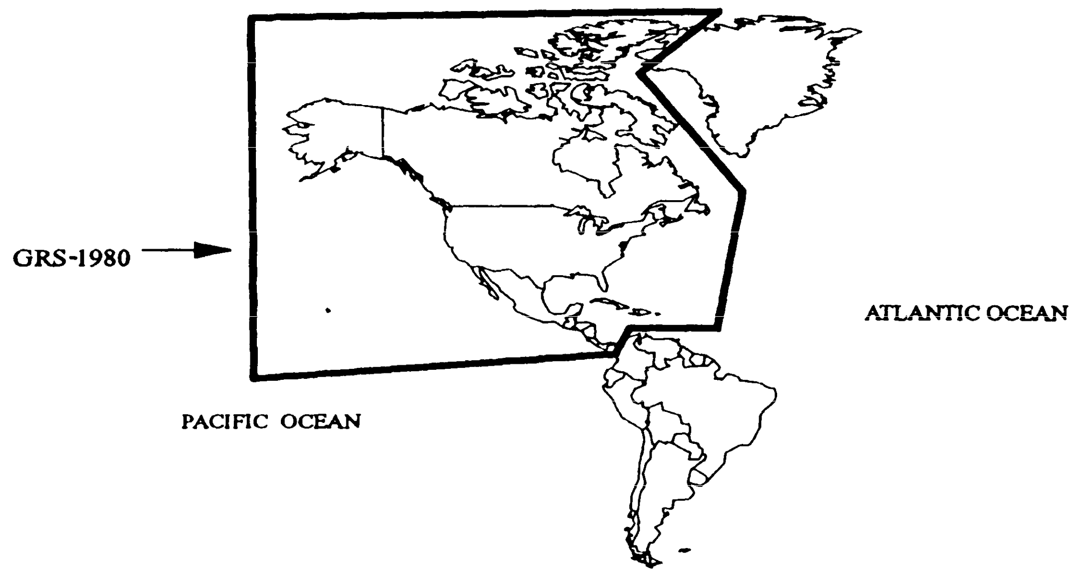


Table E-17. **Geodetic Reference System 1980 China**

GEODETIC REFERENCE SYSTEM 1980 China							
a: 6378140	b:	1/f: 298.257			PADS		
Δa: -003.000		Δfx 10⁷: -000.025			CODE:		
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Beijing 1982 (Peking 1982)	China (after 31 Dec 80)						

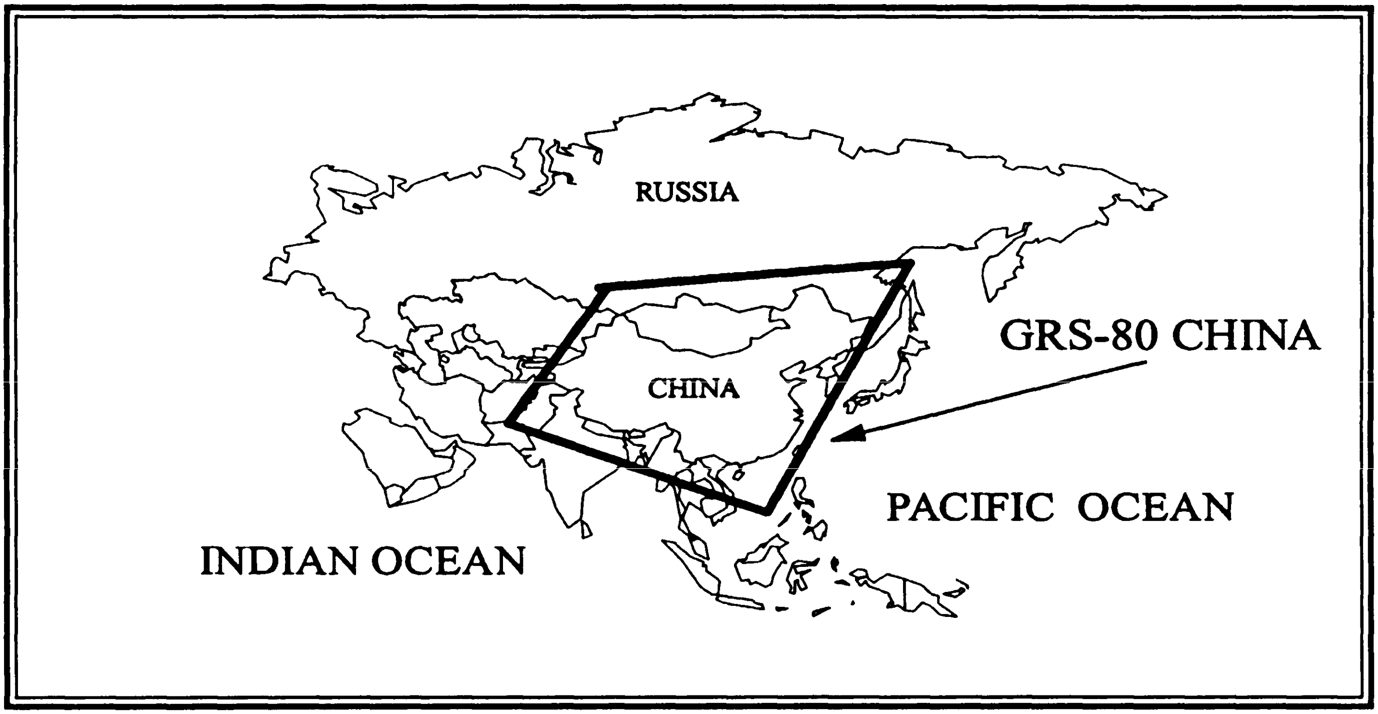


Table E-18. **Helmert 1906**

HELMERT 1906

a: 6378200	b:	1/f: 298.3	PADS
Δa: -063.000		Δfx 10[7]: +004.808	CODE:

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Old Egyptian 1907	Egypt	-130	110	-13	OEG	73	2

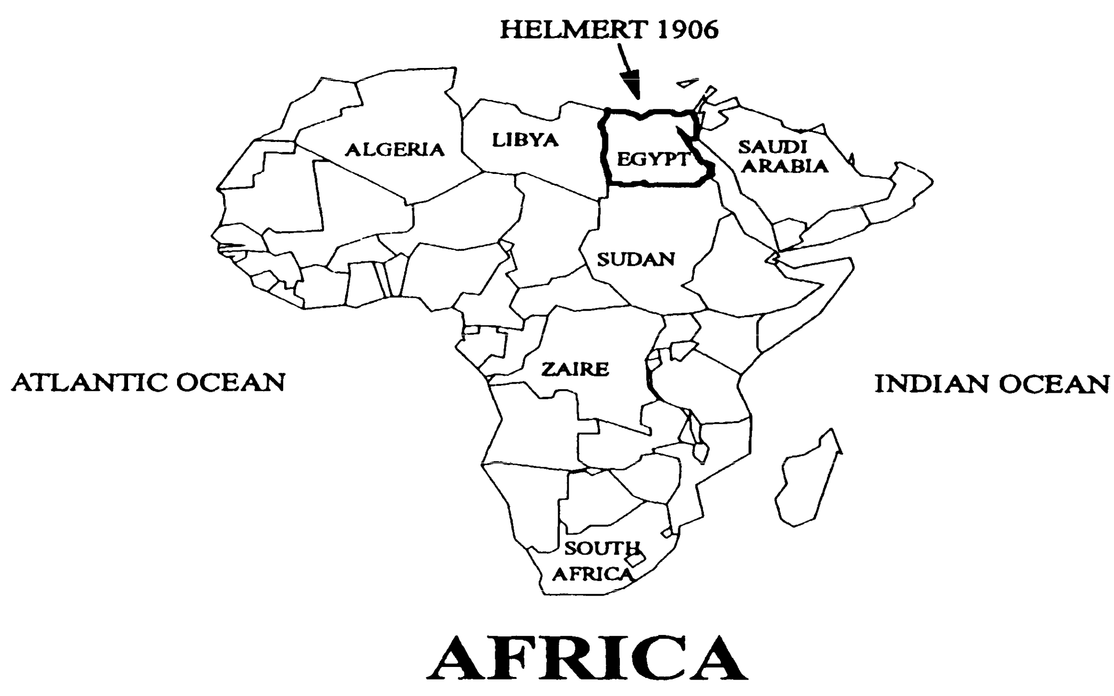


Table E-19. **Hough 1960**

HOUGH 1960								
a: 6378270	b:	1/f: 297				PADS		
Δ*a*: -133.000		Δ*f*x 10^7: -141.927				CODE: 14		
DATUM TRANSFORMATION PARAMETERS								
LOCAL DATUM TO WGS-84								
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF	
Wake-Eniwetok 1960	Marshall Islands	102	52	-38	ENW		2	

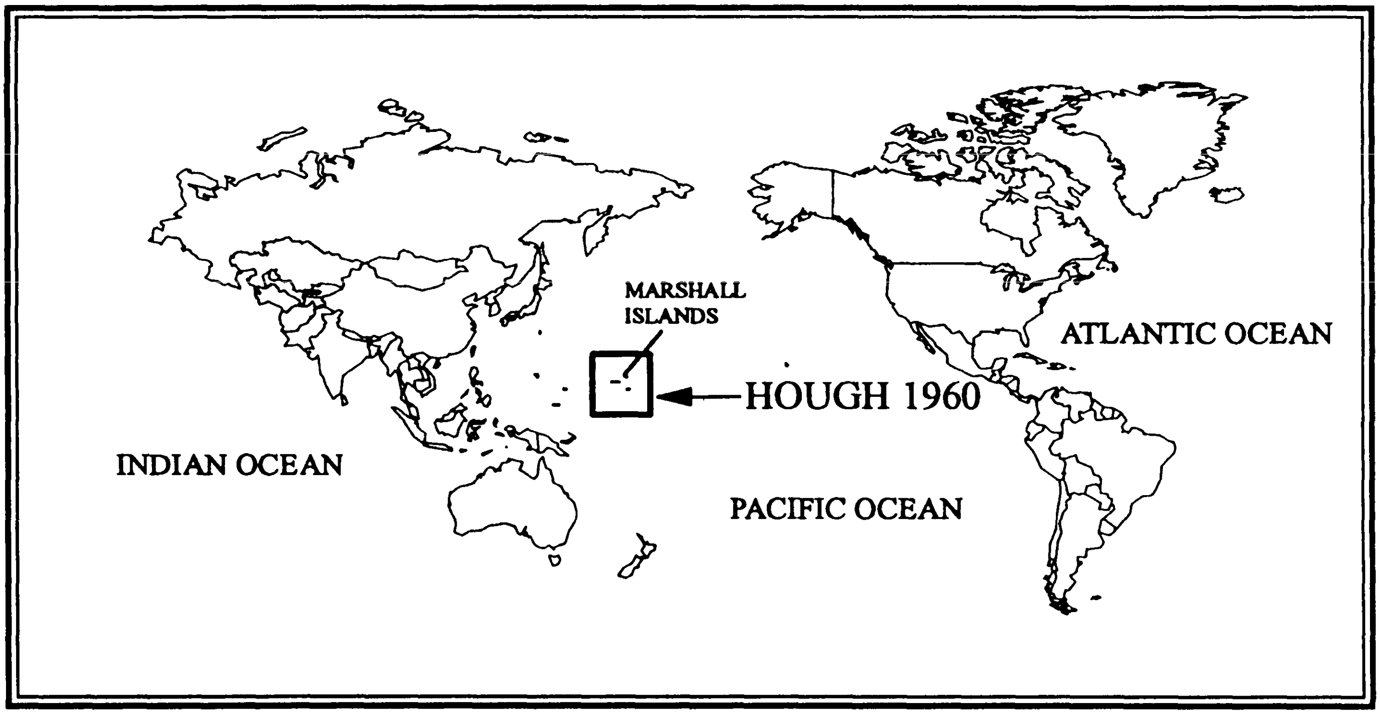


Table E-20. **Indonesian 1974**

INDONESIAN 1974								
a: 6378160.0	b:		1/f: 298.247				PADS	
Δa: -023.000			Δf x 10⁷: -001.149				CODE:	
DATUM TRANSFORMATION PARAMETERS								
LOCAL DATUM TO WGS-84								
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF	
Indonesian 1974	Indonesia	-24	-15	5	IDN		2	

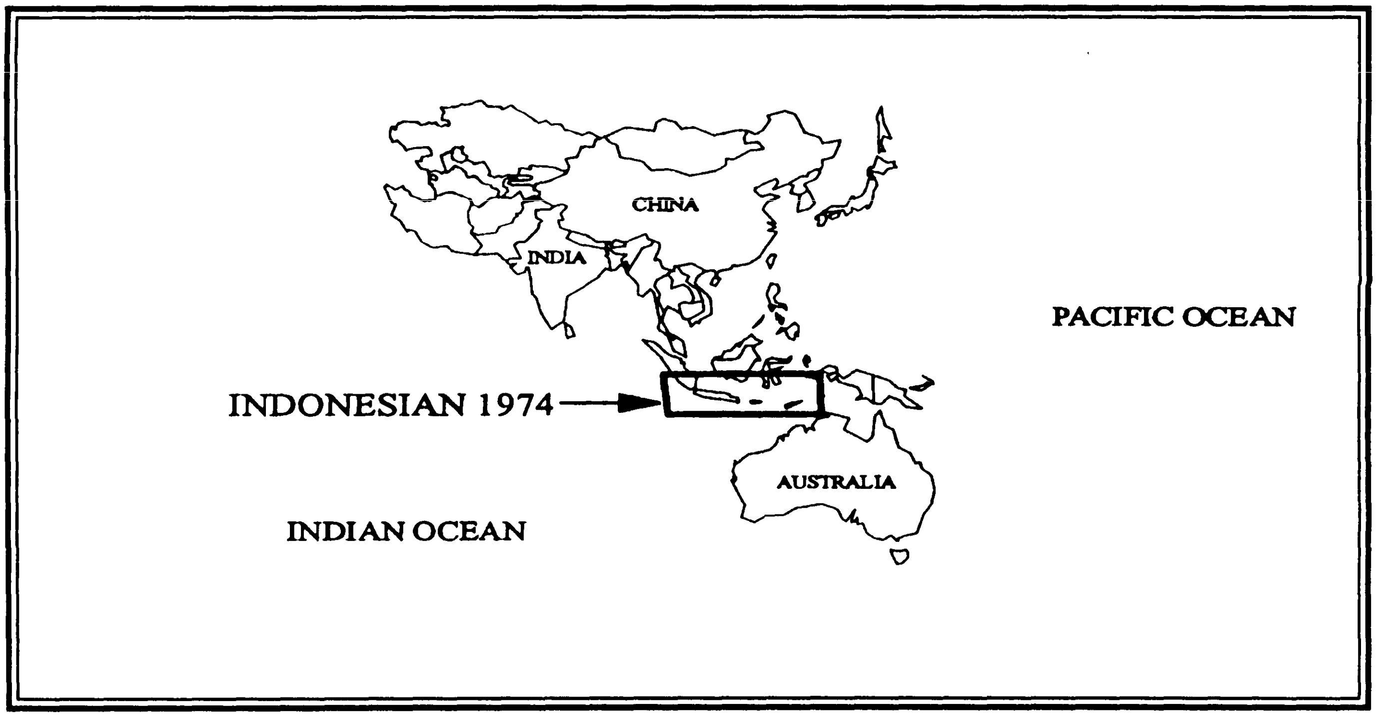


Table E-21. **International 1924**

INTERNATIONAL 1924
a: 6378388 b: 6356911.9462 1/f: 297 PADS
Δa: -251.000 Δf x 10⁷: -141.927 CODE: 2

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Ain El Abd 1970					AIN		
	Bahrain	-150	-250	-1	AIN-A		2
	Saudi Arabia	-143	-236	7	AIN-B		2
Ascension Island 1958	Ascension Island	-205	107	53	ASC		2
Astro Beacon "E" 1945	Iwo Jima	145	75	-272	ATF	8	2
Astro DOS 71/4	St. Helena Island	-320	550	-494	SHB	10	2
Astro Tern Island (Frig) 1961	Tern Island	114	-116	-333	TRN	9	2
Astronomical Station 1952	Marcus Island	124	-234	-25	ASQ	11	2
Bellevue (IGN)	Efate and Erromango Islands	-127	-769	472	IBE	14	2
Bissau	Guinea-Bissau	-173	253	27	BID		2
Bogota Observatory	Columbia	307	304	-318	BOO	16	2
Camp Area Astro	Camp McMurdo, Antarctica	-104	-129	239	CAZ		2
Campo Inchauspe 1969	Argentina	-148	136	90	CAI	17	2
Canton Astro 1966	Phoenix Islands	298	-304	-375	CAO	18	2
Chatham Island Astro 1971	Chatham Island (New Zealand)	175	-38	113	CHI	22	2
Chua Astro	Paraguay	-134	229	-29	CHU	23	2
Corrego Alegre	Brazil	-206	172	-6	COA	24	2
DOS 1968	Gizo Island (New Georgia Island)	230	-199	-752	GIZ	26	2
Easter Island 1967	Easter Island	211	147	111	EAS	27	2
European 1950 Africa					EUR		
	Egypt	-130	-117	-151	EUR-F		2
	Tunisia	-112	-77	-145	EUR-T		2

Table E-21. **International 1924 (continued)**

INTERNATIONAL 1924 Continued

a: 6378388 b: 6356911.9462 1/f: 297 PADS

Δa: -251.000 Δf x 10⁷: -141.927 CODE: 2

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
European 1950 Europe					EUR		
	Mean Solution	-87	-98	-121	EUR-M	28	2
	Western Europe (Austria, Denmark, France, Germany, Netherlands, and Switzerland)	-87	-96	-120	EUR-A		2
	Cyprus	-104	-101	-140	EUR-E		2
	England, Channel Islands, Scotland, and Shetland Islands	-86	-96	-120	EUR-G		2
	England, Ireland, Scotland, and Shetland Islands	-86	-96	-120	EUR-K		2
	Greece	-84	-95	-130	EUR-B		2
	Italy (Sardinia)	-97	-103	-120	EUR-I		2
	Italy (Sicily)	-97	-88	-135	EUR-J		2
	Malta	-107	-88	-149	EUR-L		2
	Norway and Finland	-87	-95	-120	EUR-C		2
	Portugal and Spain	-84	-107	-120	EUR-D		2
European 1950 Middle East					EUR		
	Iran	-117	-132	-164	EUR-H		2
	Israel, Kuwait, Jordan,Lebanon, Saudi Arabia, Iraq,and Syria	-103	-106	-141	EUR-S		2
European 1979	Mean Solution (Austria, Finland, Netherlands, Norway, Spain, Sweden, and Switzerland	-86	-98	-119	EUS	29	2
Gan 1970 (Gandajika Base)	Republic of Maldives	-133	-321	50	GAA	30	2

Table E-21. **International 1924 (continued)**

INTERNATIONAL 1924 Continued
a: 6378388 b: 6356911.9462 1/f: 297 PADS
Δa: -251.000 Δfx 10⁷: -141.927 CODE: 2

DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Geodetic Datum 1949	New Zealand	84	-22	209	GEO	31	2
Graciosa Base SW 1948	Azores (Faial, Graciosa, Pico, Sao Jorge, and Terceira Island)	-104	167	-38	GRA		2
Gux 1 Astro	Guadalcanal	252	-209	-751	DOB	33	2
Herat North	Afghanistan	-333	-222	114	HEN		2
Hjorsey 1955	Iceland	-73	46	-86	HJO	34	2
Hong Kong 1963	Hong Kong	-156	-271	-189	HKD	35	2
Hu-Tzu-Shan	Taiwan	-637	-549	-203	HTN		2
ISTS 061 Astro 1968	South Georgia Island	-794	119	-298	ISG		2
ISTS 073 Astro 1969	Diego Garcia	208	-435	-229	IST	39	2
Johnston Island 1961	Johnston Island	189	-79	-202	JOH		2
Kerguelen Island 1949	Kerguelen Island	145	-187	103	KEG	42	2
Kusaie Astro 1951	Caroline Islands	647	1777	-1124	KUS		2
Midway Astro 1961	Midway Islands	912	-58	1227	MID	53	2
Naparima BWI	Trinidad and Tobago	-10	375	165	NAP		2
Observatorio Meteorologico 1939	Azores (Corvo and Flores Island)	-425	-169	81	FLO	72	2
Pico De Las Nieves	Canary Islands	-307	-92	127	PLN	77	2
Pitcairn Astro 1967	Pitcairn Island	185	165	42	PIT	78	2
Porto Santo 1936 (Southeast Base)	Porto Santo and Madeira Islands	-499	-249	314	POS	90	2

Table E-21. **International 1924 (continued)**

INTERNATIONAL 1924 Continued

a: 6378388 b: 6356911.9462 1/f: 297 PADS

Δa: -251.000 Δf x 10⁷: -141.927 CODE: 2

DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Provisional South American 1956					PRP		
	Mean Solution (Bolivia, Chile, Columbia, Peru, Ecuador, Guyana, and Venezuela)	-288	175	-376	PRP-M	80	2
	Bolivia	-270	188	-388	PRP-A		2
	Northern Chile (near 19° south)	-270	183	-390	PRP-B		2
	Southern Chile (near 43° south)	-305	243	-442	PRP-C		2
	Columbia	-282	169	-371	PRP-D		2
	Ecuador	-278	171	-367	PRP-E		2
	Guyana	-298	159	-369	PRP-F		2
	Peru	-279	175	-379	PRP-G		2
	Venezuela	-295	173	-371	PRP-H		2
Provisional South Chilean 1963 (Hito XVIII 1963)	Southern Chile (near 53° south)	16	196	93	HIT	79	2
Qatar National	Qatar	-128	-283	22	QAT	82	2
Qornoq	South Greenland	164	138	-189	QUO	83	2
Reunion	Mascarene Island	94	-948	-1262	REU	44	2
Rome 1940	Sardinia	-225	-65	9	MOD	84	2
Santo (DOS) 1965	Espirito Santo Island	170	42	84	SAE	86	2
Sao Braz	Azores (Sao Miguel, Santa Maria Island)	-203	141	53	SAO	85	2
Sapper Hill 1943	East Falkland Island	-355	21	72	SAP		2
Selvagem Grande 1938 (Marco Astro)	Salvage Islands	-289	-124	60	SGM	50	2

Table E-21. **International 1924 (continued)**

INTERNATIONAL 1924 Continued

a: 6378388	b: 6356911.9462	1/f: 297	PADS
Δa: -251.000		Δf x 10⁷: -141.927	CODE: 2

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
Tananarive Observatory 1925	Madagascar	-189	-242	-91	PRP-E		2
Tristan Astro 1968	Tristan Da Cunha	-632	438	-609	TDC	94	2
Wake Island Astro 1952	Wake Atoll	276	-57	149	WAK		2
Yacare	Uruguay	-155	171	37	YAC		2
Zanderij	Suriname	-265	120	-358	ZAN	84	2

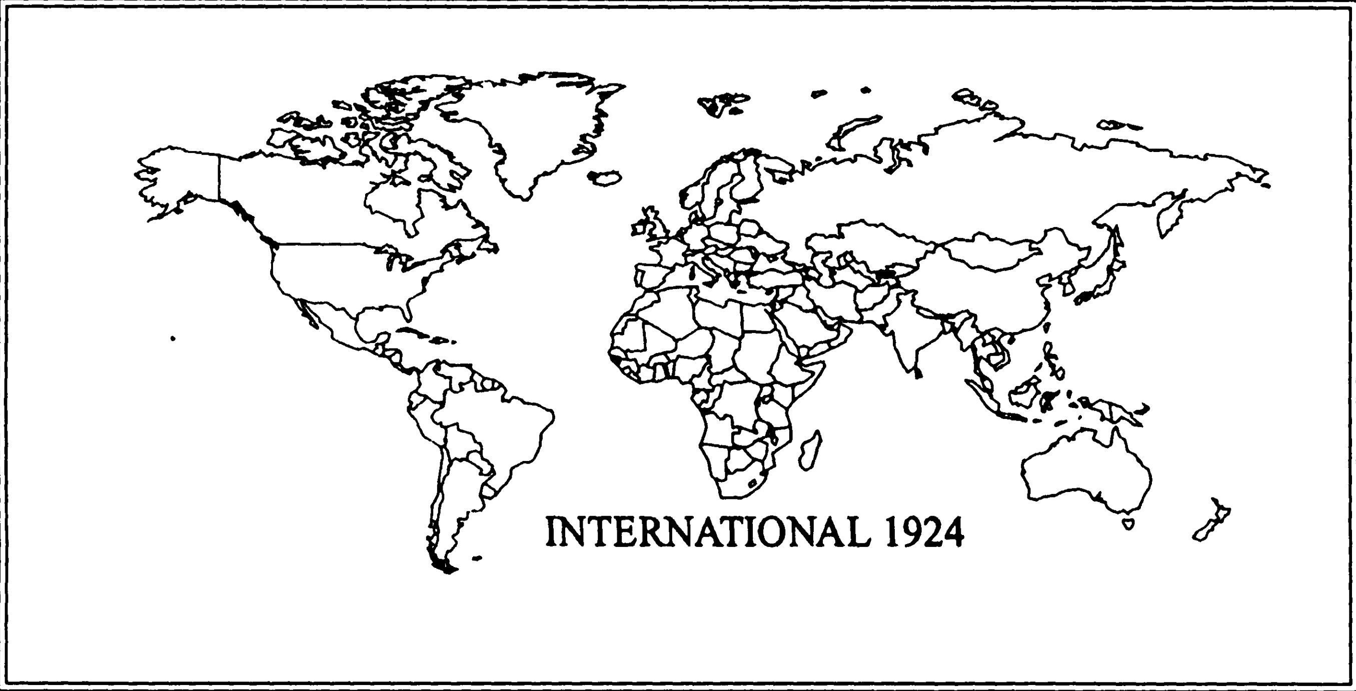


Table E-22. **Krassovsky 1940**

KRASSOVSKY 1940								
a: 6378245	b:	1/f: 298.3				PADS		
Δa: -108.000		Δfx 10^7: +004.808				CODE: 13		
DATUM TRANSFORMATION PARAMETERS								
LOCAL DATUM TO WGS-84								
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF	
Afgooye	Somalia	-43	-163	45	AFG	2	2	
Herat North (See Note three)	Afghanistan						4	
Peking 1954	Shanghai, China	-12	-113	-41	PUK			
Pulkovo 1942	Russia	28	-130	-95	PUK		2	
S-42 (Pulkovo 1942)	Hungary	28	-121	-77	SPK		2	

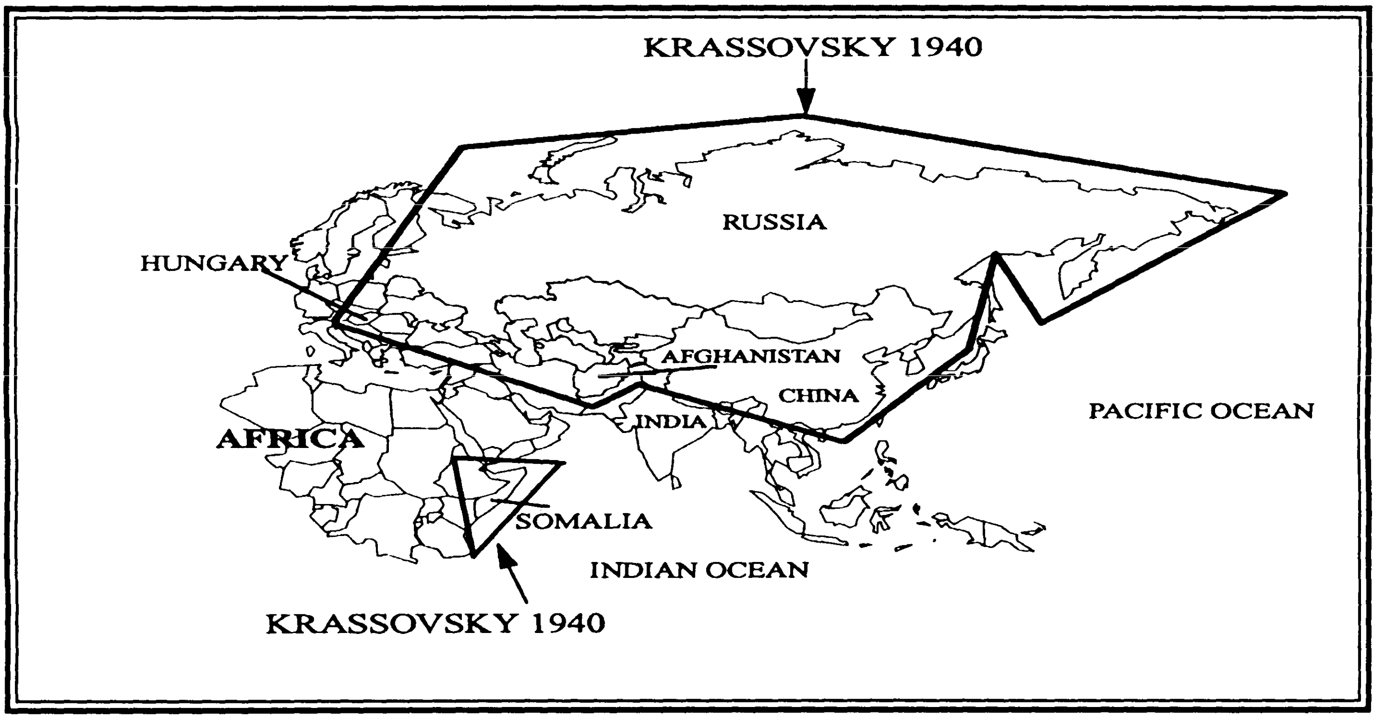


Table E-23. **Soviet Geodetic System 1985**

SOVIET GEODETIC SYSTEM 1985							
a: 6378136	b:	1/f: 298.257			PADS		
Δa: +001.000		Δf x 10⁷: -000.025			CODE:		
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
SGS-1985	Asia and Europe	3	9	-9			5

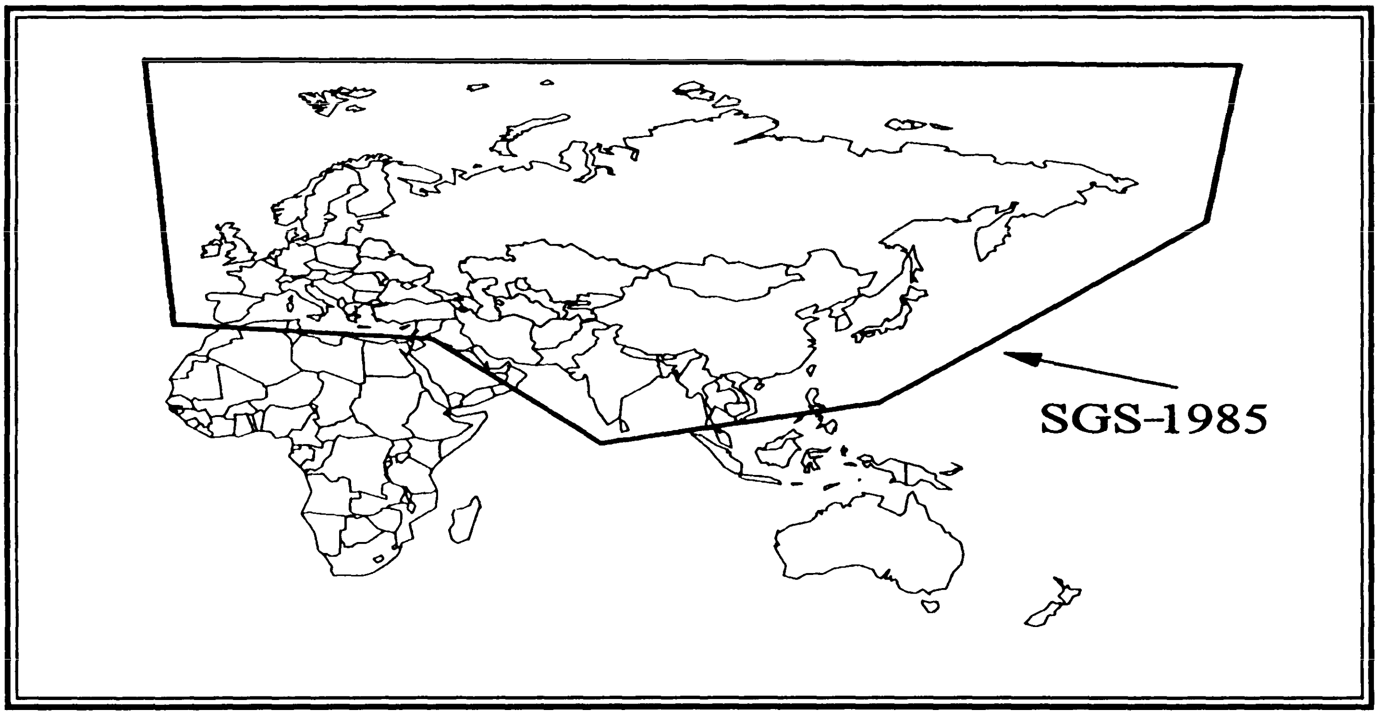


Table E-24. **South American 1969**

SOUTH AMERICAN 1969 (SEE NOTE SIX)

a: 6378160 | b: 6356774.7192 | 1/f: 298.25 | PADS CODE: 8

Δa: -023.000 | Δf x 10⁷: -000.812

DATUM TRANSFORMATION PARAMETERS

LOCAL DATUM TO WGS-84

LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
South American 1969					SAN		
	Mean Solution (South America)	-57	1	-41	SAN-M	88	2
	Argentina	-62	-1	-37	SAN-A		2
	Bolivia	-61	2	-48	SAN-B		2
	Brazil	-60	-2	-41	SAN-C		2
	Chile	-75	-1	-44	SAN-D		2
	Colombia	-44	6	-36	SAN-E		2
	Ecuador (excluding Galapagos Islands)	-48	3	-44	SAN-F		2
	Ecuador (Baltra, Galapagos Islands)	-47	26	-42	SAN-J		2
	Guyana	-53	3	-47	SAN-G		2
	Paraguay	-61	2	-33	SAN-H		2
	Peru	-58	0	-44	SAN-I		2
	Trinidad and Tobago	-45	12	-33	SAN-K		2
	Venezuela	-45	8	-33	SAN-L		2

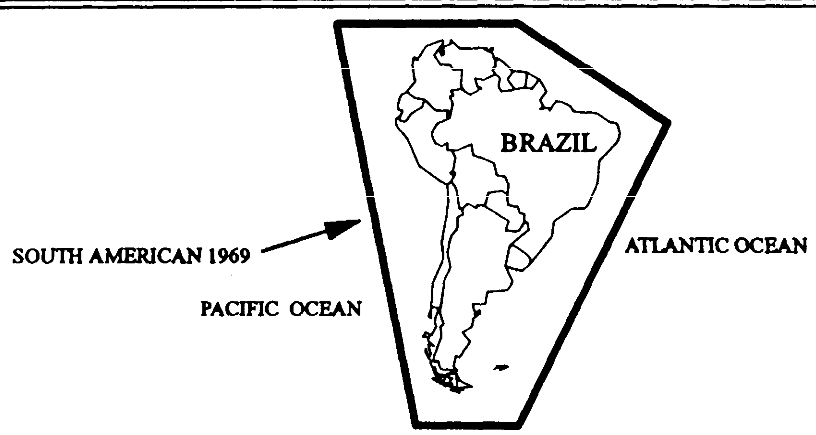
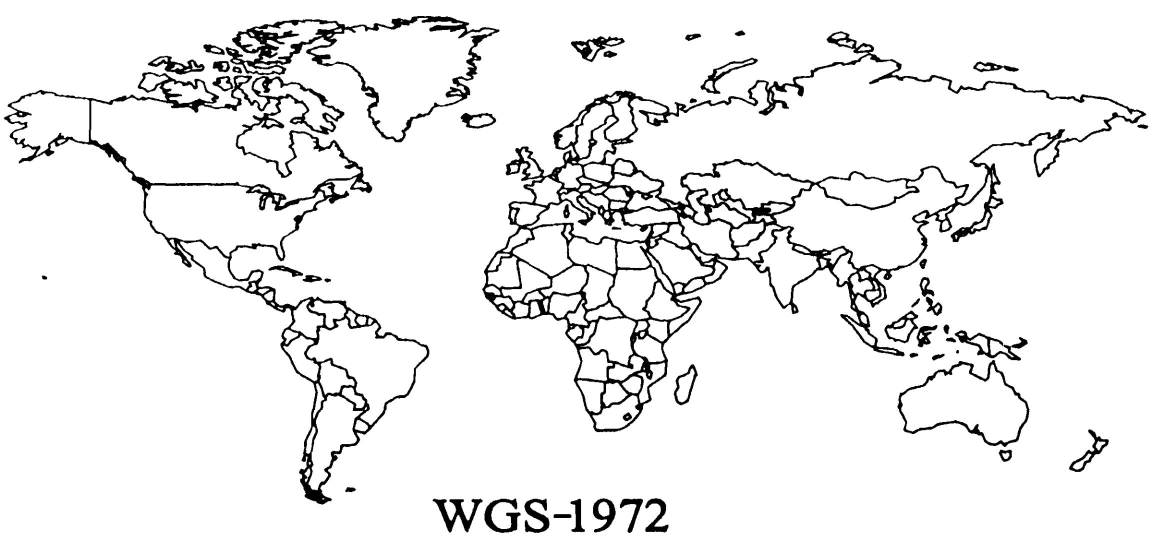


Table E-25. **World Geodetic System 1972**

WORLD GEODETIC SYSTEM 1972) a: 6378135 Δa: NA	b: 6356750.5		1/f: 298.26 Δf x 10⁷: NA			PADS CODE: 13	
DATUM TRANSFORMATION PARAMETERS							
LOCAL DATUM TO WGS-84							
LOCAL GEODETIC DATUM	COUNTRY/ AREA	TRANSFORMATION PARAMETERS ΔX	ΔY	ΔZ	DATUM CODE	DDCT CODE	REF
WGS-1972 (See Note two)	Global	NA	NA	NA	WD	97	2



E-5. NOTES FOR DATUM TABLES

a. Note 1. Any entry reading SEE NOTE ONE in Tables E-3 through E-25 of this appendix are so noted because of inconsistent listings of datums referenced to the Clarke 1880 ellipsoid. Table E-1 lists five different Clarke 1880 ellipsoids. DMA has adopted only one. Different countries have adopted different dimensions for the Clarke 1880 ellipsoid. These differences depend on two things: which of Clarke's original numbers were used ([a, b] or [a, f]) or which foot-to-meter conversion was used.

(1) In areas referenced to the ARC 1950 datum, the Clarke 1880 dimensions adopted are shown below.

a: 6378249.145326 b: 6356514.966721 f: 1/293.4663076

(2) In areas referenced to Carthage, Merchich, and Voirol datums, the adopted dimensions are shown below.

a: 6378249.2 b: 6356515.0 f: 1/293.46598

(3) The DMA-adopted dimensions are shown below.

a: 6378249.145 b: 6356514.8696 f: 1/293.465

(4) DMA TM 8350.2 with Insert 1 lists datum transformation parameters for local datums referenced to the DMA-adopted Clarke 1880 and not the dimensions adopted by other countries. Any datum with SEE NOTE ONE in the DDCT CODE column should be transformed to other datums with the user-defined option.

b. Note 2. WGS-72 is transformed to WGS-84 with a formula that is more accurate than the Abridged Molodensky formulas; therefore, datum shifts are not necessary. The formulas used are as follows:

$$\phi\text{WGS-84} = \phi\text{WGS-72} + \Delta\phi$$

$$\lambda\text{WGS-84} = \lambda\text{WGS-72} + \Delta\lambda$$

$$h\text{WGS-84} = h\text{WGS-72} + \Delta h$$

whereas:

$$\Delta\phi'' = (4.5 \cos \phi)/(a \sin 1'') + (\Delta f \sin 2\phi)/(\sin 1'')$$

$$\Delta\lambda'' = 0.554$$

$$\Delta\lambda = 4.5 \sin \phi + a\, \Delta f \sin^2 \phi - \Delta a + \Delta r$$

when:

$$\Delta f = 0.3121057 \times 10^{-7}$$

$$a = 6378135\ m$$

$$\Delta a = 2.0\ m$$

$$\Delta r = 1.4\ m$$

These formulas are explained in detail in DMA TR 8350.2.

c. Note 3. Herat North Datum was used by the Soviet Union with Krassovsky as the reference ellipsoid in northern Afghanistan. The US and United Kingdom used Herat North Datum with International as the reference ellipsoid to triangulate in southern Afghanistan. The connection between these two systems usually differs by 20 to 30 meters. Herat North Datum referenced to Krassovsky ellipsoid is programmed option in the Gauss-Kruger Grid (Module 15) in the BUCS DDCT Rev 0.

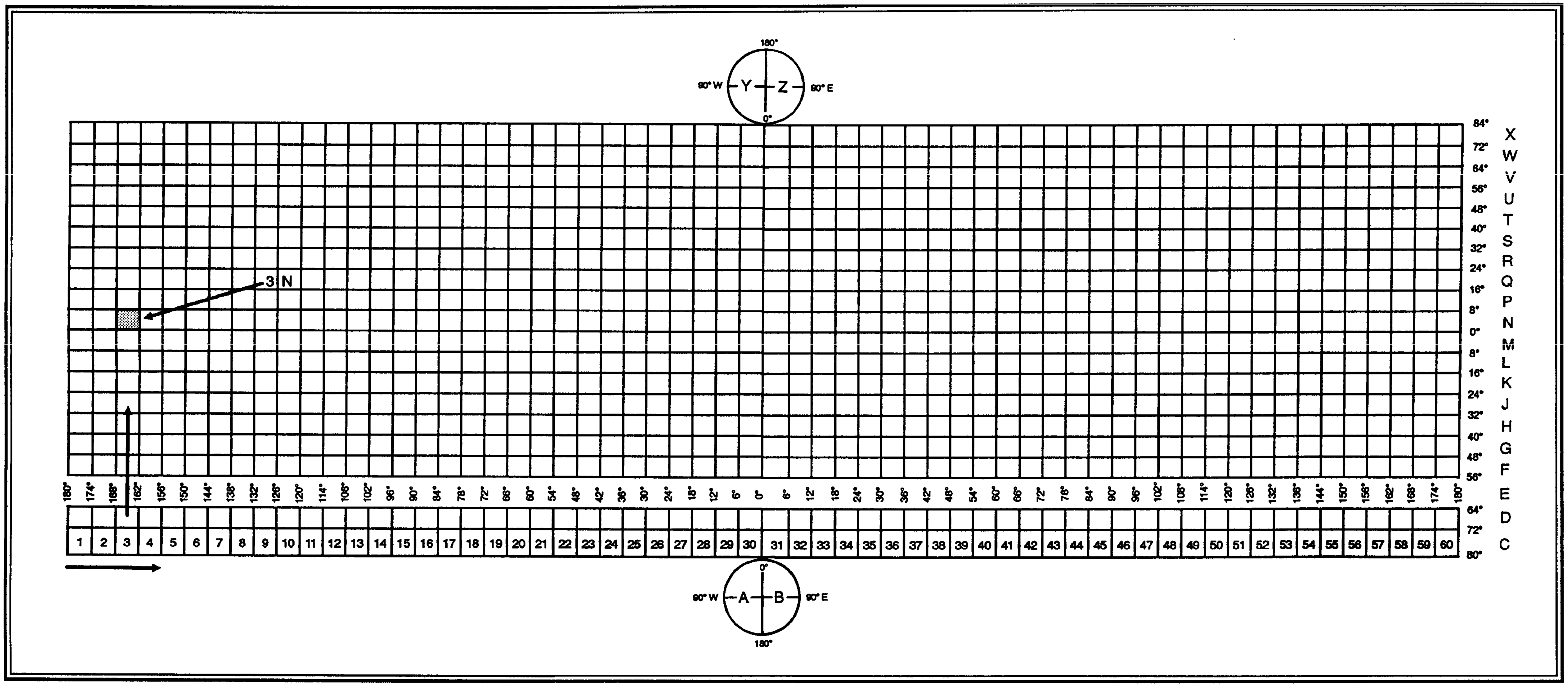
d. Note 4. Potsdam Datum was used with the Gauss-Kruger Grid in eastern Germany and is a programmed option in Module 15 of the BUCS DDCT Rev 0.

e. Note 5. The IUGG recommended the adoption of the ellipsoid GRS-67 at their 1967 meeting in Lucerne, Switzerland. The new ellipsoid was adopted for use when a greater degree of accuracy was needed than could be obtained with the International 1924 ellipsoid. The ellipsoid became part of the Geodetic Reference System of 1967, which was adopted in 1971 by the IUGG meeting in Moscow. This ellipsoid is used in both South America and Australia; however, the name was changed to South American 1969 and Australian National to more conveniently describe the reference ellipsoid. DMA TR 8350.2 lists the more convenient names of these ellipsoids.

APPENDIX F

GRID ZONE CHART

BUCS DDCT does not recognize the abnormal-sized grid zones 31, 33, 35, and 37 between 72° and 84° north latitude. Additionally, it does not recognize the absence of grid zones 32, 34, and 36 between the same latitudes. The Norwegian island group of Svalbard is the only major land mass in this region.



APPENDIX G

STAR CARDS

Surveyors should be familiar with the location of stars and the magnitude of stars. Figure G-2 through G-20 show the constellations recognized by artillery surveyors. Use the alphabetical index below to locate the constellation desired. Figure G-1 describes the magnitude of the stars in the constellations.

CONSTELLATION	SURVEY STARS	MAGNITUDE	FIGURE(S)
Andromeda	Alpheratz	2.1	G-7, G-8
Aquila	Altair	0.9	G-7
Aries	Hamal	2.2	G-8
Auriga	Capella	0.2	G-5
Bootes	Arcturus	0.2	G-3, G-17
Canis Major	Sirius	-1.6	G-6
	Adhara	1.6	
	Wezen	2.0	
Canis Minor	Procyon	0.5	G-6
Carina	Canopus	-0.9	G-19
	Avior	1.7	
	Misplacidus	1.8	
Cassiopeia	Schedar	2.3	G-18
	Caph	2.4	
	Ruchbah	1.6-2.8	
	Gamma Cassiopeiae	0.1	G-20
Centaurus	Rigil Kentaurus	0.9	
	Hadar	2.3	
	Menker	2.2	G-2
Cetus	Diphda	2.8	
	Menkar	2.3	G-3
Corona Borealis (Northern Crown)	Alphecca	2.8	G-9
Corvus	Gienah	1.0	G-20
Crux (Southern Cross)	Acrux	1.5	
	Mimosa	1.6	
	Gacrux	1.3	G-7
Cygnus	Deneb	2.4	G-18
Draco	Eltanin	0.6	G-13
Eridanus	Achemar	3.4	
	Acamar	1.2	G-5
Gemini	Pollux	1.6	
	Castor	1.9	
	Alhena		

CONSTELLATION	SURVEY STARS	MAGNITUDE	FIGURE(S)
Great Square	Alpheratz	2.1	G-10
	Enif	2.5	
	Markab	2.6	
Grus	Al Na'ir	2.2	G-11
Hydra	Alphard	2.2	G-9, G-14
	Beta Hydrus	2.9	
Leo	Regulus	1.3	G-15
	Denebola	2.2	
Libra	Zebeneigenubi	2.9	G-16
Lyra	Vega	0.1	G-7
Octans	Nu	3.7	G-14
Ophiuchus	Rasalhague	2.1	G-16
	Sabik	2.6	
Orion	Rigel	0.3	G-8
	Betelgause	0.1	
	Bellatrix	1.7	
	Alnilam	1.7	
	Alnitak	2.0	
Pavo	Peacock	2.1	G-12
Pegasus	Enif	2.5	G-10
	Markab	2.6	
Perseus	Mirfak	1.9	G-8
Phoenix	Ankaa	2.4	G-11, G-13
Piscis Austrinus	Fomalhaut	1.3	G-11
Scorpius	Antares	1.2	G-4, G-16
	Shaula	1.7	
	Dschubba	2.5	
Sagittarius	Kaus Australis	1.9	G-4
	Nunki	2.1	
Taurus	Aldebaran	1.1	G-5, G-8
	El Nath	1.8	
Triangulum Australe	Atria	1.9	G-14
Ursa Major	Alioth	1.7	G-17
	Alkaid	1.9	
	Dubhe	1.9	
	Mizar	2.4	
	Merak	2.4	
	Phecda	2.5	
Ursa Minor	Polaris	2.1	G-17, G-18
	Kochab	2.2	
Vela	Gamma Velorum	1.9	G-19
	Suhail	2.2	
Virgo	Spica	1.2	G-15

Figure G-1. **Magnitude of stars**

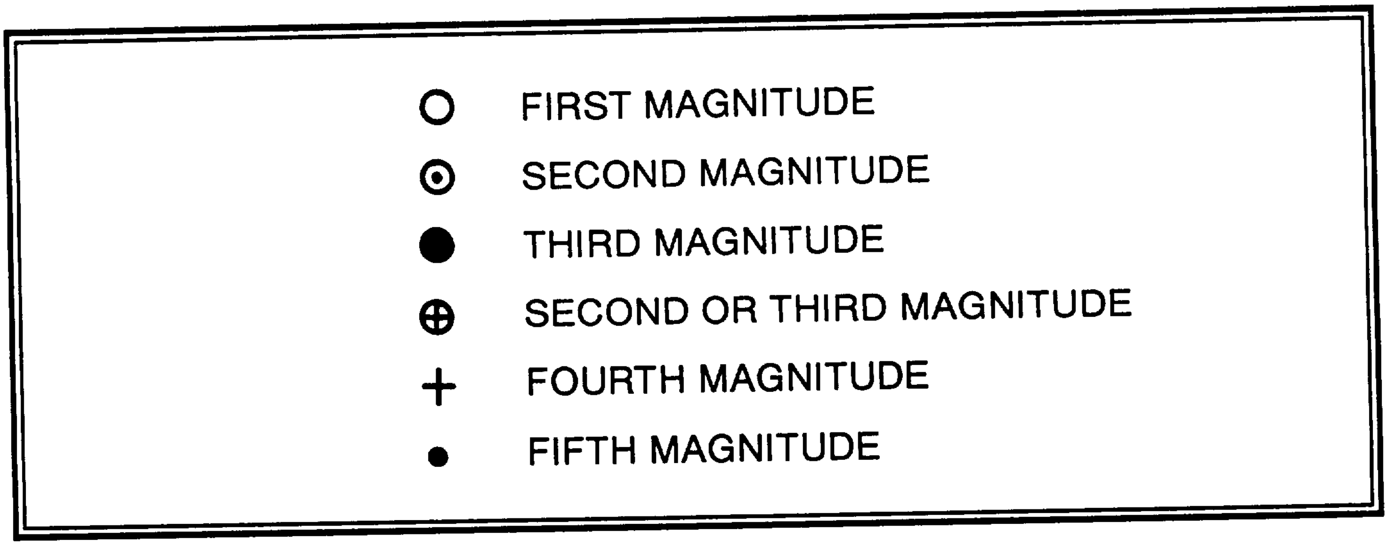


Figure G-2. **Cetus**

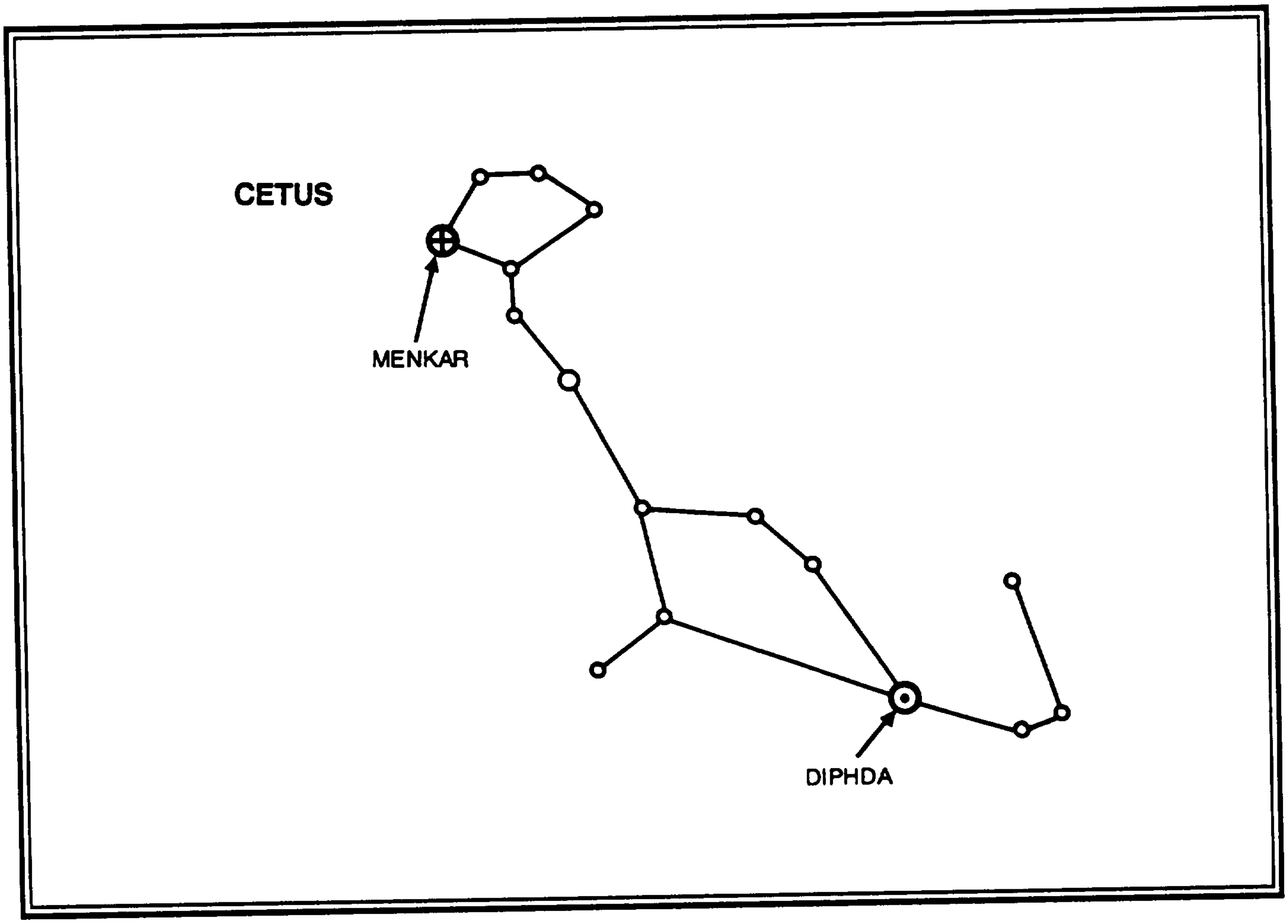


Figure G-3. **Corona Borealis and Bootes**

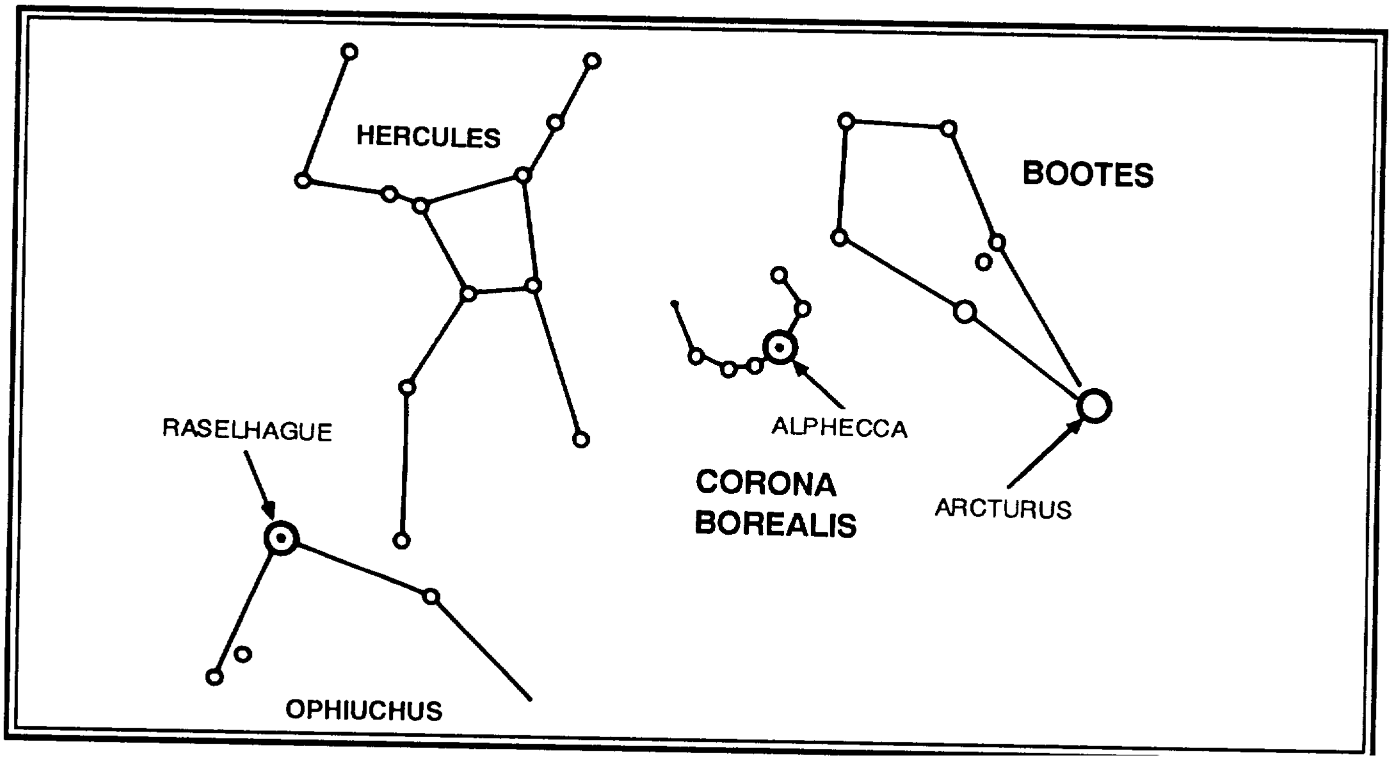


Figure G-4. **Sagittarius and Scorpius**

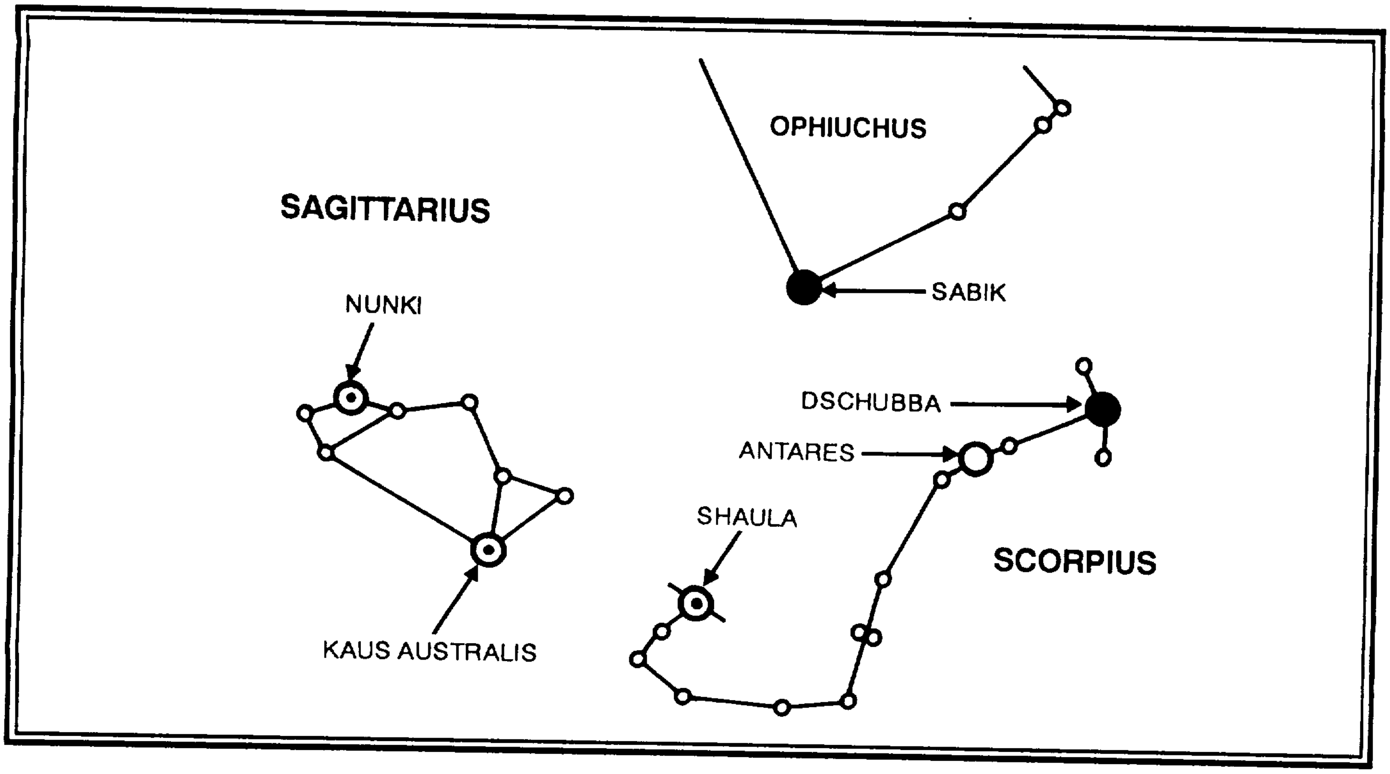


Figure G-5. **Gemini, Auriga, and Taurus**

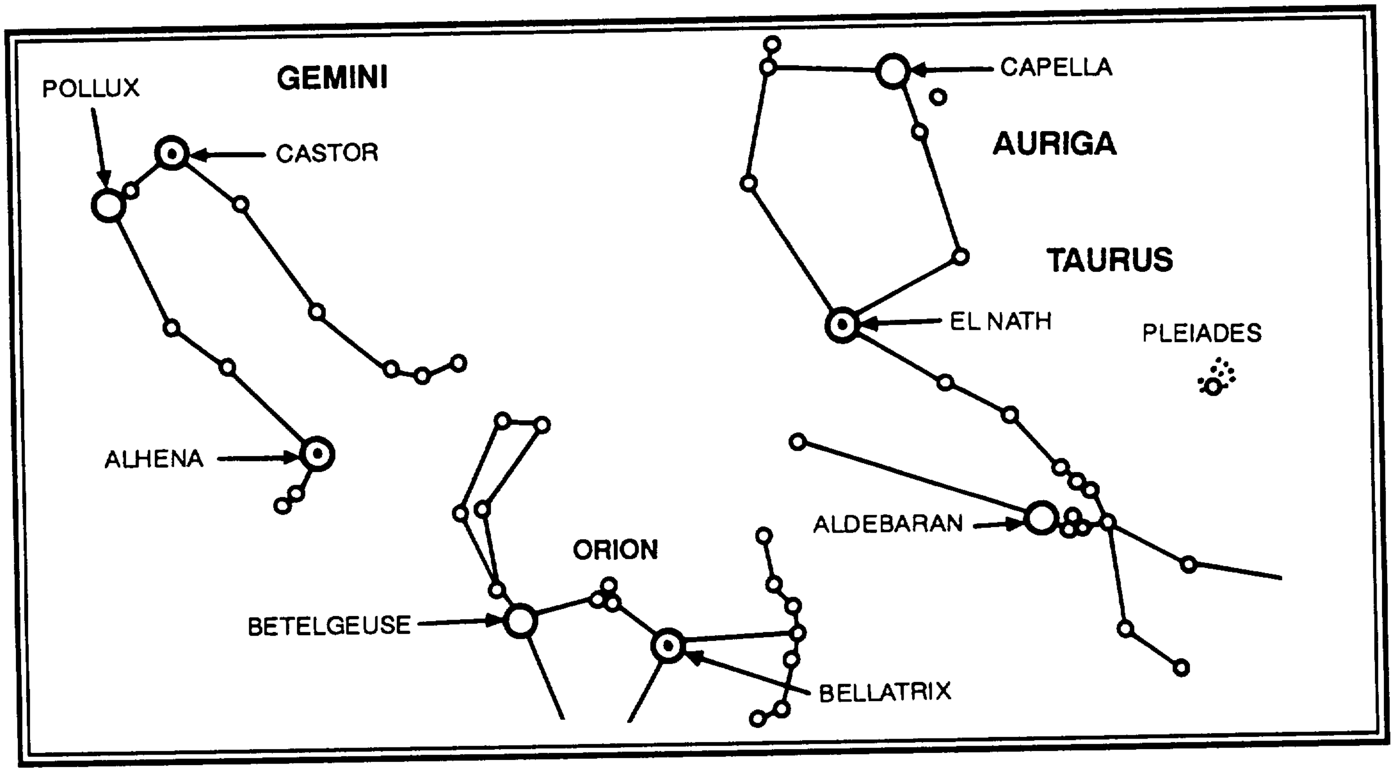


Figure G-6. **Canis Minor, Canis Major, and Orion**

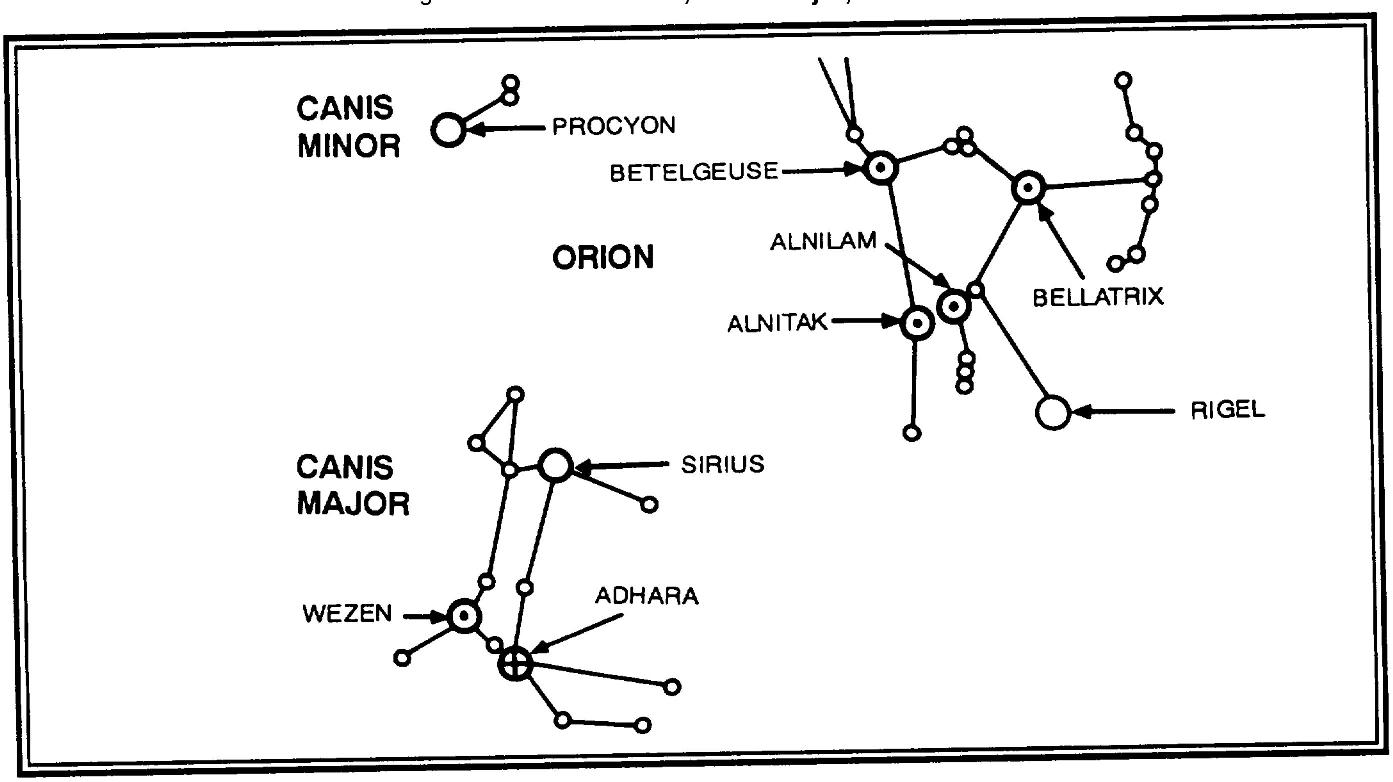


Figure G-7. **Cygnus, Lyra, and Aquila**

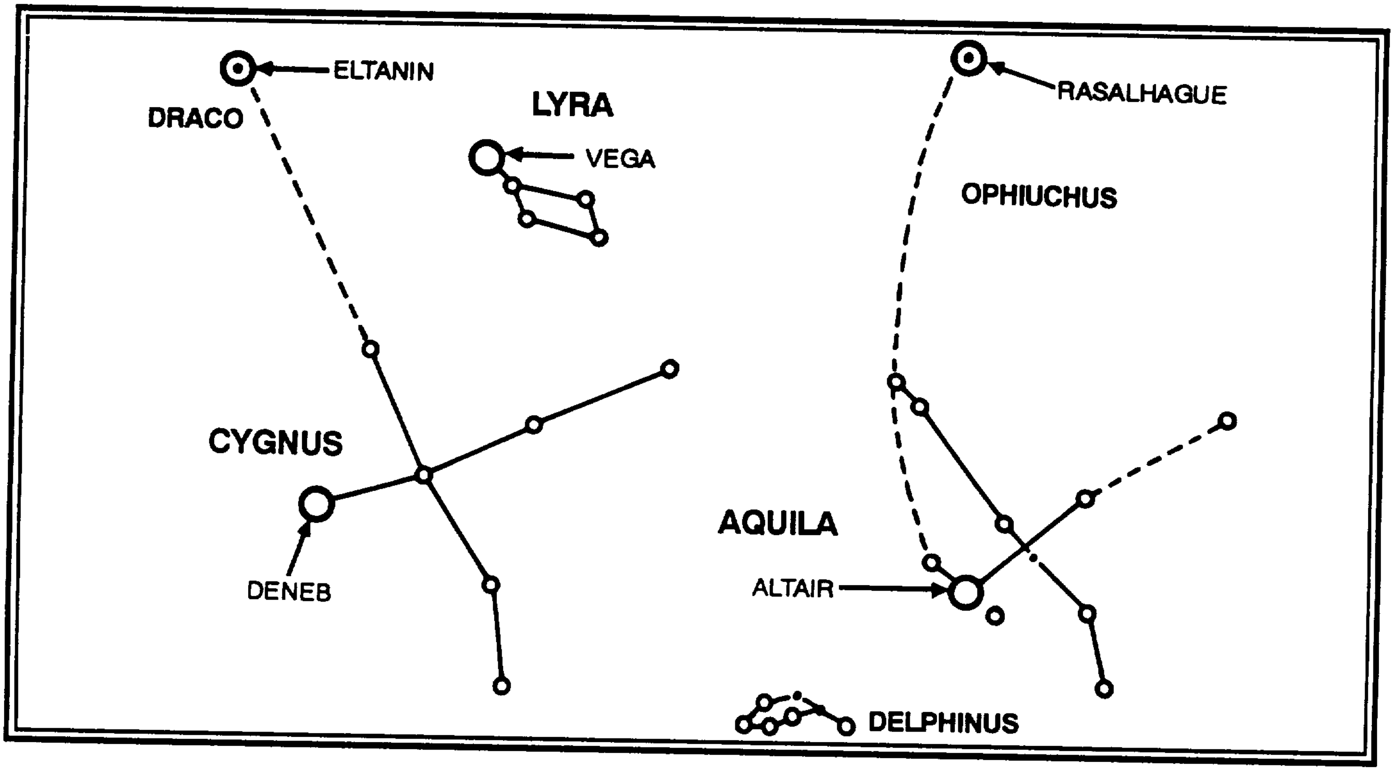


Figure G-8. **Taurus, Perseus, Aries, and Andromeda**

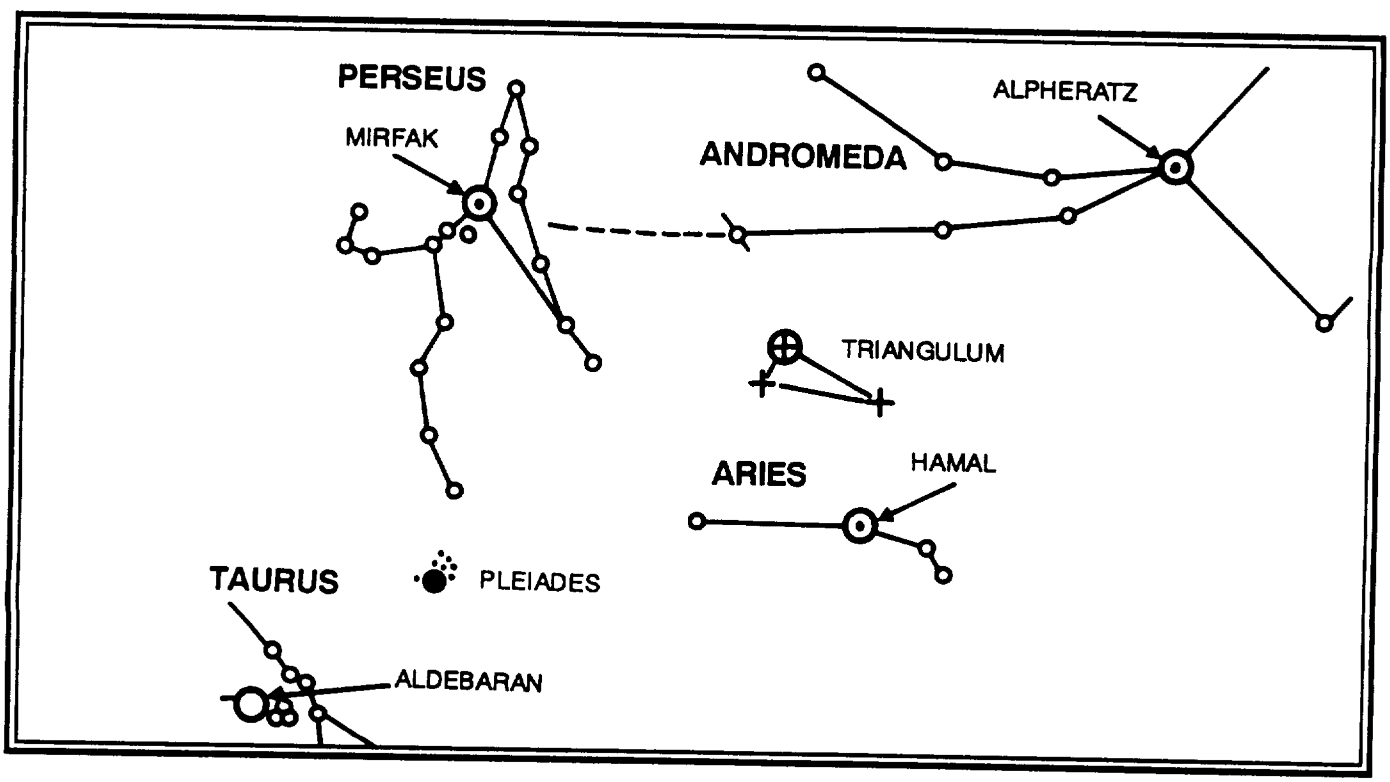


Figure G-9. **Corvus and Hydra**

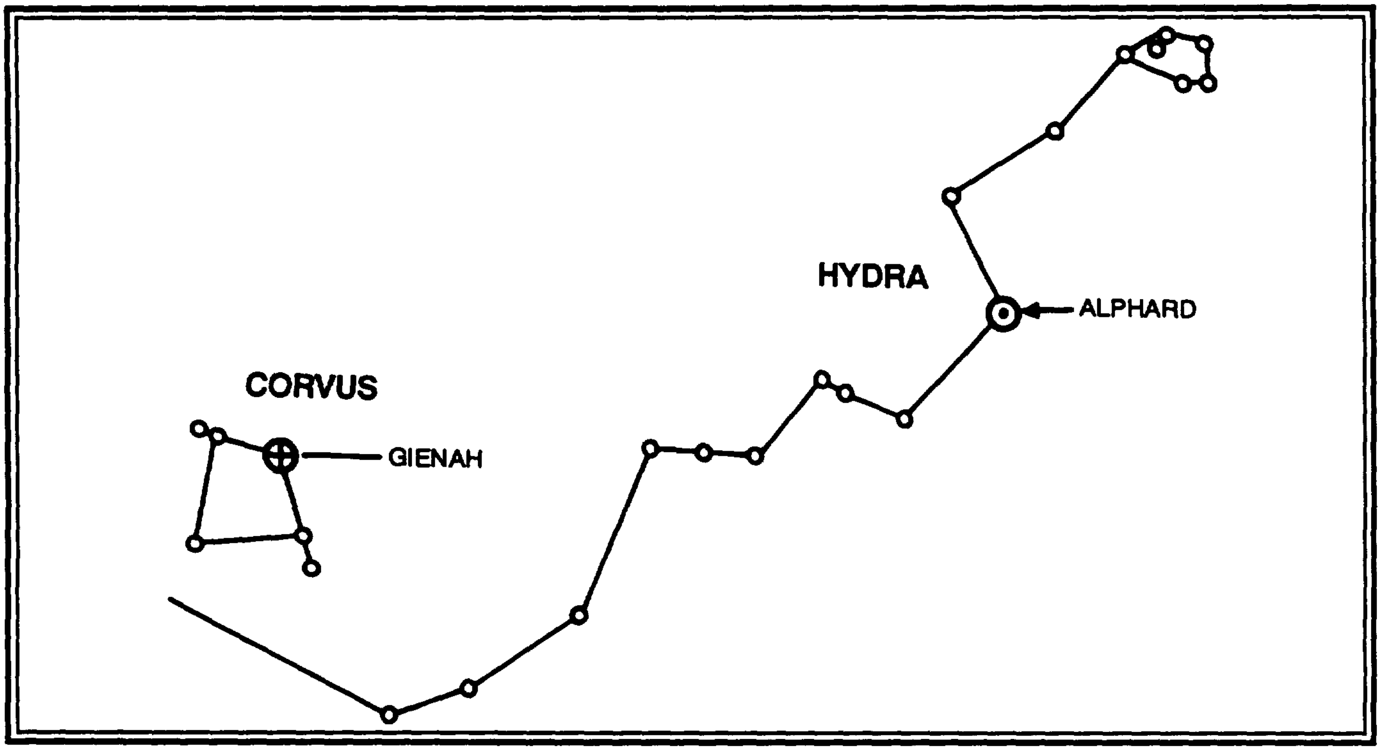


Figure G-10. **Andromeda, Great Square, and Pegasus**

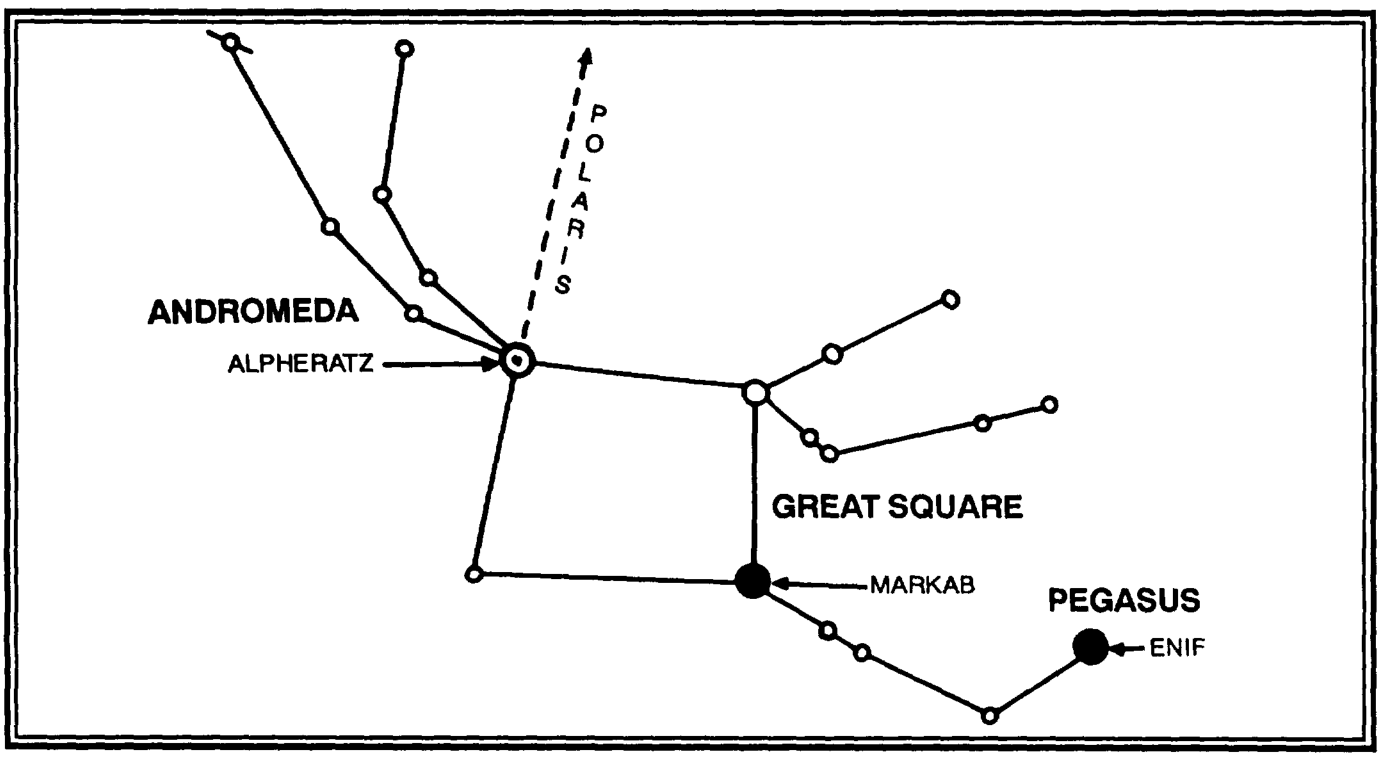


Figure G-11. **Phoenix, Piscis Austrinus, and Grus**

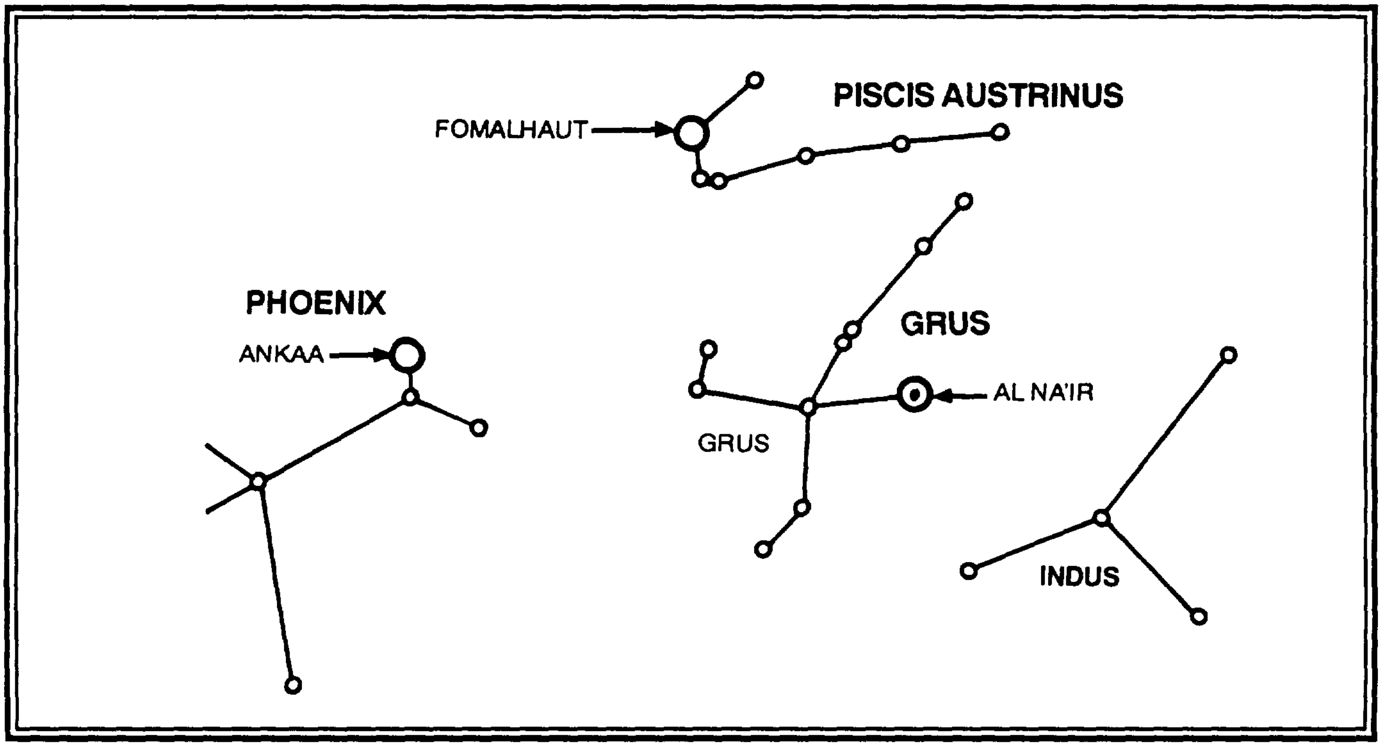


Figure G-12. **Pavo**

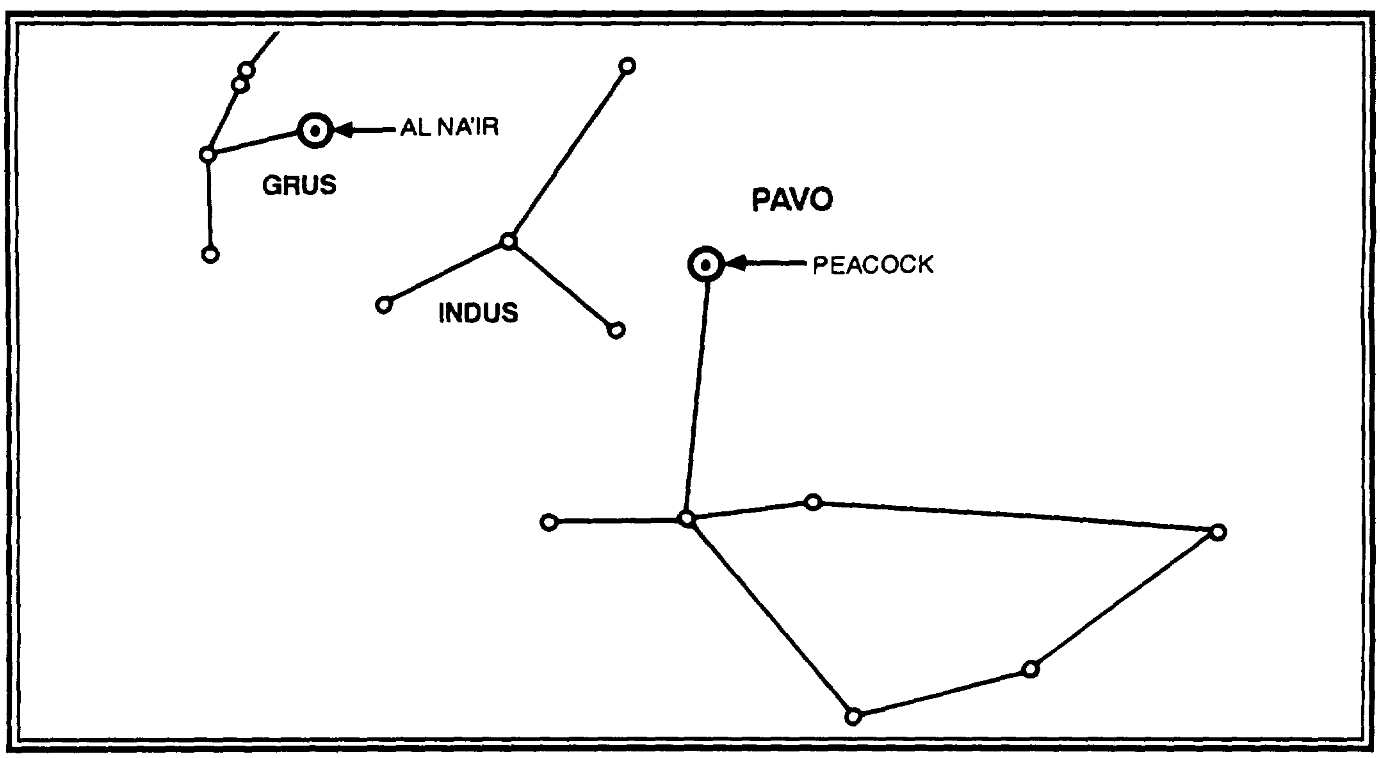


Figure G-13. **Eridanus and Phoenix**

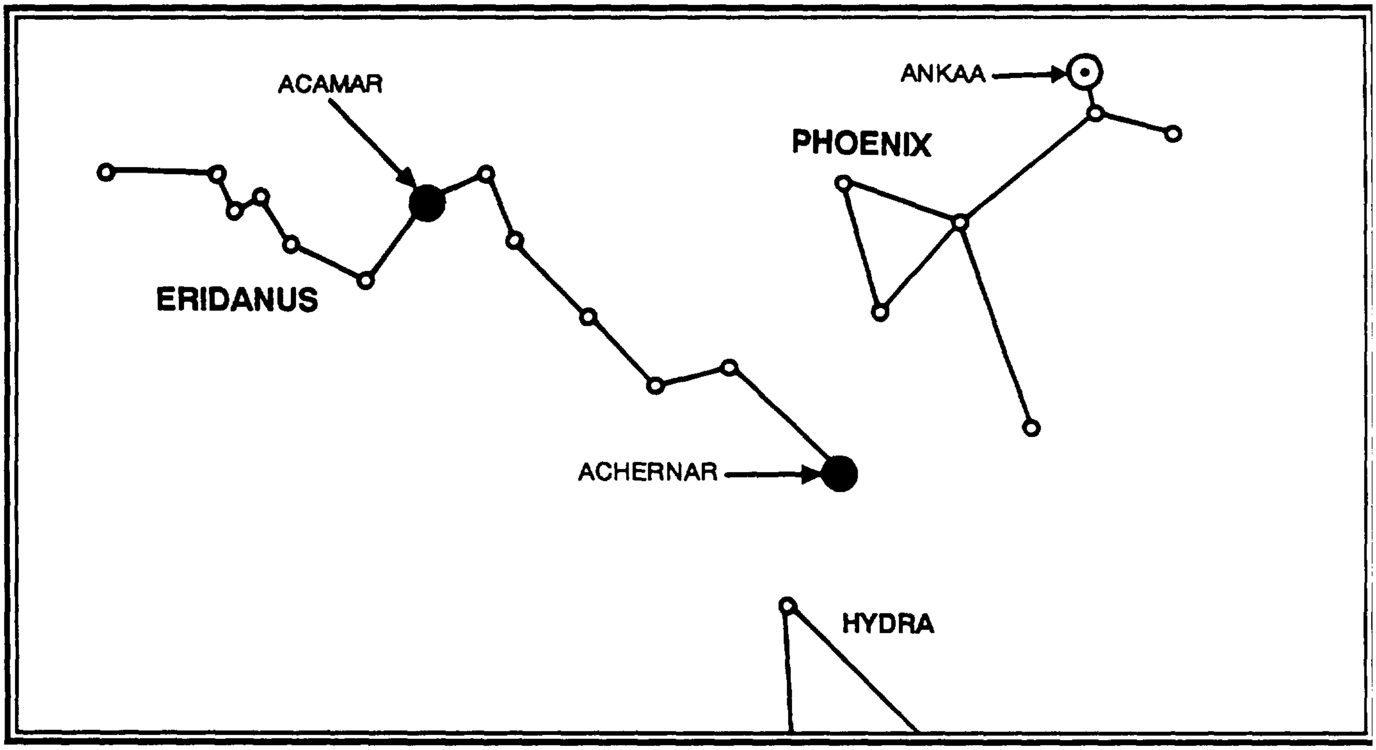


Figure G-14. **Hydra, Octans, and Triangulum Australe**

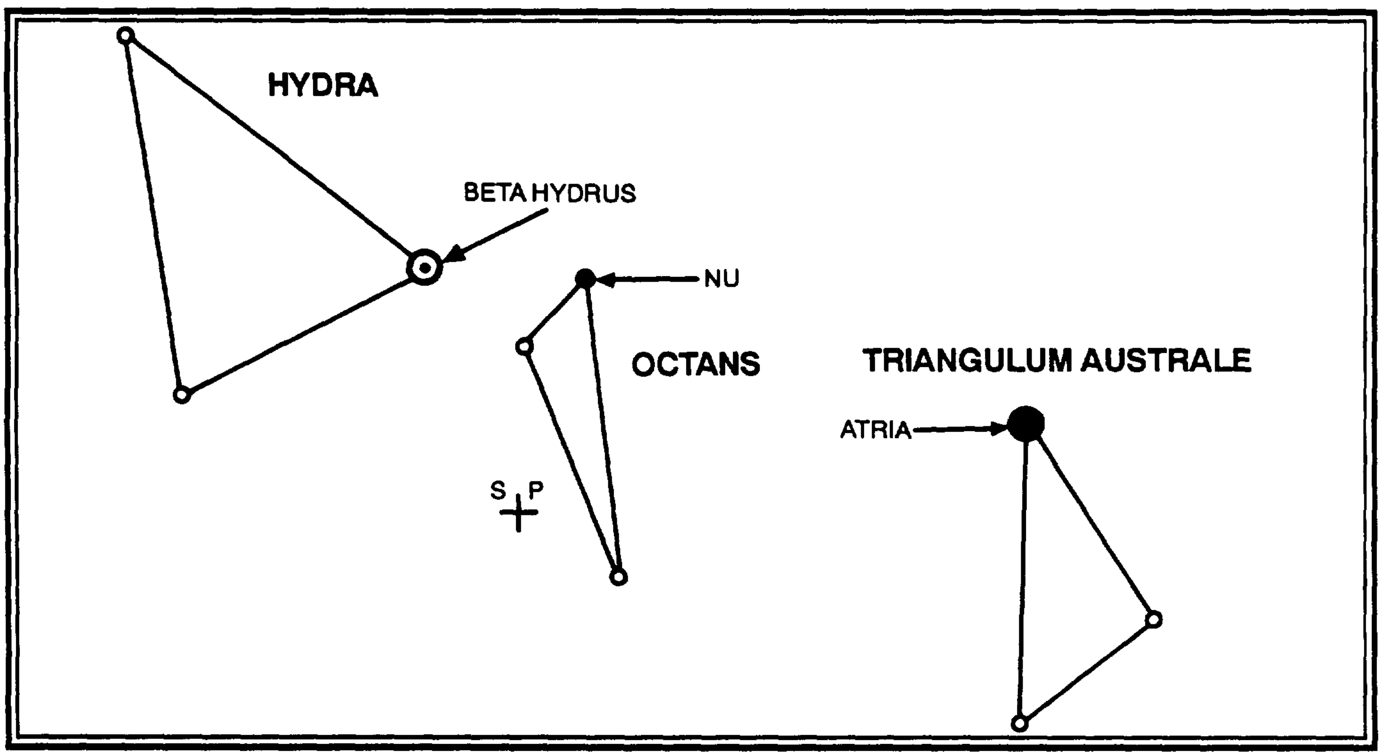


Figure G-15. **Virgo and Leo**

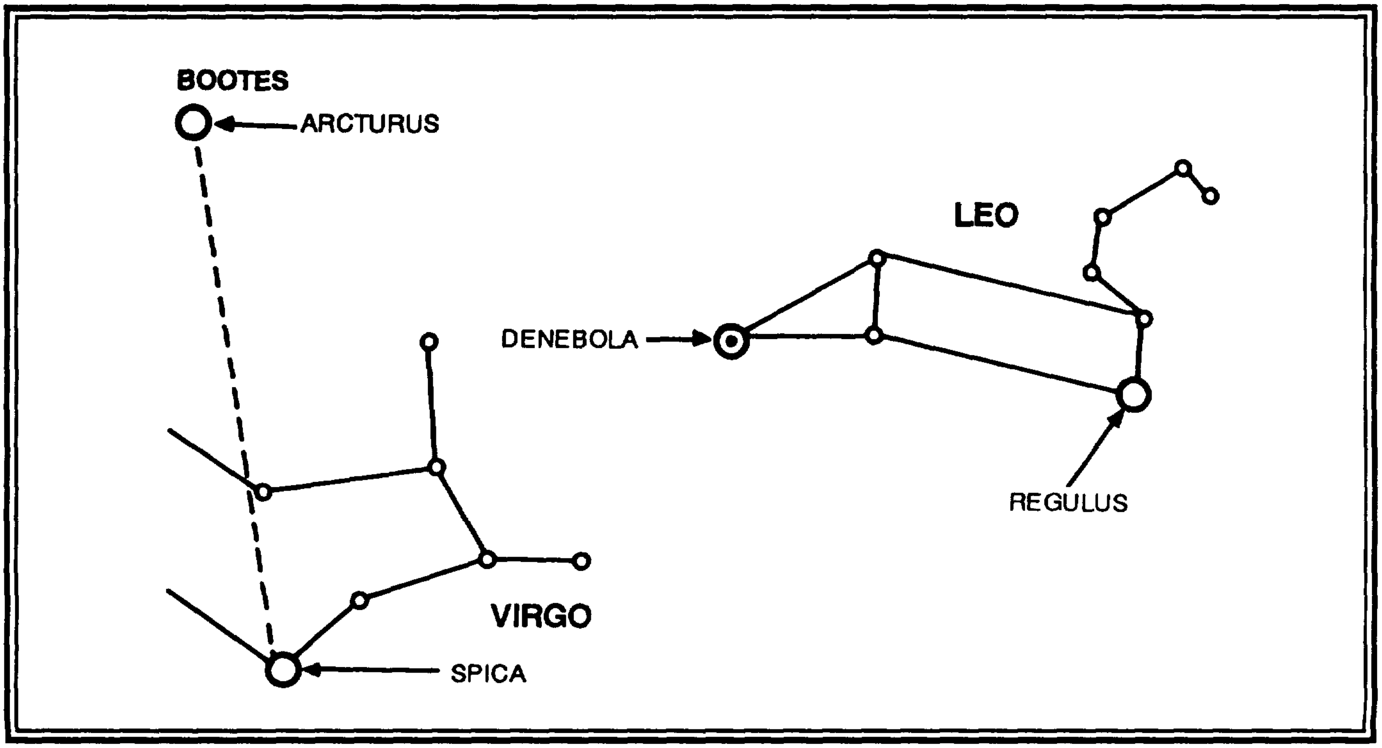


Figure G-16. **Ophiuchus, Scorpius, and Libra**

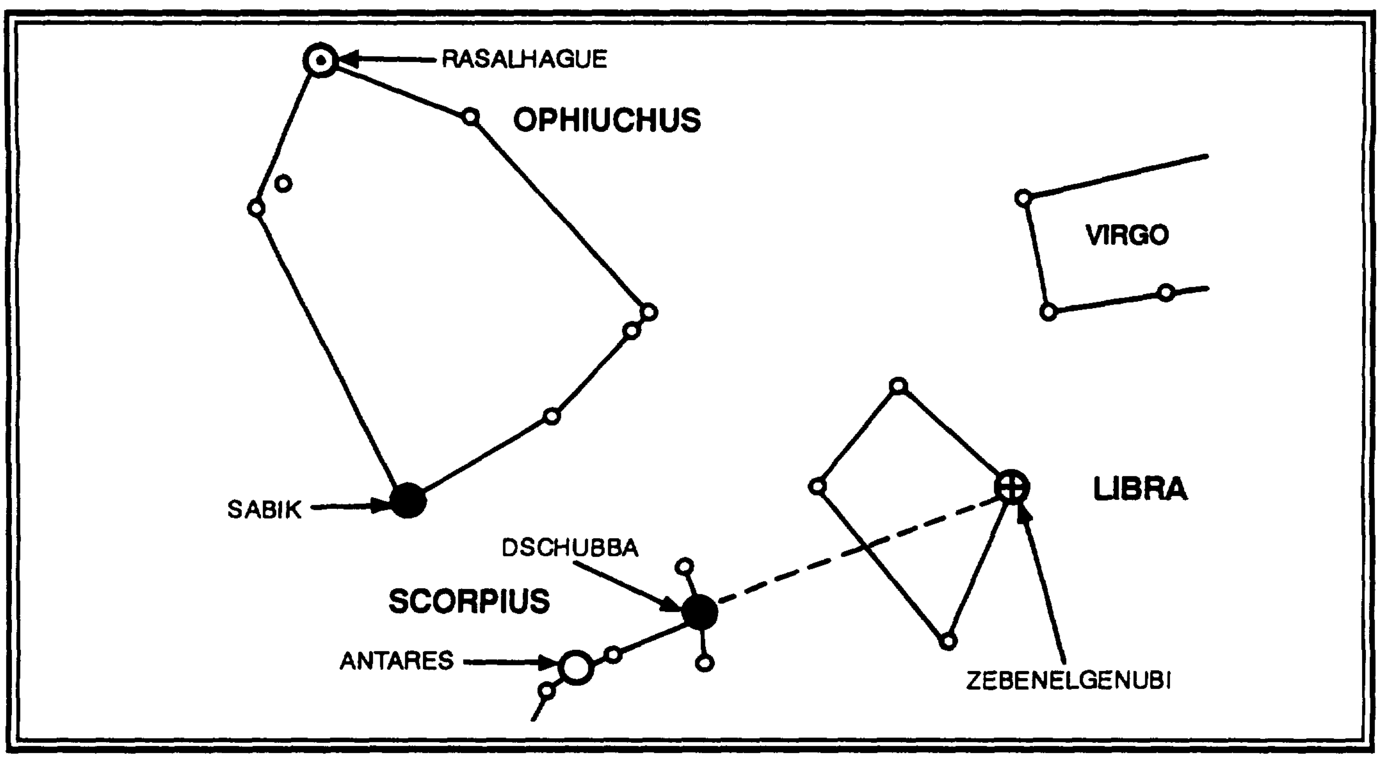


Figure G-17. **Bootes, Ursa Major, and Ursa Minor**

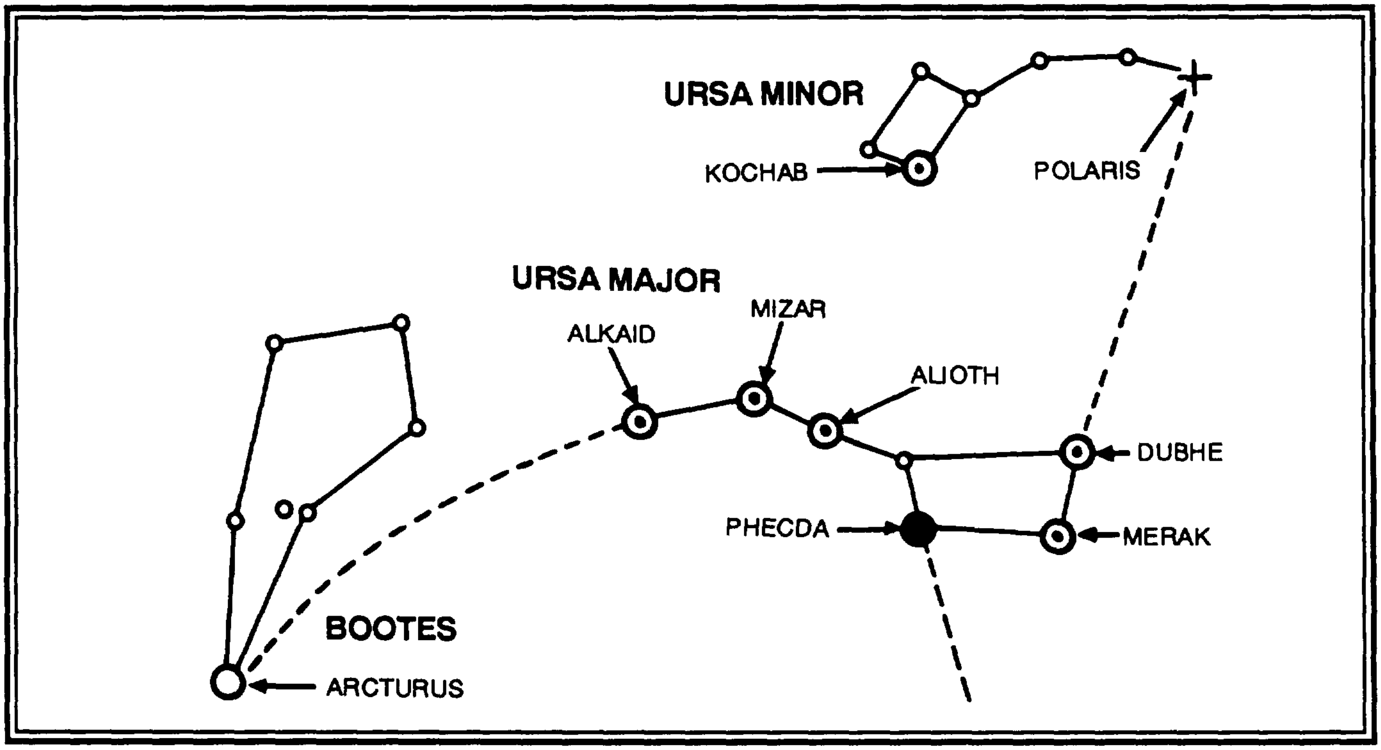


Figure G-18. **Cassiopeia, Ursa Minor, and Draco**

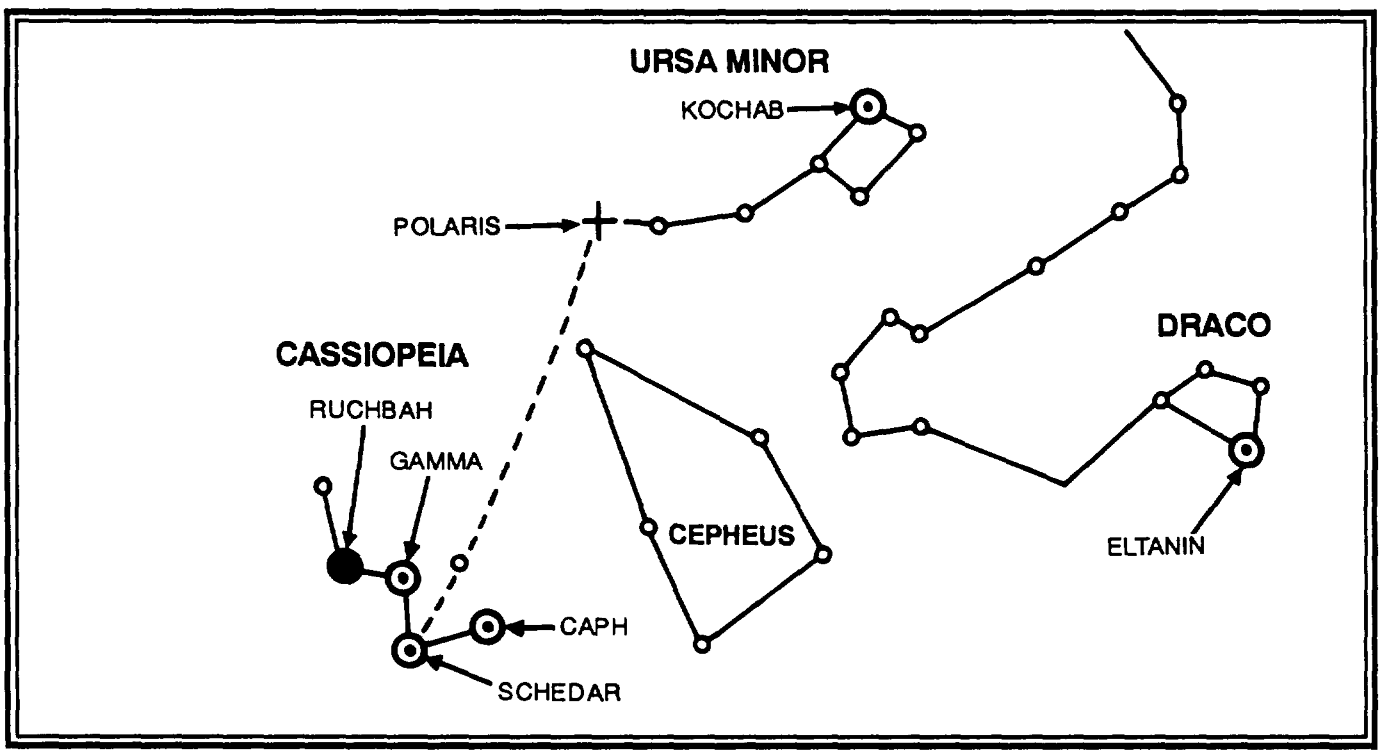


Figure G-19. **Carina and Vela**

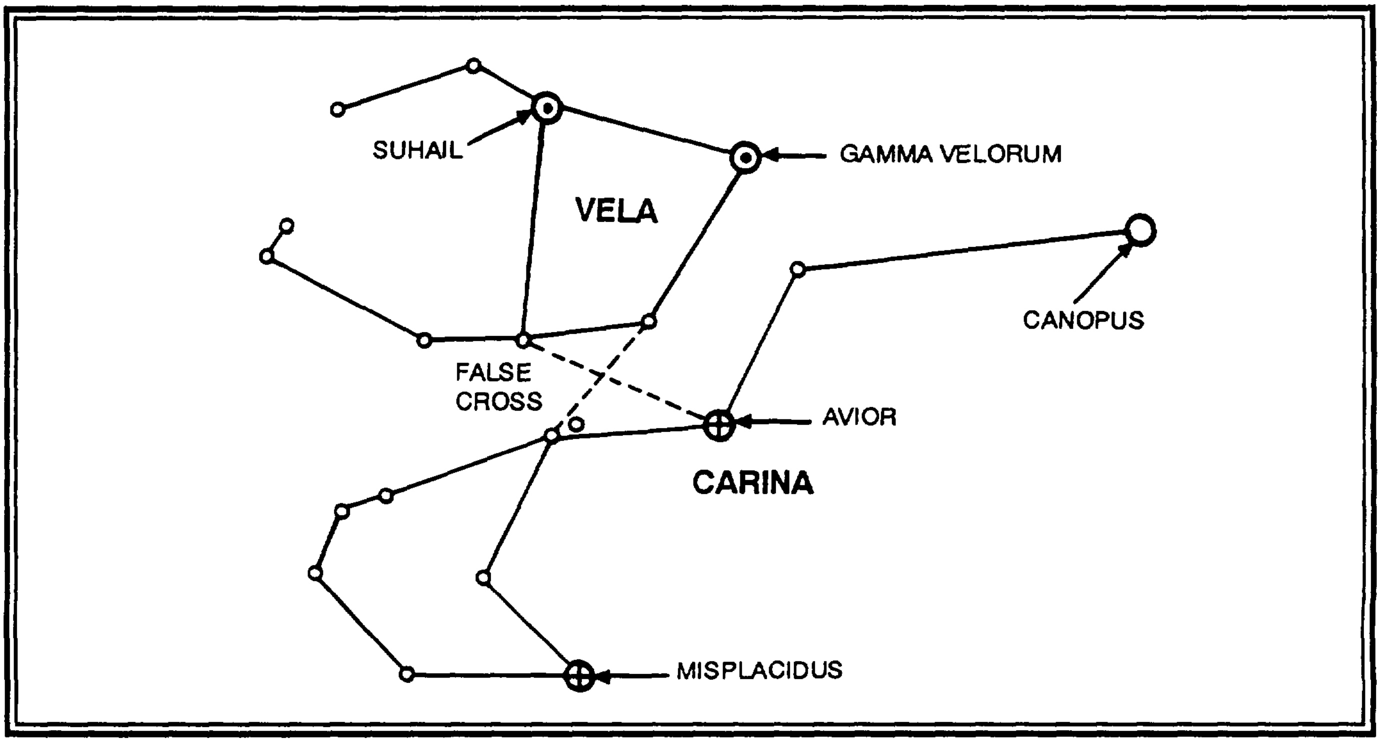
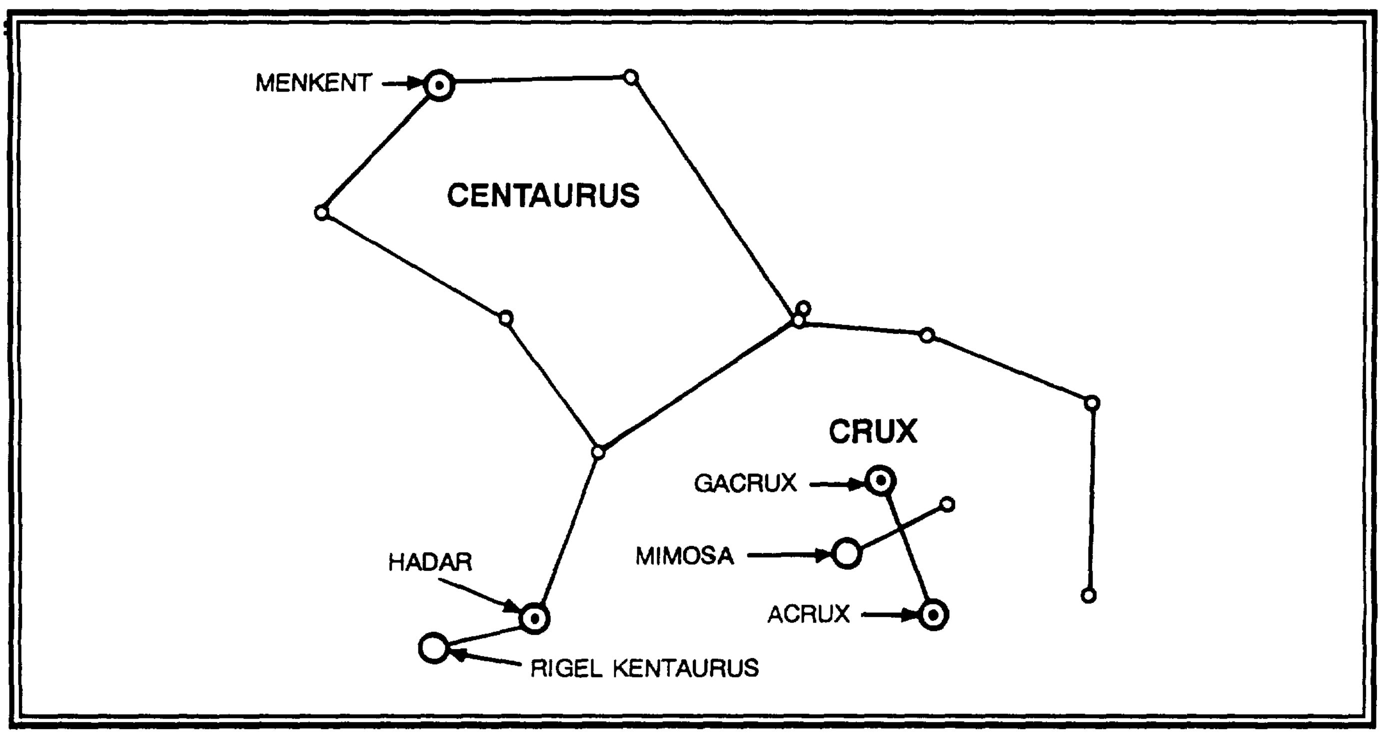


Figure G-20. **Centaurus and Crux (Southern Cross)**



★APPENDIX H
STANDARDIZATION AGREEMENTS

STANAGs are international agreements to facilitate interallied operations. Upon ratification by the United States, a STANAG is binding upon US Army forces (entire/y or with exceptions as noted). This appendix addresses STANAG 2934 that deals with the required accuracy of survey data and recording of data for survey control points.

Section I
GENERAL

The following is an extract from STANAG 2934, Section I.

*   *   *   *   *   *   *

1101. The purpose of this Chapter is to:

a. Standardize the method of expressing the artillery survey accuracy criteria for weapons, target acquisition, surveillance, and meteorological systems in current use by nations and to establish a common understanding of the criteria used by nations in order to facilitate mutual survey support.

b. Standardize which data is to be recorded for artillery survey control points and the proforma to be used by NATO forces.

1102. Participating nations agree to:

a. Use the method of expressing survey accuracy criteria described in Section II.

b. Take note of the criteria set out at Annex A to this Chapter which lists the terminal survey accuracy required by each nation for weapons, target acquisition, surveillance and meteorological systems.

c. Record the data described in Section III.

d. Use the proforma for artillery survey control points described at Annex B to this Chapter.

1103. An artillery survey control point is defined for use in this chapter as a point at which the coordinates and the altitude are known and from which the bearings/azimuths to a number of reference points are also known.

*   *   *   *   *   *   *

Section II

STANDARD SURVEY ACCURACY REQUIREMENTS FOR SURFACE-TO-SURFACE ARTILLERY

The following data are extracted from STANAG 2934, Section II and Annex A.

* * * * * * *

1104. Survey accuracy requirements are expressed in terms of probable error (PE), circular error probable (CEP), and standard deviation (SIGMA). Survey parties may express the accuracy of their work in terms of a ratio (for example, 1 in 10000) which is an absolute accuracy.

1105. PE and CEP are derived from the positive standard deviation of the measurement (Sigma - σ) as follows:

a. σ = Positive standard deviation of the measurement (Sigma).
b. PE= 0.6745 σ.
c. CEP=1.1774 σ.
d. CEP = 1.7456 PE.

Notes. 1. PE is a value which is exceeded as often as it is not; that is, it has a 50 percent probability of occurrence. With respect to fixation (position), the PE applies to both the East-West and North-South axis.

2. CEP is the radius of the circle, centered about the true position, such that any measured or calculated position has a 50 percent probability of lying within that circle.

ARTILLERY SURVEY ACCURACY CRITERIA

EQUIPMENT	ORIENTATION (PE) MILS	FIXATION/POSITION		ALTITUDE (PE) METERS
		(PE) METERS	(CEP) METERS	
Cannon Artillery				
105mm	0.40	10	17.5	10
155mm	0.40	10	17.5	10
203mm	0.40	10	17.5	10
Free-Flight Rockets				
MLRS	-	4.6	8	3.6[1]
Mortar-Locating Radar	0.40	5.7	10.0	10
Artillery-Locating Radar	0.40	5.7	10.0	3
Medium Range Ground Surveillance Radar				
AN/TPQ-25A/58B	3.0	25	43.7	10
Meteorological Tracking Equipment				
AN/TMQ-31	9.0	65	114	10
GLLD	2.0	17	30	20

[1] Applies to the accuracy requirements for the establishment of initiation/calibration/navigation update points.

* * * * * * *

Section III

RECORDING OF DATA FOR ARTILLERY SURVEY CONTROL POINTS

An extract of STANAG 2934 is shown below.

* * * * * * *

EXPLANATORY NOTES

AGREEMENT

1. This NATO Standardization Agreement (STANAG) is promulgated by the Chairman MAS under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consultation with the tasking authority. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals, and instructions implementing this STANAG will include a reference to the STANAG number for the purposes of identification.

DEFINITIONS

4. Ratification is 'The declaration by which a nation formally accepts the content of this Standardization Agreement.'

5. Implementation is 'The fulfillment by a nation's forces concerned of their obligations under this Standardization Agreement.'

6. Reservation is "The stated qualification by a nation which describes that part of this Standardization Agreement which it cannot implement or can implement only with limitations."

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

7. Page iii gives details of the state of ratification and implementation of this agreement by the NATO nations. If no details are shown, it signifies that the nation has not yet notified the tasking authority of its intentions. Page iv (and subsequent) gives details of reservations and proprietary rights that have been stated.

8. If an amendment of substance of a new edition (other than an editorially amended edition) is promulgated, all previous ratification, implementation and reservation/restriction details are deleted from pages iii and iv and the amendment or new edition is processed in the same manner as the original agreement.

Note. The Artillery Survey Control Point Proforma (Amex B to STANAG 2934) has been adapted as a DA form (DA Form 5075-R) and is discussed in Chapter 14, with the exception that datum and ellipsoid must be included. See the sample Artillery Survey Control Point Proforma in Annex B and instructions in Section III, 1107d, located in this appendix, for examples. It is suggested that you still use DA Form 5075-R; just include the datum and ellipsoid data in the UTM ZONE and UTM SQUARE blocks. (See the back of this book for a reproducible copy of DA Form 5075-R.)

* * * * * * *

RESERVATIONS

DA: Denmark will not use the proforma (Annex A), but will use existing Danish Trig Lists with text in Danish and English. In the trig lists all information according to STANAG 2865 is found except:

a. Paragraphs 4b and 5j (direction to orient equipment).

b. Paragraph 5e (accuracy).

c. Paragraph 51 (verification block).

IT: In the space LOCATION DIAGRAM in Annex A, Italy will also record a vertical sketch with indications of the altitude of the different collimation plans.

NO: Norway will use an artillery survey control point proforma with a different layout than that described in Annex A to STANAG 2865. The Norwegian format will not include information on:

a. UTM square.

b. Accuracy.

c. Longitude/latitude.

d. Bearing/azimuth to aiming points in degrees or grads.

e. Method of determination.

The Norwegian format will include grid bearing/azimuth to only two reference objects from the artillery survey control point.

* * * * * * *

ARTILLERY SURVEY CONTROL POINTS

1106. The functions of an artillery survey control point are to:

a. Provide a point from which survey may be opened or closed.

b. Enable users to fix and orient their equipments on the grid applicable to their particular area.

1107. The artillery survey control point proforma (Annex B) will permit quick identification of the control point and extraction of data without any ambiguity. The following information is required:

a. A control point number and, if desirable, a loclity name.

b. A map series and sheet number.

c. The grid coordinates and the altitude of the control point. (The altitude is that of the ground at the control point above mean sea level unless otherwise stated.)

d. The type of grid, grid origin, ellipsoid, and datum (normally UTM zone and UTM square).

e. The accuracy of the data. (See Section II.)

f. The specification of the survey methods used:

(1) Horizontal, for exmple, triangulation.

(2) Vertical, for example, altimetry.

(3) Azimuth/orientation, for example, gyroscope.

g. A diagram showing the location of the control point in relation to local topographical detail. The diagram is given in order that the control point may be easily recognized on the ground.

h. The description of the control point; that is, how it is marked on the ground.

j. The grid bearing/azimuths, in mils, to at least four reference objects. Two of these reference objects must be between 100 and 500 meters of the control point.

k. A description and sketch showing the exact point of lay and the approximate distance from the control point, for each reference object.

1. A verification block containing:

(1) The unit.

(2) By whom prepared.

(3) By whom checked.

(4) The date.

Notes. 1. There are several ways of writing numbers by hand. The English-speaking nations, for example, use 17.11. Other nations, for example, use 17,11. Both of these examples can be used but are not to be mixed.

2. When an artillery survey control point is situated near a UTM zone border and two sets of data are available, separate proforma must be prepared for each UTM zone.

3. The Artillery Survey Control Point Proforma may be printed in national languages, but the format must not be altered.

ANNEX B

ARTILLERY SURVEY CONTROL POINT PROFORMA

BEARING PICKET CARD/ARTILLERY SURVEY CONTROL POINT				
UTM Zone	UTM Square	Station name		Accuracy
		Station number		E + N:
Datum	Ellipsoid	Map series sheet No.		Azimuth:
				Altitude:
How Marked		E:	N:	Altitude
		Long:	Lat:	

Notes	Location Diagram
Warning. Two different ways of writing numbers: 17.11 and 17,11	

N

Description	Sketch	Distance	Grid Bearing/Azimuth
			Mils:
			Degrees:
			Grads:
			Mils:
			Degrees:
			Grads:
			Mils:
			Degrees:
			Grads:
			Mils:
			Degrees:
			Grads:
			Mils:
			Degrees:
			Grads:

Method of Determination	Unit:
Horizontal:	Prepared:
Vertical:	Checked:
Azimuth/Orientation:	Date:
Notebook Reference:	

ANNEX C

EVALUATION CHECKLIST

ARTILLERY SURVEY

GENERAL

1. This Chapter agrees the method of expressing artillery survey accuracy criteria for weapons, target acquisition, surveillance and meteorological systems in current usc by nations. It also shows the proforma to be used by NATO forces for wording artillery survey control point data

2. Evaluation opportunities will arise during field training exercises.

EVALUATION PLAN

3. The information required should be obtained by:

a. Observation of artillery survey teams.

b. Discussion with survey officers/NCOs.

c. Review of national implementing documents.

Questionnaire

4. Which of the following equipment types were evaluated? State exact type:

a. Cannon Artillery

b. Free Flight Rocket

c. Surface to Surface Guided Weapon

d. Mortar Locating Radar

e. Artillery Locating Radar

f. Sound Ranging

g. Light Ranging (Flash Spotting)

h. Ground Surveillance Radar

i. Drone

j. RPV

k. Meterological Equipment

l. Ground Laser Locator Designator

5. Was the proforma shown at Annex B (Artillery Survey Control Point) used to record survey data? State yes or no............ If no, give details:

....

....

....

6. Were all serials on the form completed? State yes or no............

7. Were all the various headings on the form understood by the survey teams? State yes or no............ If no, give details:

....

....

....

8. Was an Artillery Survey Control Point produced by one nation and used by the survey team from another nation? State yes or no............If yes, give details:

....

....

....

9. Did the nation using the form require any additional survey information that cannot be shown on the form? State yes or no............ If yes, give details:

....
....
....

10. Was the survey data shown on the form given to sufficient accuracy to enable the receiving nation to use it? State yes or no . . . .

11. Was survey carred forward to the weapon/equipment position from the Artillery Survey Control Point? State yes or no.. . . . . .If yes, how far?...

12. If an Artillery Survey Control Point was not used to provide survey information how was survey initiated? Mark those used:

FIXATION	
Trig Point	
Map	
GPS	
Other	

ORIENTATION	
Astro	
Gyroscopic Orienter	
Compass	
Other	

13. Were gross-error checks on accuracy conducted during the survey process (e.g. compass checks)? State yes or no . . . .

14. Were the accuracies achieved at the weapon/equipment in accordance with the figures shown at Annex A? State yes or no . . . .

15. Do national publications reflect the national accuracies shown at Annex A? State yes or no . . . .

16. Were there any observations made by exercise participants concerning survey that should be considered by the Arty WP. State yes or no . . . . If YES give:

a. Nation ....

b. Rank and position of participant ....

c. Observation ....

17. Evaluators own observations:

....
....
....
....

* * * * * * *

GLOSSARY

AC alternating current

accuracy the degree of conformity with a standard

ADD additional (BUCS)

AE allowable radial error

AFATDS advanced field artillery tactical data system

AFG Afgooye (BUCS)

AFSO aerial fire support observer

AHIP advanced helicopter improvement program

ALB AirLand Battle

altitude the altitude of a celestial body is the arc of its vertical circle measured from the observer's horizon to the body, or it is the vertical angle at the observer's position between the horizon and the body

am ante meridiem

amp ampere

angle t the interior angle of the PZS triangle at the pole. It is measured either eastward or westward between the observer's meridian and the hour circle of the celestial body.

AOC area of concentration

approx approximately

AR accuracy ratio (also with BUCS)

ARTEP Army training and evaluation program

arty artillery

★**AS** antispooling

astro astronomic

astro alt astronomic observation (altitude method)

az azimuth

AZ azimuth (BUCS)

azimuth the horizontal angle measured clockwise between a reference direction and the line to an observed or designated point

azimuth angle the angle less than 180° between the plane of the celestial meridian and the vertical plane containing the observed object, reckoned from the direction of the elevated pole. In astronomic work, the azimuth angle is the spherical angle at the zenith in the astronomical triangle composed of the pole, the zenith, and the star.

azimuth astronomic the angle between the plane of the observer's meridian and the plane of the hour circle containing the observed body, measured in the plane of the horizon, preferably clockwise from north

azimuth, geodetic the angle between the geodetic meridian and the tangent to the geodetic line at the observer, measured in the plane perpendicular to the ellipsoidal normal of the observer, preferably clockwise from north. (See survey, geodetic.)

azimuth, grid an azimuth measured from grid north. (See azimuth, plane and azimuth, projected geodetic.)

azimuth magnetic an azimuth measured from magnetic north

azimuth, plane the angle measured in a clockwise direction between grid north and a line on the grid

azimuth, projected geodetic at the point of observation, the horizontal angle measured clockwise between grid north and the tangent to the geodetic line to an observed or designated point. This term must not be confused with geodetic azimuth.

az mk azimuth mark

AZMK azimuth mark (BUCS)

AZ/MK azimuth to azimuth mark (BUCS)

B_o B_o in FM 6-300, Tables 12a through e

B_1 B_1 in FM 6-300, Tables 12a through e

B_2 B_2 in FM 6-300, Tables 12a through e

BA=1 side of triangle between Points A and B (BUCS)

baseline a surveyed line, established with more than usual care, to which surveys are referred for coordination and correlation; used as a known length of a triangle side for computing other triangle sides. When misinterpretation is not probable, the abbreviation term base may be used.

basic control horizontal or vertical control, in which the locations of the stations have been accurately coordinated and correlated and forming a framework to which other surveys are adjusted. For artillery purposes, this term can be applied to control points established by fourth-order accuracy or higher orders of accuracy.

BC battery center

B/C Point B or C (BUCS)

BCS battery computer system

bde brigade

bldg building

blvd boulevard

bn battalion

bn SCP battalion survey control point

BOIP basis of issue plan

BRP boresight reference point

btry battery

BUCS backup computer system

BWI British West Indies

C Celsius

★**CA** comparative accuracy (BUCS); course acquisition

CA=2 side of triangle between Points C and A (BUCS)

cav cavalry

CDU control and display unit (PADS)

celestial coordinates the coordinates used to locate a heavenly body by various systems. The coordinates used in the field artillery are declination and right ascension.

celestial equator the great circle on the celestial sphere whose plan is perpendicular to the axis of rotation of the earth. A great circle is a circle, the plane of which passes through the center of a sphere.

celestial horizon that circle on the celestial sphere formed by the intersection of the celestial sphere and a plane through the center of the earth and perpendicular to the zenith-nadir line

celestial North and South Poles the points at which the prolonged polar axis of the earth intersects the celestial sphere

celestial sphere an imaginary sphere of indefinitely large radius whose center is the center of the earth. (Practical astronomy assumes that the earth is stationary and that the celestial bodies rotate about the earth from east to west on this sphere.)

CEP circular error probable

CEWI combat electronic warfare intelligence

ck check

CK check (BUCS)

CM central meridian

cmd command

colatitude the side of the PZS triangle from the celestial pole to the zenith. The complement of altitude, or 90° minus the altitude. The term has significance only when used in connection with altitude measured from the celestial horizon, when it is synonymous with zenith distance.

C2 command and control

CMPTD computed (BUCS)

COLT combat observation/lasing team

comm communication

cont continue

CONUS continental United States (also in BUCS)

CONV conversion (BUCS)

CONVG convergence (BUCS)

COP chief of party

CORR correction (BUCS)

COS cosine (BUCS)

cot cotangent

CPT captain

CST central standard time

CTOC corps tactical operations center

CTR center (BUCS)

CUCV commercial utility cargo vehicle

culmination the passage of the celestial body across the meridian of the observer. Every celestial body will have two culminations. The passage across the upper branch of the observer's meridian is upper culmination (or upper transit), and the passage across the lower branch is lower culmination (or lower transit).

CVG convergence (BUCS)

D direct

(D) direct (BUCS)

DA Department of the Army; Denmark (STANAG)

datum a reference element, such as a line or plane, by reference to which the positions of other elements are determined. (See datum, horizontal and datum, sea level.)

datum, horizontal in plane surveying, the grid system of reference used for the horizontal control of an area, defined by the casting and northing of one station in the area and the azimuth from this selected station to an adjacent station. This term is differentiated from the term *common grid* in that the latter implies a common datum.

datum, sea level a level surface to which heights are referred. The generally adopted level datum is mean sea level. For tactical surveys, an arbitrary level datum is often assumed, as in the case of some local surveys in which arbitrary level datums are often adopted and defined in terms of an assumed elevation for some physical mark (bench mark).

DAYLT daylight (BUCS)

★**db** decibel

DC direct current; daily change (BUCS)

DD.MMSS degrees, minutes, seconds (BUCS)

DD.MMYY day, month, year (BUCS)

DDCT datum-to-datum coordinate transformations

dE difference in casting

declination the angular distance from the celestial equator measured along the hour circle of the celestial body. Declination is positive when the body is north of the celestial equator and negative when it is south of the celestial equator. Declination corresponds to latitude to the earth.

DECLN declination (BUCS)

DEF defined (BUCS)

dH difference in height

dist distance

DIST distance (BUCS)

distance, horizontal the distance measured in a horizontal plane, as distinguished from a distance measured on a scope. Horizontal distance refers primarily to taped distances or to distances reduced to horizontal by computations.

div arty division artillery

DMA Defense Mapping Agency

dN difference in northing

★ **DoD** Department of Defense

DOS Director of Overseas Survey

DS direct support

DST daylight saving time

★**DTM** datum (AN/PSN-11)

E east; casting (BUCS)

EAC echelon above corps

ECCM electronic counter-countermeasures

★**ECEF** earth-centered, earth-fixed

ecliptic the great circle formed on the celestial sphere by the plane of the orbit of the earth. If one could observe the sun and the stars at the same time, he would see the sun and stars moving slowly across the sky, with the sun gaining slightly on the stars each day. Therefore, since for purposes of practical astronomy the earth is assumed to be stationary, the ecliptic is assumed to be the path of the sun. This ecliptic intersects the celestial equator at two points at an angle of 23.50.

ECU electronic control unit (SIAGL)

eE error in casting

el elevation

electronic line of sight the characteristics of intervening terrain that make possible the transmission of a radio wave between two separated components of the electronic distance-measuring equipment systems

elongation the elongations of a celestial body are two points in its apparent orbit at which the bearing from the observer's meridian is the greatest. A star is said to be at eastern elongation when its bearing is at its maximum to the east and at western elongation when its bearing is at its maximum to the west.

★**ElHold** elevation hold (AN/PSN-11)

ELPS ellipsoid (BUCS)

eN error in northing

engr engineer

EOL end of orienting line

equinox the equinoxes are the two ponts where the ecliptic intersects the celestial equator. The point where the apparent annual path of the sun crosses the celestial equator from south to north is called the vernal equinox, or first point of Aries. The other pint is called the autumnal equinox, where the sun is on the celestial equator diametrically opposite the vernal equinox. The equinoctial points move slowly westward along the ecliptic at a rate of about 50 seconds a year. As a result, all the fixed stars gradually change their positions with respect to the equator and the vernal equinox.

F Fahrenheit; fast (BUCS); flattening (BUCS)

FA field artillery

FDC fire direction center

FGCC Federal Geodetic Control Committee

FIST fire support team

1 LT first lieutenant

FLAT flattening

FM frequency modulated; field manual

FO forward observer

★**FOM** figure of merit (AN/PSN-11)

FP firing point

FRAGO fragmentary order

FRIG French Frigate Shoals

FS fire support

FSCOORD fire support coordinator

FSE fire support element

FSTK far stake

FWD forward (BUCS)

GAT Greenwich apparent time

GAZ grid azimuth

geo geographic

GEO geographic (BUCS)

GHA Greenwich hour angle

GK Gauss-Kruger

GMD Greenwich mean date

GMT Greenwich mean time

GN grid north

GPS global positioning system

GR.BRIT Great Britain (BUCS)

GRS global reference system

GRU gyroscopic reference unit (SIAGL)

GS general support

GSR general support reinforcing

GST Greenwich sidereal time

gyro gyroscopic

H height

HHB headquarters and headquarters battery

HHC headquarters and headquarters company

HH.MMSS hours, minutes, seconds

HI height of instrument

HMMWV high-mobility multipurpose wheeled vehicle

horiz horizontal

horizon the horizon for any place on the surface of the earth is the great circle formed on the celestial sphere by the extension of the plane of the observer's horizon. In general, the apparent or visible junction of earth and sky as seen from any specific position.

hour angle the angle at the celestial poles between the plane of the observer's meridian and the plane of the hour circle of the star. Stated simply, the hour angle is the angle at the pole between the observer's meridian and the meridian (hour circle) of the celestial body. This angle is similar to differences in longitude on the earth's surface. It is measured westward from the observer's meridian. Generally, the angle is considered as an arc measured along the celestial equator toward the west and is expressed in units of time or arc.

hour circle any great circle on the celestial sphere whose plane is perpendicular to the plane of the celestial equator

HQ headquarters

HRS hours (BUCS)

HT height of target; height (BUCS)

HT/I height of instrument (BUCS)

HT/T height of target (BUCS)

hvy heavy

hwy highway

Hz hertz

HZ horizontal (BUCS)

ID identification

IEW intelligence and electronic warfare

IGN Institute Geographic Nationally

IMU inertial measuring unit (PADS)

inst instrument

IO instrument operator

IRR infrared reflector

ISTS International Satellite Tracking Station

IT Italy (STANAG)

★ **IUGG** International Union of Geodesy and Geophysics

km kilometer

KN known (BUCS)

L left (BUCS); leading (BUCS)

lat latitude

LAT latitude **(BUCS)**

latitude the angular distance, for a specific spot on the surface of the earth, from 00 to 90° north or south of the equator

LC Lesser Cayman Island

LDG leading edge (BUCS)

LF left (BUCS)

LG longitude (BUCS)

LHA local hour angle

LID light infantry division

LIN line information number

LNG longitude (BUCS)

long longitude

longitude the angular distance, for a specific spot on the surface of the earth, from 00 to 180° east or west of the Greenwich meridian, which is used by most nations as the prime or initial meridian

LMT local mean time

LRIP low-rate initial production

LS launcher site

LST local sidereal time (also in BUCS)

It light

ltr letter

m̸ mil

m meter

M minor (BUCS)

MAJ major

MAJOR semimajor axis (BUCS)

mal malfunction

★**MAPS** modular azimuth positioning system

MEAS measure (BUCS)

met meteorological

METT-T mission, enemy, terrain and weather, troops and time available

MHz megahertz

MIN minutes (BUCS)

MINOR semiminor axis (BUCS)

MLRS multiple launch rocket system

mm millimeter

MMSS minutes, seconds (BUCS)

MMSSS minutes, seconds to the nearest tenth (BUCS)

mn mean

MN mean (BUCS)

MOS military occupational specialty

MS measuring section

★**MSL** mean sea level

MSN mission (BUCS)

mt mountain

MTLR moving-target-locating radar

MTOE modification tables of organization and equipment

M/V manpack/vehicular

N north; northing (BUCS)

NAD North American datum

NBC nuclear, biological, chemical

NICAD nickel-cadmium

no number

NO Norway (STANAG)

NOAA National Oceanic and atmospheric Administration

NREF north reference point

★**NSG** north-seeking gyroscope

NSN national stock number

O1 Observer 1 (or Observation Post 1)

O2 Observer 2 (or Observation Post 2)

OBS observation (BUCS)

observer's meridian the great circle on the celestial sphere that passes through the celestial poles and the observer's zenith-nadir

obsr observer

OCC occupied (BUCS)

OL orienting line

OMB Office of Management and Budget

one-position, two-position refers to initial readings on the circle of the instrument measuring an angle and is used to determine the degree of refinement in the performance of angular value determinations with the theodolite

OP observation post

oper operator

OPORD operation order

OPS observation posts (BUCS)

ORD ordnance (BUCS)

OS orienting station

P Point P (BUCS)

PADS position and azimuth determining system

PAE position, azimuth, elevation (PADS)

parallax the difference in altitude of a body as seen from the center of the earth and from a point on the surface of the earth. There is no apparent parallax of the fixed stars, but that of the sun and planets is measurable. Parallax makes the body appear lower than it actually is; therefore, the correction is added.

PASP platoon area survey point

PDS position determining system

PE probable error

PFC private first class

PGM program (BUCS)

PLGR precise lightweight GPS receiver

plt platoon

pm post meridiem

PMCS preventive maintenance checks and services

polar distance the algebraic complement of the declination (90° minus the declination)

pos position

POS position (BUCS)

PPM parts per million

★**PPS** precise positioning system

prime vertical the vertical circle that is perpendicular to the plane of the observer's meridian and intersects the celestial horizon at the points directly true east and west of the observer's meridian

pro forma provided in advance to prescribe form or to describe items (according to form)

PROV provisional (BUCS)

PS power supply (PADS)

PT point (BUCS)

PTS points (BUCS)

★P/Y precise (PPS code)

R reverse; right (BUCS); reinforcing

RA right ascension (also in BUCS)

RAM random-access memory

RATELO radiotelephone operator

rcdr recorder

rd road

RDG reading (BUCS)

RE radial error of closure; radial error (BUCS)

RECIP reciprocal (BUCS)

recon reconnaissance

recip reciprocal

RECIP reciprocal (BUCS)

REFR refraction (BUCS)

refraction the refraction of a celestial body is the apparent displacement of the body caused by the bending of light rays passing through layers of air of varying density. The celestial body will appear higher than it really is; therefore, the correction is subtracted. A simple example of refraction can be seen by placing a spoon in a glass half full of water.

rejection limit used in FA survey to refer to a maximum allowable deviation from a mean value of two or more angular measurements

REQD required (BUCS)

restitution point a point identifiable on a photograph for which a chart location is known and which is used to transfer (restitute) other points from the photograph to the firing chart. The chart locations of these points may be determined by inspection or by survey.

REV revision (BUCS)

revolution the turning of a body about an exterior point or axis. The earth revolves about the sun on a 600-million-mile orbit at a speed of about 18.5 miles per second. Practical astronomy assumes that the earth is stationary and the celestial bodies move about it from east to west on the celestial sphere.

RF radio frequency

right ascension the right ascension of a celestial body is the arc on the celestial equator measured from the vernal equinox eastward to the hour circle of the body. It is measured in units of time from 0 to 24 hours. Right ascension corresponds to longitude on earth.

rotation the turning of a body on its axis. The terminal points of the axis of the earth are the North and South Poles. The rotation is from west to east.

RP registration point

★**R3SP** rearm, refuel, resupply, and survey point

RSO reconnaissance and survey officer

RSOP reconnaissance, selection, and occupation of position

RT right (BUCS)

S south (also in BUCS)

★**SA** selective availability

SCH scheme (BUCS)

SCP survey control point

SDT self-development test

sec second

SEC second (BUCS)

SEDME-MR survey equipment, distance-measuring, electronic (medium-range)

set (one set, two sets, and so on) used in reference to astronomic observations of a celestial body. One set consists of the field data that result from the observation of a celestial body with the telescope of the observing instrument, first in the direct position, then in the reverse position.

SFC sergeant first class

★**SGS** Soviet Geodetic System

SGT sergeant

★**SHTU** simplified hand-held terminal unit

SIAGL survey instrument, azimuth gyro, lightweight

SIC survey information center

sidereal time time determined by the stars

SIDRL sidereal (BUCS)

SIMO simultaneous observation

sin sine

SIN sine (BUCS)

SL slope (BUCS)

SLGR small lightweight GPS receiver

slope distance the straight-line distance between two points of unequal heights. Normal usage is associated with electronic distance-measuring equipment. (Do not use the term *slant distance.)*

SM soldier's manual

SO south (BUCS)

SOI signal operation instructions

SOJT supervised on-the-job training

solar time time determined by the sun

solstices the solstices are two points on the ecliptic midway between the equinoxes. When the ecliptic is north of the celestial equator, the midpoint is called the summer solstice and occurs about 21 June. When the ecliptic is south of the celestial equator, the midpoint is called the winter solstice and occurs about 21 December. As can easily be seen, the solstices occur when the sun is at its greatest distance north or south of the equator.

SOP standing operating procedure

SOR Sorol

SPC specialist

SPCE survey planning and coordination element

SPCO survey planning and coordination officer

sph spheroid

★**SPS** standard positioning system

SRP/PDS stabilization reference package/position-determining system

SSG staff sergeant

sta station

STA station (BUCS)

STP soldier training publication

SUBT subtended or subtense (BUCS)

SURV survey (BUCS)

survey, geodetic survey that takes into consideration the size and shape of the earth; implies a reference spheroid that mathematically represents the geoid and the horizontal and vertical control datums

survey, plane those survey procedures common to field artillery in which the effect of the curvature of the earth is almost entirely neglected, and computations of the relative positions of the stations are made by using the principles of plane geometry and plane trigonometry

SUSV small-unit support vehicle

★**SV** satellite vehicle (AN/PSN-11)

svy survey (radio net)

SW southwest

SYS system (BUCS)

T telescope (field notebook)

TA target acquisition

TAB target acquisition battery

TACFIRE tactical fire direction system

TAN tangent (BUCS)

TASCP target area survey control point

TA2 true azimuth

TBL table (BUCS)

temp temperature

TG trainer's guide

tgt target

Thai Thailand (BUCS)

theod theodolite

TM technical manual

TOC tactical operations center

TOE tables of organization and equipment

topo topographic

TR trailing edge (BUCS)

trig triangulation

TRIG TRAV trig traverse (BUCS)

TRL trailing edge (BUCS)

TS traverse station

TTL total traverse length

tundra treeless plain in arctic regions

TZ time zone (BUCS)

U/A unadjusted/adjusted

unk unknown

UNK unknown (BUCS)

updt updated(d)

★ **UPS** universal polar stenographic

UTM universal transverse mercator (also in BUCS)

V voice (radio net)

VA vertical angle (also in BUCS)

v DC volts direct current

VE vernal equinox

vert vertical

vertical circle any great circle on the celestial sphere that passes through the observer's zenith-nadir

VHF very high frequency

Viet Vietnam (BUCS)

w/ with

W west (also in BUCS); watch (BUCS)

WC watch correction

WCS world geodetic system (BUCS)

WLR weapons-locating radar

WT water tower

XO executive officer

Y/N yes/no (BUCS)

zenith-nadir the zenith and nadir for any place on the surface of the earth are two points where an extension of the observer's plumb line intersects the celestial sphere. The zenith is the point directly overhead, and the nadir is the point directly underneath.

Z-VEL zero velocity (PADS)

REFERENCES

SOURCES USED

These are the sources quoted or paraphrased in this publication.

STANAG 2373/QSTAG 269. *Survey Accuracy Requirements for Surface-to-Surface Artillery.* 24 January 1992/3 September 1981.

STANAG 2865. *Recording of Data for Survey Control Points.* 30 December 1991.

Note. STANAGs and QSTAGs can be obtained from the following:

Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

A DD Form 1425 may be used to requisition these documents.

DOCUMENTS NEEDED

These documents must be made available to the intended users of this publication.

DA Form 4446. *Level, Transit, and General Survey Record Book.* November 1975.

DA Form 5075-R. *Artillery Survey Control Point.* March 1982.

DA Form 5590-R. *Computation of Azimuth and/or Distance From Coordinates (BUCS).* December 1986.

DA Form 5591-R. *Computation of Coordinates and Height From Azimuth, Distance, and Vertical Angle (BUCS).* December 1986.

DA Form 5592-R. *Computation of Plane Triangle Coordinates and Height From One Side, Three Angles, and Vertical Angles (BUCS).* December 1986.

DA Form 5593-R. *Computation of Coordinates and Height by Three-Point Resection (BUCS).* December 1986.

DA Form 5594-R. *Computation of Astronomic Azimuth by Altitude Method, Sun (BUCS).* December 1986.

DA Form 5595-R. *Computation of Astronomic Azimuth by Altitude Method, Star (BUCS).* December 1986.

DA Form 5598-R. *Computation of Astronomic Azimuth by Polaris Tabular Method (BUCS).* December 1986.

DA Form 5599-R. *Computation-Convergence of True Azimuth to Grid Azimuth (BUCS).* December 1986.

DA Form 5600-R. *Computation-Conversion of Geographic Coordinates to UTM Coordinates (BUCS).* December 1986.

DA Form 5601-R. Computation-Conversion of UTM Coordinates to Geographic Coordinate (BUCS). December 1986.

DA Form 5602-R. *Computation—Zone-to-Zone Transformation—UTM Grid Coordinates and UTM Grid Azimuth (BUCS).* December 1986.

DA Form 5603-R. *Computation of Trig Traverse/Subtense (BUCS).* December 1986.

DA Form 5604-R. *Computation of Coordinates and Height by Intersection (BUCS).* December 1986.

DA Form 7287-R. *Computation of Datum-to-Datum Coordinate Transformation (Program 15—Gauss-Kruger Datums)(BUCS).* June 1993.

DA Form 7288-R. *Computation of Datum-to-Datum Coordinate Transformation (Program 15-Gauss-Kruger [GK]).* June 1993.

DA Form 7289-R. *Computation of Datum-to-Datum Coordinate Transformation (Program 16—User-Defined) (BUCS).* June 1993.

DA Form 7284-R. *Computation of Star Identification (BUCS).* June 1993.

DA Form 7285-R. *Computation of Arty Astro (BUCS).* June 1993.

DA Form 7286-R. *Computation of Hasty Astro (BUCS).* June 1993.

★ DA Form 7356-R. *Computation of Azimuth and Distance From Coordinates (FED MSR).* Sep 96.

★ DA Form *7357-R. Computation of Coordinates and Height From Azimuth, Distance, and Vertical Angle (FED MSR).* Sep 96.

★ *DA* Form 7358-R. *Computation of Plane Triangle Coordinates and Height From One Side, Three Angles, and Vertical Angle (FED MSR).* Sep 96.

★ DA Form *7359-R. Computation of Coordinates and Height by Three-Point Resection (FED MSR).* Sep 96.

★ *DA Form 7360-R, Computation of Astronomic Azimuth by Altitude Method (FED MSR).* Sep 96.

★ DA Form 7361-R. *Computation of Astronomic Azimuth by the Hasty Astro Method (FED MSR).* Sep 96.

★ DA Form 7362-R. *Computation of Azimuth and Vertical Angle to Selected Star (Star ID) (FED MSR).* Sep 96.

★ DA Form 7363-R. *Computations of Astronomic Azimuth by Polaris Tabular Method (FED MSR).* Sep 96.

★ DA Form 7364-R. *Computation-Convergence of True Azimuth to Grid Azimuth (FED MSR).* Sep 96.

★ DA Form 7365-R. *Computation of Trig Traverse (FED MSR).* Sep 96.

★ DA Form 7366-R. *Computation of Coordinates and Height by Intersection (FED MSR).* Sep 96.

★ DA Form 7367-R. *Computation ofAstronomic Azimuth by the Arty Astro Method (FED MSR).* Sep 96.

★ DA Form 7368-R. *Computation-Conversion UTM to GEO Coordinate, GEO to UTM Coordinate, Zone-to-Zone Transformation (FED MSR).* Sep 96.

★ DA Form 7369-R. Computation—Datum-to-Datum Coordinate Transformation Listed Datums (FED MSR). Sep 96.

★ DA Form 7370-R. *Computation—Datum-to-Datum Coordinate Transformation Gauss Kruger (GK) Datums (FED MSR).* Sep 96.

★ *DA Form* 7371-R. *Computation-Datum-to-Datum Coordinate Transformation User-Defined Datums (FED MSR).* Sep 96.

FM 6-50. *Tactics, Techniques, and Procedures for the Field ArtilIery Cannon Battery.* 20 November 1992.

FM 6-300. *Army Ephemeris, 1993-1997.* 23 July 1992.

FM 21-26. *Map Reading and Land Navigation.* 30 September 1987.

FM 21-31. *Topographic Symbols.* 19 June 1961.

FM 25-100. *Training the Force.* 15 November 1988.

FM 25-101. *Battle Focused Training.* 30 September 1990.

FM 31-70. *Basic Cold Weather Manual.* 12 April 1968.

FM 31-71. *Northern Operations.* 21 June 1971.

FM 90-5 (HTF). *Jungle Operations.* 16 August 1982.

FM 90-6 (HTF). *Mountain Operations.* 30 June 1980. *FM 90-10* (HTF). *Military Operations on Urbanized Terrain (MOUT) (How to Fight).* 15 August 1979.

FM 101-5-1. *Operational Terms and Symbols.* 21 October 1985.

TM 5-6675-200-14. *Operator's, Organizational, Direct Support and General Support Maintenance Manual for Theodolite: Directional, 5.9 Inch Long Telescope; Detachable Tribrach w/Accessories and Tripod (Wild Heerbrugg Model T-16-0.2 Mil)* . . . . 31 May 1973.

TM 5-6675-205-20P. *Organizational Maintenance Repair Parts and Special Tool Lists: Theodolite: Directional; 0.002 Mil Graduation: 5.9-Inch Long Telescope, Detachable Tribrach; w/Accessories and Tripod (Wild Heerbrugg Models T-2-56-C-MIL)... (Model T-2-56-M-MIL). . .* (Model *T-2-56-M-MIL, Reference and T-2-56-C-MIL, Reference)* . . . . 10 December 1969.

TM 5-6675-233-20P. *Organizational Maintenance Repair Parts and Special Tools List: Theodolite: Directional; 0.002 Mil Graduation; 5.9-Inch Long Telescope; Detachable Tribrach w/Accessories and Tripod (Wild Heerbrugg Models T2-63 MIL)... (Model T2-67* MIL)...and (Model T2-66-C MIL) . . . . 25 June 1970.

TM 5-6675-243-15. *Operator 's, Organizational, Direct Support, Genera! Support, and Depot Maintenance Manual (Including Repair Parts List): Light, Target, Surveying u/w Range Pole, Self-Iluminating w/Carrying Case (Military Design)* . . . . 3 March 1966.

TM 5-6675-250-10. *Operator's and Organizational Maintenance Manual: Survey Instrument, Azimuth, Gyro, Lightweight Model AG-8, Type 1* ....30 June 1986.

TM 5-6675-270-15. *Operator's, Organizational, Direct and General Support and Depot Maintenance Manual: Theodolite: Directional; 0.2 Mil Graduation; 5.9 In. Long Telescope w/Accessories (Wild Heerbrugg Models) (Mode! T16-MIL66, Type II)..., (Model T16-MIL-68, Type II.. and Theodolite, Directional, 1 Min Graduation; 5.9 Inch Long Telescope w/Accessories (Wild Heerbrugg Model T16-68 DEG Type I)* . . . . 12 March 1970.

TM5-6675-296-14. *Operator's, Organizational, Direct Support and General Support Maintenance Manual for Theodolite, Directional: 0.002 Mil Graduation, 5.9 Inch Long Telescope, Detachable Tribrach w/Acceswories and Tripod (Wild Heerbrugg Models T2-56-C-MIL)..., (Model T2-56-M-MIL)..., (Model T2-63-MIL)..., (Model T2-66-C-MIL)..,, (Model T2-68-MIL)...; Theodolite, Directional (Reference) (Wild Heerbrugg Models T2-56-C-MIL, T2-56-M-MIL, T2-63-MIL, T2-66-C-MIL, T2-67MIL and T2-68MIL)* . . . . *28* June 1977.

TM 5-6675-302-14&P. *Operator's Organizational, Direct Support and General Support Maintenance Manual Including Repair Parts and Special Tools List for Target Set, Azimuth Laying (Wild Heerbrugg Model 242406)...and (Model USATS-79)* . . . . 25 February 1982.

TM 5-6675-304-12. Operator's and Organizational Maintenance Manual for Survey Electronic Distance Measuring Equipment, Infrared, Model DM-60(A4-1)....31 July 1980.

TM 5-6675-308-12. Operator's and Organizational Maintenance Manual for Position and Azimuth Determining System, AN/USQ- 70, Part No. 880500-1...(TM 08837A-12/1A) . . . . 28 October 1988.

*TM 5-6675-330-10. *Operator Manual North-Seeking Gyroscope (NSN 6675-01-391-9079).* 10 June 1994.

Note. TM 5-6675-330-10 is numbered TO 33D7-9-53-1 for the US Air Force.

TM 9-1220-242-12&P. *Operator's and Organizational Maintenance Manual (Including Repair Parts and Special Tools List for Computer Set, Field Artillery, General.. and Computer Set, Field Artillery, Missile* . . . . 25 May 1983.

TM 9-1290-262-10. *Operator's Manual for Aiming Circle, M2 W/E... and M2A2 W/E* . . . . 15 April 1981.

TM 9-6140-200-14. *Operator's, Unit, Intermediate Direct Support and Intermediate General Support Maintenance Manual for Lead-Acid Storage Batteries; 4HN, 24 Volt... MS75047-1; 2HN, 12 Volt... MS35000-1; 6TN, 12 Volt...MS35000-3; 6TL, 12 Volt... MS52149-1* . . . . 13 July 1989.

TM 9-7000-200-13&P. *Operator's, Organizational, and Direct Support Maintenance Manual Including Repair Parts and Special Tools List for Computer System, Backup, General... and Special* . . . .3 June 1985.

★TM 11-5825-291-13, *Satellite Signals Navigation System AN/PSN-11.* 1 June 1994.

★TM 11-7025-300-10. *Opeator's Mnual Forward Entry Device (FED) Mer/Survey (MSR) (Digital Data Set, AN/PSG-7 Software) (NSN 7035-01-342-4837) (EIC: N/A),* 1 November 1993.

★TM 11-7025-311-12&P. *Operator's Unit Maintenance Manual Including Repair Parts and Special Tools List for Printer, Automatic Data Processing Part Number 50786 (NSN 7025-01-381-0760) (EIC: N/A).* 1 February 1994.

READINGS RECOMMENDED

These readings contain relevant supplemental information.

AR 70-38. *Research, Development, Test, and Evaluation of Material for Extreme Climatic Conditions.* 1 August 1979.

AR 115-11. *Army Topography.* 1 March 1980.

AR 310-25. *Dictionary of United States Army Terms.* 15 October 1983.

AR 310-50. *Authorized Abbreviations and Brevity Codes.* 15 November 1985.

AR 600-20. *Army Command Policy.* 30 March 1988.

Classification, Standards of Accuracy and General Specifications of Geodetic Control Surveys

Note. The above document can be obtained from the National Geodetic Survey Division, National Oceanic and Atmospheric Administration, Rockville, MD 20852.

DA Form 2028. *Recommended Changes to Publications and Blank Forms.* February 1974.

DA Pam 351-20. *Army Correspondence Course Program Catalog.* 1 April 1991.

DMA Technical Manual (TM) 8358.1, *Datums, Ellipsoids, Grid and Grid Reference Systems, Preliminary Edition, Undated, DMA Stock No. DMA TM 8358.1 TEXT* (Replaces Department of the Army TM 5-241-1 titled Grids and Grid References.)

DMA Technical Report (TR) 8350.2 *Department of Defense World Geodetic System 1984.* September 1987.

Order DMA TM 8358.1 from:

Defense Mapping Agency Combat Support Center
ATTN: DDCP
Washington, DC 20315-0020

Requests for DMA TR 8350.2 should be sent to:

Defense Mapping Agency
ATTN: PR
Building 56
United States Naval Observatory
Washington, DC 20305-3000

FM 5-105. *Topographic Operations.* 9 September 1987.

FM 5-146. *Engineer Topographic Units.* September 1979.

FM 6-20. *Fire Support in the AirLand Battle.* 17 May 1988.

FM 6-30. *Tactics, Techniques, and Procedures for Observed Fire.* 16 July 1991.

FM 6-40. *Field Artillery Manual Cannon Gunnery.* 27 December 1988.

FM 6-50. *Tactics, Techniques, and Procedures for the Field Artillery Cannon Battery.* 20 November 1990.

FM 6-121. *Tactics, Techniques, and Procedures for Field Artillery Target Acquisition.* 25 September 1990.

HP71B Owner's Manual.

HP71B Reference Manual.

HP71B Interface Owner's Manual.

HP2225B Reference Manual.

Note. These manuals, published by Hewlett-Packard Company, are issued with the backup computer system. For further information, address inquires to:

Portable Computer Division
1000 Northeast Circle Boulevard
Corvallis, Oregon 97330

Specifications to Support Classifications, Standards of Accuracy, and General Specification of Geodetic Control Surveys

Note. The above document can be obtained from the National Geodetic Survey Division, National Oceanic and Atmospheric Administration, Rockville, MD 20852.

STANAG 2210. *Trig Lists (Lists of Geodetic Data).* 9 June 1969.

STANAG 2211. *Geodetic Datums, Spheroids, Grids, and Grid References,* 15 July 1991.

STP 6-82C 14-SM-TG. *Soldier's Manual and Trainer's Guide: 82C, Field Artillery Surveyor (Skill Levels 1/2/3/4).* 17 July 1991.

TM 5-232. *Elements of Surveying.* 1 June 1971.

INDEX

This index is organized alphabetically by topic and subtopic. Topics and subtopics are identified by page number.

ARTILLERY SURVEY CONTROL POINT

For use of this form, see FM 6-2; the proponent agency is TRADOC.

ANNEX A TO STANAG 2865

UTM ZONE	UTM SQUARE	STATION NAME		ACCURACY
		STATION NUMBER		E + N
				AZIMUTH
DATAUM	ELLIPSOID	MAP SERIES SHEET NO		ALTITUDE
HOW MARKED		E	N	ALTITUDE
		LONGITUDE	LATITUDE	

NOTES **WARNING:** *THERE ARE TWO DIFFERENT WAYS OF WRITING THE NUMBERS 1, 7 AND 1·7*	N ↑ LOCATION DIAGRAM

DA FORM 5075-R (MAR 82)

DESCRIPTION	SKETCH	DISTANCE	GRID BEARING/AZIMUTH
			MILS
			DEGREES
			GRADS
			MILS
			DEGREES
			GRADS
			MILS
			DEGREES
			GRADS
			MILS
			DEGREES
			GRADS
			MILS
			DEGREES
			GRADS

METHOD OF DETERMINATION	UNIT
HORIZONTAL	PREPARED
VERTICAL	CHECKED
AZIMUTH/ORIENTATION	DATE
NOTEBOOK REFERENCE	

REVERSE OF DA FORM 5075-R (MAR 82)

COMPUTATION OF AZIMUTH AND/OR DISTANCE FROM COORDINATES (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

INSTRUCTIONS

NOTES: 1 PRESS [illegible] AFTER COMPLETION OF EACH STEP
2 RECORD ADDITIONAL SETS OF DATA IN DATA RECORD COLUMN
3 FOUR AZIMUTH/DISTANCE SETS CAN BE RECORDED
4 ENTER FIELD DATA IN BLOCKS MARKED ▶

STEP	PROMPT	PROCEDURE
1		CALL PROGRAM 1
2	AZIMUTH/DISTANCE	
3	E OCC STA: 0.00	ENTER EASTING OF OCCUPIED STATION
4	N OCC STA: 0.00	ENTER NORTHING OF OCCUPIED STATION
5	E OF AZMK: 0.00	ENTER EASTING OF AZIMUTH MARK
6	N OF AZMK: 0.00	ENTER NORTHING OF AZIMUTH MARK
7	^AZ TO AZMK: 0.000	RECORD AZIMUTH
8	DIST AZMK: 0.000	RECORD DISTANCE
9	MORE POINTS (Y/N):	ENTER Y OR N
10	END OF MSN (Y/N):	ENTER Y OR N

REMARKS:

DATA RECORD

OCCUPIED STATION NAME:	OCCUPIED STATION NAME:
EASTING: ▶	EASTING: ▶
NORTHING: ▶	NORTHING: ▶
AZIMUTH MARK NAME:	AZIMUTH MARK NAME:
EASTING: ▶	EASTING: ▶
NORTHING: ▶	NORTHING: ▶
AZIMUTH (MILS):	AZIMUTH (MILS):
DISTANCE (METERS):	DISTANCE (METERS):

DATA RECORD

OCCUPIED STATION NAME:	OCCUPIED STATION NAME:
EASTING: ▶	EASTING: ▶
NORTHING: ▶	NORTHING: ▶
AZIMUTH MARK NAME:	AZIMUTH MARK NAME:
EASTING: ▶	EASTING: ▶
NORTHING: ▶	NORTHING: ▶
AZIMUTH (MILS):	AZIMUTH (MILS):
DISTANCE (METERS):	DISTANCE (METERS):

COMPUTATION OF COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE, AND VERTICAL ANGLE (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES:
1. OFFSET LEGS ARE NOT GIVEN STATION NUMBERS
2. STEP 17. FOR ADDITIONAL LEGS, ENTER N AND PROGRAM GOES TO STEP 7
3. STEP 17. FOR CLOSURE, ENTER Y AND PROGRAM GOES TO STEP 1, BACK OF FORM
4. FOUR TRAVERSE LEGS CAN BE RECORDED PER FORM
5. SEE BACK OF FORM FOR CLOSURE AND ADJUSTMENT
6. ENTER FIELD DATA IN BLOCKS MARKED ▶

INSTRUCTIONS

STEP	PROMPT	PROCEDURE
1		CALL PROGRAM 2
2	TRAVERSE	
3	E OCC STA: 0.00	ENTER EASTING OF OCCUPIED STATION
4	N OCC STA: 0.00	ENTER NORTHING OF OCCUPIED STATION
5	HT OCC STA: 0.0	ENTER HEIGHT OF OCCUPIED STATION
6	AZ TO REAR: 0.000	ENTER AZIMUTH TO REAR STATION
7	MN SCH LEG (Y/N):	ENTER Y OR N
8	HZ < FWD: 0.000	HORIZONTAL ANGLE TO FORWARD STATION
9	VA (+/-) 0.000	VERTICAL ANGLE TO FORWARD STATION
10	RECIP VA (Y/N):	ENTER Y OR N
11	^DIST FWD (-SL/+HZ) 0.000	ENTER HORIZONTAL OR SLOPE DISTANCE
12	HZ DIST: 0.000	RECORD HORIZONTAL DISTANCE
13	E FWD STA: 0.00	RECORD EASTING
14	N FWD STA: 0.00	RECORD NORTHING
15	HT FWD STA: 0.0	RECORD HEIGHT
16	AZ TO REAR: 0.000	RECORD AZIMUTH TO REAR
17	CLOSURE (Y/N):	ENTER Y OR N

REMARKS:

DATA RECORD

REAR STATION:	REAR STATION:
STATION NAME: NUMBER:	STATION NAME: NUMBER:
EASTING:	EASTING:
NORTHING:	NORTHING:
HEIGHT (METERS):	HEIGHT (METERS):
AZIMUTH TO REAR (MILS):	AZIMUTH TO REAR (MILS):
HORIZONTAL ANGLE (MILS): ▶	HORIZONTAL ANGLE (MILS): ▶
VERTICAL ANGLE (MILS): ▶ + -	VERTICAL ANGLE (MILS): ▶ + -
(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
SLOPE DISTANCE (METERS): ▶ (-)	SLOPE DISTANCE (METERS): ▶ (-)
HORIZONTAL DISTANCE (METERS): ▶ +	HORIZONTAL DISTANCE (METERS): ▶ +
STATION NAME: NUMBER:	STATION NAME: NUMBER:
EASTING:	EASTING:
NORTHING:	NORTHING:
HEIGHT (METERS):	HEIGHT (METERS):
AZIMUTH TO REAR (MILS):	AZIMUTH TO REAR (MILS):
HORIZONTAL ANGLE (MILS): ▶	HORIZONTAL ANGLE (MILS): ▶
VERTICAL ANGLE (MILS): ▶ + -	VERTICAL ANGLE (MILS): ▶ + -
(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
SLOPE DISTANCE (METERS): ▶ (-)	SLOPE DISTANCE (METERS): ▶ (-)
HORIZONTAL DISTANCE (METERS): ▶ +	HORIZONTAL DISTANCE (METERS): ▶ +

DA FORM 5591-R, DEC 86

CLOSURE ADJUSTMENT

NOTES: 1. STEP 11, CHECK SPECIFICATIONS ON CLOSURE
2. IF STEP 12 IS N, PROGRAM GOES TO STEP 19
3. IF STEP 12 IS Y, PROGRAM PERFORMS ADJUSTMENT ON EACH MAIN SCHEME STATION OF THE TRAVERSE
4. FOUR ADJUSTED STATIONS CAN BE RECORDED PER FORM

INSTRUCTIONS				DATA RECORD	
STEP	**PROMPT**		**PROCEDURE**	**CLOSURE DATA**	**ADJUSTED DATA**
1	CLOSING <:	0.000	ENTER CLOSING ANGLE	CLOSING ANGLE (MILS):	STATION NAME:
2	CMPTD AZ:	0.000	RECORD AZIMUTH FORWARD	COMPUTED AZIMUTH FORWARD (MILS):	STATION NUMBER:
3	KN AZ FWD:	0.000	ENTER KNOWN AZIMUTH	KNOWN AZIMUTH FORWARD (MILS):	EASTING:
4	AZ CORR:	0.000	RECORD TOTAL AZIMUTH CORRECTION	TOTAL AZIMUTH CORRECTION (MILS):	NORTHING:
5	KN HT:	0.0	ENTER KNOWN HEIGHT	KNOWN HEIGHT (METERS):	HEIGHT (METERS):
6	HT CORR:	0.0	RECORD TOTAL HEIGHT CORRECTION	TOTAL HEIGHT CORRECTION (METERS):	ADJUSTED AZIMUTH TO REAR (MILS)
7	KN EAST:	00.0	ENTER KNOWN EASTING	KNOWN EASTING:	STATION NAME:
8	KN NORTH:	0.00	ENTER KNOWN NORTHING	KNOWN NORTHING:	STATION NUMBER:
9	TTL:	0.000	RECORD TOTAL TRAVERSE LENGTH	TOTAL TRAVERSE LENGTH (METERS):	EASTING:
10	RE:	0.00	RECORD RADIAL ERROR	RADIAL ERROR (METERS):	NORTHING:
11	AR: 1/		RECORD ACCURACY RATIO	ACCURACY RATIO	HEIGHT (METERS):
				ADJUSTED DATA	ADJUSTED AZIMUTH TO REAR (MILS):
12	^ADJUST (Y/N):		ENTER Y OR N	STATION NAME	STATION NAME:
13	STA	—	RECORD STATION NUMBER	STATION NUMBER	STATION NUMBER:
14	EAST:	0.00	RECORD ADJUSTED EASTING	EASTING:	EASTING:
15	NORTH:	0.00	RECORD ADJUSTED NORTHING	NORTHING:	NORTHING:
16	HT:	0.0	RECORD ADJUSTED HEIGHT	HEIGHT (METERS):	HEIGHT (METERS):
17	AZ TO REAR:	0.000	RECORD ADJUSTED AZIMUTH TO REAR	ADJUSTED AZIMUTH TO REAR (MILS):	ADJUSTED AZIMUTH TO REAR (MILS):
18	AZ FWD AZMK:	0.000	RECORD ADJUSTED AZIMUTH FORWARD		ADJUSTED AZIMUTH FORWARD (MILS):
19	END OF MSN (Y/N):		ENTER Y OR N		

REMARKS

COMPUTATION OF PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES, AND VERTICAL ANGLES (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

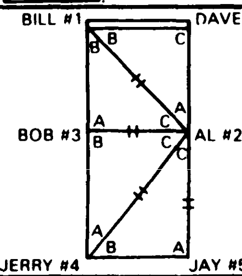
COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES:
1. IF STEP 21 IS Y, PROGRAM GOES TO STEP 1, BACK OF FORM
2. IF STEP 21 IS N, PROGRAM GOES TO STEP 22
3. STEP 22 IS Y IF STATION IS START POINT FOR COMPUTATIONS NEXT PROMPT IS "END OF TRIANGLE # ____." THEN PROGRAM GOES TO STEP 9
4. STEP 22 IS N IF STATION IS NOT START POINT PROGRAM THEN GOES TO STEP 23.
5. STEP 23. ENTER STATION NUMBER OF START POINT, THEN PROGRAM GOES TO STEP 9
6. SEE BACK OF FORM FOR SURVEY CLOSURE
7. ENTER FIELD DATA IN BLOCKS MARKED

SKETCH: (DRAW SKETCH, AND LABEL STATIONS BY NAME AND NUMBER.)

SAMPLE SKETCH

NOTES:
1. DRAW A DIAGRAM OF THE TRIANGLE SCHEME AND LABEL STARTING BASE, REQUIRED SIDE, INTERIOR ANGLES, AND STATIONS BY NAME
2. NUMBER THE STATIONS IN THE ORDER THAT THE STATIONS ARE COMPUTED. THE STARTING STATION IS NUMBER 1



INSTRUCTIONS / DATA RECORD

STEP	PROMPT		PROCEDURE	DATA RECORD	DATA RECORD
				REAR STATION:	REAR STATION:
1			CALL PROGRAM 3	STATION NAME: NUMBER:	STATION NAME: NUMBER:
2	TRIANGULATION				
3	EAST B/C:	0.00	ENTER EASTING OF B OR C	EASTING:	EASTING:
4	NORTH B/C:	0.00	ENTER NORTHING	NORTHING:	NORTHING:
5	HT B/C:	0.0	ENTER HEIGHT	HEIGHT (METERS):	HEIGHT (METERS):
6	AZ BASE:	0.000	ENTER AZIMUTH OF BASE	AZIMUTH OF BASE (MILS):	AZIMUTH OF BASE (MILS):
7	BASE DIST:	0.000	ENTER BASE DISTANCE	BASE DISTANCE (METERS):	BASE DISTANCE (METERS):
8	GRID BASE (Y/N):		ENTER Y OR N	(GRID/HORIZONTAL)	(GRID/HORIZONTAL)
9	ANGLE A:	0.000	ENTER ANGLE A	ANGLE A (MILS):	ANGLE A (MILS):
10	ANGLE B:	0.000	ENTER ANGLE B	ANGLE B (MILS):	ANGLE B (MILS):
11	ANGLE C:	0.000	ENTER ANGLE C	ANGLE C (MILS):	ANGLE C (MILS):
12	VA (+/-)	0.000	ENTER VERTICAL ANGLE	VERTICAL ANGLE (MILS): + -	VERTICAL ANGLE (MILS): + -
13	RECIP VA (Y/N)		ENTER Y OR N	(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
14	CLOSURE IS:	0.000	CHECK SPECIFICATIONS ON CLOSURE	REMARKS:	
15	SIDE BA=1, CA=2:	0	ENTER 1 OR 2		
16	E OF_:	0.00	RECORD EASTING		
17	N OF _:	0.00	RECORD NORTHING		
18	HT OF _:	0.0	RECORD HEIGHT		
19	AZ TO REAR:	0.000	RECORD AZIMUTH TO REAR		
20	BASE DIST:	0.000	RECORD NEXT BASE		
21	CLOSE (Y/N):		ENTER Y OR N		
22	STA _ START (Y/N):		ENTER Y OR N		
23	# OF START PT: _	00	ENTER NUMBER		

DA FORM 5592-R, DEC 86

CLOSURE ON KNOWN POINT OR CHECK BASE

INSTRUCTIONS (KNOWN POINT)			DATA RECORD
STEP	PROMPT	PROCEDURE	
1	KN PT = 1, CK BASE = 2 0	ENTER 1	KNOWN POINT (TRIG LIST)
2	CLOSING <: 0 000	ENTER CLOSING ANGLE	CLOSING ANGLE (MILS):
3	CMPTD AZ: 0 000	RECORD COMPUTED AZIMUTH TO AZIMUTH MARK	COMPUTED AZIMUTH (MILS):
4	KN AZ FWD: 0 000	ENTER KNOWN AZIMUTH	KNOWN AZIMUTH (MILS):
5	AZ ERROR: 0 000	RECORD TOTAL AZIMUTH ERROR	AZIMUTH ERROR (MILS)
6	KN HT: 0 0	ENTER KNOWN HEIGHT	KNOWN HEIGHT (METERS):
7	HT ERROR: 0 0	RECORD TOTAL HEIGHT ERROR	HEIGHT ERROR (METERS):
8	KN EAST: 0 00	ENTER KNOWN EASTING	KNOWN EASTING:
9	KN NORTH: 0 00	ENTER KNOWN NORTHING	KNOWN NORTHING
10	TOTAL DIST: 0 000	RECORD TOTAL MAIN SCHEME DISTANCE	TOTAL DISTANCE (METERS):
11	RE: 0 00	RECORD RADIAL ERROR	RADIAL ERROR (METERS):
12	AR: 1/	RECORD ACCURACY RATIO	ACCURACY RATIO: (CHECK SPECIFICATIONS)
13	END OF MSN (Y/N):	ENTER Y OR N	

INSTRUCTIONS (CHECK BASE)			DATA RECORD
STEP	PROMPT	PROCEDURE	
1	KN PT = 1, CK BASE = 2	ENTER 2	CHECK BASE:
2	MEASURED AZ: 0 000	ENTER MEASURED AZIMUTH	MEASURED AZIMUTH (MILS):
3	MEAS BASE: 0 000	ENTER MEASURED BASE	MEASURED BASE (METERS):
4	AZ ERROR: 0 000	RECORD AZIMUTH ERROR	AZIMUTH ERROR (MILS)
5	CA: 1/	RECORD COMPARATIVE ACCURACY	COMPARATIVE ACCURACY: (CHECK SPECIFICATIONS)
6	END OF MSN (Y/N):	ENTER Y OR N	

REMARKS:

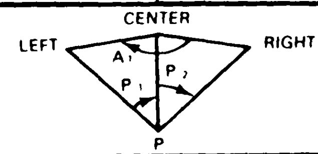
REVERSE OF DA FORM 5592-R, DEC 86

COMPUTATION OF COORDINATES AND HEIGHT BY THREE-POINT RESECTION (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES:
1. FOR STEP 15, SEE FM 6-2, CHAPTER 6
2. IF STEP 20 IS Y, PROGRAM GOES TO STEP 21
3. IF STEP 20 IS N, PROGRAM GOES TO STEP 22
4. IF STEP 21 IS Y, PROGRAM GOES TO STEP 10
5. IF STEP 21 IS N, PROGRAM GOES TO STEP 3
6. ENTER FIELD DATA IN BLOCKS MARKED ▶.



INSTRUCTIONS / DATA RECORD

STEP	PROMPT		PROCEDURE	DATA RECORD	
1			CALL PROGRAM 4		
2	RESECTION				
3	E LFT STA:	0.00	ENTER EASTING OF LEFT STATION	EASTING OF LEFT:	EASTING OF LEFT:
4	N LFT STA:	0.00	ENTER NORTHING OF LEFT STATION	NORTHING OF LEFT	NORTHING OF LEFT:
5	E CTR STA:	0.00	ENTER EASTING OF CENTER STATION	EASTING OF CENTER:	EASTING OF CENTER:
6	N CTR STA:	0.00	ENTER NORTHING OF CENTER STATION	NORTHING OF CENTER:	NORTHING OF CENTER
7	HT CTR STA:	0.00	ENTER HEIGHT OF CENTER STATION	HEIGHT OF CENTER:	HEIGHT OF CENTER:
8	E RT STA:	0.00	ENTER EASTING OF RIGHT STATION	EASTING OF RIGHT:	EASTING OF RIGHT
9	N RT STA:	0.00	ENTER NORTHING OF RIGHT STATION	NORTHING OF RIGHT:	NORTHING OF RIGHT:
10	< LF TO CTR:	0.000	ENTER ANGLE P_1	▶ HORIZONTAL ANGLE P_1 (MILS)	▶ HORIZONTAL ANGLE P_1 (MILS)
11	< CTR TO RT:	0.000	ENTER ANGLE P_2	▶ HORIZONTAL ANGLE P_2 (MILS)	▶ HORIZONTAL ANGLE P_2 (MILS)
12	VA P - CTR:	0.000	ENTER VERTICAL ANGLE FROM P TO CENTER	▶ VERTICAL ANGLE FROM P TO CENTER (MILS): ±	▶ VERTICAL ANGLE FROM P TO CENTER (MILS): ±
13	HT/T AT CTR:	0.0	ENTER HEIGHT OF TARGET AT CENTER	HEIGHT OF TARGET (METERS):	HEIGHT OF TARGET (METERS):
14	HT/I AT P:	0.0	ENTER HEIGHT OF INSTRUMENT AT P	HEIGHT OF INSTRUMENT (METERS):	HEIGHT OF INSTRUMENT (METERS):
15	SUM OF <'S:	0.000	CHECK SPECIFICATIONS (2845-3555 INVALID 3-PT)	SUM OF ANGLES:	SUM OF ANGLES:
16	E OF P:	0.00	RECORD EASTING OF P	EASTING OF P:	EASTING OF P:
17	N OF P:	0.00	RECORD NORTHING OF P	NORTHING OF P:	NORTHING OF P:
18	HT OF P:	0.0	RECORD HEIGHT OF P	HEIGHT OF P (METERS):	HEIGHT OF P (METERS):
19	AZ P TO CTR:	0.000	RECORD AZIMUTH FROM P TO CENTER	AZIMUTH FROM P TO CENTER (MILS):	AZIMUTH FROM P TO CENTER (MILS):
20	ANOTHER 3-PT (Y/N):		ENTER Y OR N	REMARKS	
21	SAME L/R/CTR (Y/N):		ENTER Y OR N		
22	END OF MSN (Y/N):		ENTER Y OR N		

DA FORM 5593-R, DEC 86

ADDITIONAL INSTRUCTIONS

GIVEN: COORDINATES OF LEFT, CENTER, AND RIGHT STATIONS.
HEIGHT OF CENTER STATION.

FIELD DATA: OBSERVE HORIZONTAL ANGLES P_1 AND P_2
OBSERVE VERTICAL ANGLE TO CENTER.
MEASURE HEIGHT OF INSTRUMENT AND HEIGHT OF TARGET TO NEAREST 0.1 METER.

GUIDE: RECORD GIVEN AND FIELD DATA IN DATA RECORD.
IF INTENDED TO EXTEND CONTROL, A FOURTH POINT AND A SECOND COMPUTATION MUST BE MADE. OBTAIN A SECOND SET OF DATA FOR POINT P, AND COMPUTE AN ACCURACY RATIO AS FOLLOWS:

AR = 1:(DISTANCE FROM P TO CLOSEST KNOWN POINT / RADIAL ERROR FOR MEAN COORDINATES OF P)

STEP 15: IF SUM OF ANGLES IS BETWEEN 2845 AND 3555, A NEW POINT P OR NEW POINT LEFT, CENTER, AND/OR RIGHT MUST BE SELECTED.

LIMITATIONS: ANGLES P_1, P_2, LEFT AND RIGHT SHOULD BE GREATER THAN 400 MILS, PREFERABLY GREATER THAN 533 MILS

REMARKS:

COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD, SUN (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1. IF STEP 15 IS Y, PROGRAM GOES TO STEP 10
2. IF STEP 15 IS N, PROGRAM GOES TO STEP 16
3. SEE BACK OF FORM FOR REJECTION CRITERIA.
4. ENTER FIELD DATA IN BLOCKS MARKED ▶.

INSTRUCTIONS

STEP	PROMPT		PROCEDURE
1			CALL PROGRAM 5
2	ALTITUDE METHOD		
3	USE SUN (Y/N):		ENTER Y
4	LAT(-:S):	0.0000000	ENTER LATITUDE OF STATION
5	LG(-:W)	0.0000000	ENTER LONGITUDE OF STATION
6	^DECLN (TBL 2/10A) (DD.MMSSS):	0.00000	ENTER DECLINATION OF SUN (FM 6-300, TABLE 2)
7	DC DECLN (sec):	0000	ENTER DAILY CHANGE IN SECONDS OF DECLINATION
8	WC(-:F; MMSS):	0.0000	ENTER WATCH CORRECTION
9	TZ CORR (-:E):	00	ENTER TIME ZONE CORRECTION IN HOURS
10	MN W TIME:	00.00000	ENTER MEAN WATCH TIME
11	REFR(TBL1,mil):	0.00	ENTER REFRACTION (TABLE 1b)
12	HZ < SUN	0.000	ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO SUN
13	VA:	0.000	ENTER VERTICAL ANGLE TO SUN
14	ASTRO AZ/MK:	0.000	RECORD ASTRONOMIC AZIMUTH TO AZIMUTH MARK
15	ADD SETS REQD(Y/N):		ENTER Y OR N
16	4TH/5TH ORDER(4/5):	0	ENTER 4 OR 5
17	MN ASTRO AZ:	0.000	RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK
18	GRID ZONE:	00	ENTER GRID ZONE
19	GRID AZ/MK:	0.000	RECORD GRID AZIMUTH TO AZIMUTH MARK
20	END OF MSN (Y/N):		ENTER Y OR N

DATA RECORD

AZIMUTH MARK:	APPROXIMATE AZIMUTH TO AZIMUTH MARK (MILS):
STATION:	TEMPERATURE:
LATITUDE: + − ° ' "N S	
LONGITUDE: + − ° ' "E W	
DECLINATION: + − ° ' "	
DAILY CHANGE (SECONDS): + −	
WATCH CORRECTION: (SLOW) + (FAST) −	MINUTES / SECONDS
TIME ZONE CORRECTION: + − W E	

SET ___	SET ___	SET ___
▶ HOURS / MINUTES / SECONDS	▶ HOURS / MINUTES / SECONDS	▶ HOURS / MINUTES / SECONDS
ENTER AS + MILS	ENTER AS + MILS	ENTER AS + MILS
▶ HORIZONTAL ANGLE (MILS):	▶ HORIZONTAL ANGLE (MILS)	▶ HORIZONTAL ANGLE (MILS)
▶ VERTICAL ANGLE (MILS):	▶ VERTICAL ANGLE (MILS)	▶ VERTICAL ANGLE (MILS):
ASTRONOMIC AZIMUTH (MILS):	ASTRONOMIC AZIMUTH (MILS):	ASTRONOMIC AZIMUTH (MILS):

MEAN ASTRONOMIC AZIMUTH (MILS):

GRID ZONE:

GRID AZIMUTH (MILS):

REMARKS

DA FORM 5594-R, DEC 86

ADDITIONAL INSTRUCTIONS

GIVEN: TIME ZONE OF AREA OF OPERATION.

FIELD DATA: APPROXIMATE AZIMUTH TO AZIMUTH MARK.
TEMPERATURE AT TIME OF OBSERVATION.
LATITUDE AND LONGITUDE OF STATION.
LOCAL DATE OF OBSERVATION.
MEAN WATCH TIME OF OBSERVATION AND WATCH CORRECTION.
HORIZONTAL CLOCKWISE ANGLE FROM AZIMUTH MARK TO SUN.
OBSERVED ALTITUDE (VERTICAL ANGLE) TO SUN.

GUIDE: RECORD GIVEN AND FIELD DATA IN DATA RECORD.
ENTER LATITUDE AND LONGITUDE IN THE FORMAT OF (DD.MMSSS): DEGREES, MINUTES, AND SECONDS.
USING LOCAL DATE, EXTRACT DECLINATION (DD.MMSSS) AND DAILY CHANGE IN SECONDS FROM FM 6-300, TABLE 2.
ENTER MEAN WATCH TIME IN THE FORMAT OF (HH.MMSSS): HOURS, MINUTES, AND SECONDS.
USING OBSERVED ALTITUDE AND TEMPERATURE, EXTRACT REFRACTION FROM FM 6-300.
STEP 16 ENABLES THE PROGRAM TO PERFORM REJECTION BASED ON FOURTH- OR FIFTH-ORDER SPECIFICATIONS (0.150 MIL FOR FOURTH-ORDER AND 0.3 MIL FOR FIFTH-ORDER).

LIMITATIONS: ONLY THREE SETS OF DATA CAN BE COMPUTED AT ONE TIME.
SUN MUST BE WITHIN 530 MILS OF PRIME VERTICAL.
SUN MUST BE BETWEEN 175 MILS AND 800 MILS (1,060 MILS IF THE CARD METHOD IS USED OR SPECIAL EYEPIECES ARE AVAILABLE).
SUN MUST NOT BE WITHIN 2 HOURS OF OBSERVER'S MERIDIAN.

REMARKS

COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD, STAR (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1 STEP 10, SEE BACK OF FORM TO DETERMINE IF STAR IS EAST OR WEST
2 IF STEP 12 IS Y, PROGRAM GOES TO STEP 7
3 IF STEP 12 IS N, PROGRAM GOES TO STEP 13
4 SEE BACK OF FORM FOR REJECTION CRITERIA
5 ENTER FIELD DATA IN BLOCKS MARKED ▶

INSTRUCTIONS / DATA RECORD

STEP	PROMPT	PROCEDURE	DATA RECORD		
			AZIMUTH MARK	APPROXIMATE AZIMUTH TO AZIMUTH MARK (MILS)	
1		CALL PROGRAM 5			
2	ALTITUDE METHOD		STATION	TEMPERATURE	
3	USE SUN (Y/N):	ENTER N			
			STAR NAME:	STAR NUMBER, TABLE 9:	
4	LAT(- S) 0 0000000	ENTER LATITUDE OF STATION	LATITUDE + ° ' "N - S		
5	LG(- W) 0 0000000	ENTER LONGITUDE OF STATION	LONGITUDE + ° ' "E - W		
6	∧DECLN (TBL 2/10A) (DD MMSSS) 0 00000	ENTER DECLINATION OF STAR (FM 6-300, TABLE 10A)	DECLINATION + ° ' " -		
			SET ___	SET ___	SET ___
7	REFR (TBL 1, mil) 0 00	ENTER REFRACTION (TABLE 1b)	ENTER AS + MILS	ENTER AS + MILS	ENTER AS + MILS
8	HZ<STAR 0 000	ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO STAR	▶ HORIZONTAL ANGLE (MILS)	▶ HORIZONTAL ANGLE (MILS)	▶ HORIZONTAL ANGLE (MILS)
9	VA 0 000	ENTER VERTICAL ANGLE TO STAR	▶ VERTICAL ANGLE (MILS)	▶ VERTICAL ANGLE (MILS)	▶ VERTICAL ANGLE (MILS)
10	STAR EAST (Y/N)	ENTER Y OR N			
11	ASTRO AZ/MK 0 000	RECORD ASTRONOMIC AZIMUTH TO AZIMUTH MARK	ASTRONOMIC AZIMUTH (MILS)	ASTRONOMIC AZIMUTH (MILS)	ASTRONOMIC AZIMUTH (MILS)
12	ADD SETS REQD(Y/N)	ENTER Y OR N			
13	4TH/5TH ORDER(4/5) 0	ENTER 4 OR 5			
14	MN ASTRO AZ 0 000	RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK	MEAN ASTRONOMIC AZIMITH (MILS)		
15	GRID ZONE 00	ENTER GRID ZONE	GRID ZONE		
16	GRID AZ/MK 0 000	RECORD GRID AZIMUTH TO AZIMUTH MARK	GRID AZIMUTH (MILS)		
17	END OF MSN (Y/N)	ENTER Y OR N			

REMARKS

ADDITIONAL INSTRUCTIONS

GIVEN: TIME ZONE OF AREA OF OPERATION.

FIELD DATA: APPROXIMATE AZIMUTH TO AZIMUTH MARK.
TEMPERATURE AT TIME OF OBSERVATION.
STAR NAME AND NUMBER.
LATITUDE AND LONGITUDE OF STATION.
LOCAL DATE OF OBSERVATION.
HORIZONTAL CLOCKWISE ANGLE FROM AZIMUTH MARK TO STAR.
OBSERVED ALTITUDE (VERTICAL ANGLE) TO STAR.

GUIDE: RECORD GIVEN AND FIELD DATA IN DATA RECORD.
ENTER LATITUDE AND LONGITIDE IN THE FORMAT OF (DD.MMSSS): DEGREES, MINUTES, AND SECONDS.
USING LOCAL DATE, EXTRACT DECLINATION (DD.MMSSS) FROM FM 6-300, TABLE 10A.
USING OBSERVED ALTITUDE AND TEMPERATURE, EXTRACT REFRACTION FROM FM 6-300.
DETERMINE IF STAR IS EAST OR WEST BY ADDING THE HORIZONTAL ANGLE TO THE APPROXIMATE AZIMUTH OF THE AZIMUTH MARK.
STEP 13 ENABLES THE PROGRAM TO PERFORM REJECTION BASED ON FOURTH- OR FIFTH-ORDER SPECIFICATIONS (0.150 MIL FOR FOURTH-ORDER AND 0.3 MIL FOR FIFTH-ORDER).

LIMITATIONS: ONLY THREE SETS OF DATA CAN BE COMPUTED AT ONE TIME.
STAR MUST BE WITHIN 530 MILS OF PRIME VERTICAL.
STAR MUST BE BETWEEN 175 MILS AND 800 MILS (UNLESS THE CARD METHOD IS USED OR SPECIAL EYEPIECES ARE AVAILABLE).
STAR MUST NOT BE WITHIN 2 HOURS OF OBSERVER'S MERIDIAN.

REMARKS:

COMPUTATION OF ASTRONOMIC AZIMUTH BY POLARIS TABULAR METHOD (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1 IF STEP 15 IS Y, PROGRAM GOES TO STEP 8
2 IF STEP 15 IS N, PROGRAM GOES TO STEP 16
3 SEE BACK OF FORM FOR REJECTION CRITERIA
4 ENTER FIELD DATA IN BLOCKS MARKED ▶

INSTRUCTIONS

STEP	PROMPT	PROCEDURE
1		CALL PROGRAM 8
2	POLARIS TAB METHOD	
3	LAT(-:S): 0.0000000	ENTER LATITUDE OF STATION
4	LG(-:W): 0.0000000	ENTER LONGITUDE OF STATION
5	TZ CORR (-E) 00	ENTER TIME ZONE CORRECTION IN HOURS
6	^SIDRL TIME (TBL 2) (HH.MMSSS) 00.00000	ENTER SIDEREAL TIME (FM 6-300, TABLE 2)
7	WC(-:F;.MMSS): 0.0000	ENTER WATCH CORRECTION
8	MN W TIME: 00.00000	ENTER MEAN WATCH TIME
9	HZ< STAR 0.000	ENTER HORIZONTAL ANGLE FROM AZIMUTH MARK TO STAR
10	(LST)HRS __ MIN __ __	RECORD LOCAL SIDEREAL TIME
11	B 0 (TBL 12) 00.0	ENTER B 0 (+/-)
12	B 1 (TBL 12) 0.0	ENTER B 1 (+/-)
13	B 2 (TBL 12) 0.0	ENTER B 2 (+/-)
14	ASTRO AZ/MK: 0.000	RECORD ASTRONOMIC AZIMUTH TO AZIMUTH MARK
15	ADD SETS REQD(Y/N):	ENTER Y OR N
16	4TH/5TH ORDER(4/5): 0	ENTER 4 OR 5
17	MN ASTRO AZ: 0.000	RECORD MEAN ASTRONOMIC AZIMUTH TO AZIMUTH MARK
18	GRID ZONE 00	ENTER GRID ZONE
19	GRID AZ/MK: 0.000	RECORD GRID AZIMUTH TO AZIMUTH MARK
20	END OF MSN (Y/N):	ENTER Y OR N

DATA RECORD

AZIMUTH MARK:

APPROXIMATE AZIMUTH TO AZIMUTH MARK (MILS):

STATION:

LATITUDE: + - ° ' "N S

LONGITUDE: + - ° ' "E W

TIME ZONE CORRECTION: + - W E

SIDEREAL TIME: + HOURS MINUTES SECONDS

WATCH CORRECTION: (SLOW) + (FAST) - HOURS MINUTES SECONDS

SET __	SET __	SET __
HOURS MINUTES SECONDS	HOURS MINUTES SECONDS	HOURS MINUTES SECONDS
HORIZONTAL ANGLE (MILS):	HORIZONTAL ANGLE (MILS):	HORIZONTAL ANGLE (MILS):
HOURS, MINUTES	HOURS, MINUTES	HOURS, MINUTES
B 0, B 1, B 2	B 0, B 1, B 2	B 0, B 1, B 2
ASTRONOMIC AZIMUTH (MILS):	ASTRONOMIC AZIMUTH (MILS):	ASTRONOMIC AZIMUTH (MILS):

MEAN ASTRONOMIC AZIMUTH (MILS):

GRID ZONE:

GRID AZIMUTH (MILS):

REMARKS:

DA FORM 5598-R, DEC 86

ADDITIONAL INSTRUCTIONS

GIVEN: TIME ZONE OF AREA OF OPERATION.

FIELD DATA: APPROXIMATE AZIMUTH TO AZIMUTH MARK.
LATITUDE AND LONGITUDE OF STATION.
LOCAL DATE OF OBSERVATION.
MEAN WATCH TIME OF OBSERVATION AND WATCH CORRECTION.
HORIZONTAL CLOCKWISE ANGLE FROM AZIMUTH MARK TO POLARIS.

GUIDE: RECORD GIVEN AND FIELD DATA IN DATA RECORD.
ENTER LATITUDE AND LONGITUDE IN THE FORMAT OF (DD.MMSSS): DEGREES, MINUTES, AND SECONDS.
USING LOCAL DATE, EXTRACT SIDEREAL TIME (HH.MMSSS): HOURS, MINUTES, AND SECONDS.
ENTER WATCH CORRECTION IN THE FORMAT OF (.MMSS): MINUTES AND SECONDS.
ENTER MEAN WATCH TIME IN THE FORMAT OF (HH.MMSSS).
USE LOCAL SIDEREAL TIME FROM STEP 10, LATITUDE, AND DAY AND MONTH TO ENTER TABLE 12. EXTRACT B_0, B_1, AND B_2.
STEP 16 ENABLES THE PROGRAM TO PERFORM REJECTION BASED ON FOURTH- OR FIFTH-ORDER SPECIFICATIONS (0.150 MIL FOR FOURTH - ORDER AND 0.3 MIL FOR FIFTH - ORDER).

LIMITATIONS: ONLY THREE SETS OF DATA CAN BE COMPUTED AT ONE TIME.
OBSERVER'S LOCATION MUST BE BETWEEN 5° AND 70° NORTH LATITUDE.

REMARKS:

COMPUTATION—CONVERGENCE OF TRUE AZIMUTH TO GRID AZIMUTH (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1 IF STEP 9 IS Y, PROGRAM GOES TO STEP 2
2 IF STEP 9 IS N, PROGRAM GOES TO STEP 10
3 FOUR CONVERGENCE PROBLEMS CAN BE RECORDED PER FORM
4 ENTER FIELD DATA IN BLOCKS MARKED ▶

INSTRUCTIONS

STEP	PROMPT		PROCEDURE
1			CALL PROGRAM 9
2	GRID CONVERGENCE		
3	LAT(-:S):	0.0000000	ENTER LATITUDE OF STATION
4	LG(-:W):	0.0000000	ENTER LONGITUDE OF STATION
5	TRUE AZ:	0.000	ENTER TRUE AZIMUTH
6	GRID ZONE:	00	ENTER GRID ZONE NUMBER
7	CONVG:	0.000	RECORD CONVERGENCE
8	GRID AZ:	0.000	RECORD GRID AZIMUTH
9	ANOTHER CVG (Y/N)		ENTER Y OR N
10	END OF MSN (Y/N):		ENTER Y OR N

DATA RECORD

AZIMUTH MARK:	AZIMUTH MARK:
STATION:	STATION:
LATITUDE: ° ' "N + - S	LATITUDE: ° ' "N + - S
LONGITUDE: ° ' "E + - W	LONGITUDE: ° ' "E + - W
TRUE AZIMUTH (MILS): ▶	TRUE AZIMUTH (MILS): ▶
GRID ZONE:	GRID ZONE:
CONVERGENCE (MILS):	CONVERGENCE (MILS):
GRID AZIMUTH (MILS):	GRID AZIMUTH (MILS):

REMARKS:

DATA RECORD

AZIMUTH MARK:	AZIMUTH MARK:
STATION:	STATION:
LATITUDE: ° ' "N + - S	LATITUDE: ° ' "N + - S
LONGITUDE: ° ' "E + - W	LONGITUDE: ° ' "E + - W
TRUE AZIMUTH (MILS): ▶	TRUE AZIMUTH (MILS): ▶
GRID ZONE:	GRID ZONE:
CONVERGENCE (MILS):	CONVERGENCE (MILS):
GRID AZIMUTH (MILS):	GRID AZIMUTH (MILS):

DA FORM 5599-R, DEC 86

COMPUTATION—CONVERSION OF GEOGRAPHIC COORDINATES TO UTM COORDINATES (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1. IF STEP 10 IS Y, PROGRAM GOES TO STEP 2
2. IF STEP 10 IS N, PROGRAM GOES TO STEP 11
3. TWO CONVERSION PROBLEMS CAN BE RECORDED PER FORM

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	STATION:	STATION:
1		CALL PROGRAM 10		
2	GEO/UTM/ZONE-ZONE			
3	SPHEROID CODE: 0 1=CLARKE 1866 2=INTERNATIONAL 3=CLARKE 1880 4=EVEREST 5=BESSEL 6=AUSTRALIAN 7=WGS-72 8=GRS-80	ENTER SPHEROID CODE	SPHEROID:	SPHEROID:
4	FUNCTION CODE: 0 1=GEO TO UTM 2=UTM TO GEO 3=ZONE TO ZONE	ENTER 1		
5	LAT(-S): 0.0000000	ENTER LATITUDE OF STATION	LATITUDE: ° ' "N + - S	LATITUDE: ° ' "N + - S
6	LG(-W): 0.0000000	ENTER LONGITUDE OF STATION	LONGITUDE: ° ' "E + - W	LONGITUDE: ° ' "E + - W
7	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE:	GRID ZONE:
8	EAST: 0.00	RECORD EASTING OF STATION	EASTING:	EASTING:
9	NORTH: 0.00	RECORD NORTHING OF STATION	NORTHING:	NORTHING:
10	ANOTHER CONV (Y/N):	ENTER Y OR N		
11	END OF MSN (Y/N):	ENTER Y OR N		

REMARKS:

DA FORM 5600-R, DEC 86

COMPUTATION—CONVERSION OF UTM COORDINATES TO GEOGRAPHIC COORDINATES (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1. IF STEP 11 IS Y, PROGRAM GOES TO STEP 2

2. IF STEP 11 IS N, PROGRAM GOES TO STEP 12.

3. TWO CONVERSION PROBLEMS CAN BE RECORDED PER FORM

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	STATION:	STATION:
1		CALL PROGRAM 10		
2	GEO/UTM/ZONE-ZONE			
3	SPHEROID CODE: 0 1=CLARKE 1866 2=INTERNATIONAL 3=CLARKE 1880 4=EVEREST 5=BESSEL 6=AUSTRALIAN 7=WGS-72 8=GRS-80	ENTER SPHEROID CODE	SPHEROID:	SPHEROID:
4	FUNCTION CODE: 0 1=GEO TO UTM 2=UTM TO GEO 3=ZONE TO ZONE	ENTER 2		
5	EAST: 0.00	ENTER EASTING OF STATION	EASTING:	EASTING:
6	NORTH: 0.00	ENTER NORTHING OF STATION	NORTHING:	NORTHING:
7	LATITUDE (N/S):	ENTER N OR S		
8	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE:	GRID ZONE:
9	. LAT:	RECORD LATITUDE OF STATION	LATITUDE: ° ′ ″N + - . S	LATITUDE: ° ′ ″N + - . S
10	. LNG:	RECORD LONGITUDE OF STATION	LONGITUDE: ° ′ ″E + - . W	LONGITUDE: ° ′ ″E + - . W
11	ANOTHER CONV (Y/N):	ENTER Y OR N		
12	END OF MSN (Y/N):	ENTER Y OR N		

REMARKS:

DA FORM 5601-R, DEC 86

COMPUTATION OF COORDINATES AND HEIGHT BY INTERSECTION (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1 IF STEP 17 IS Y, PROGRAM GOES TO STEP 18
2 IF STEP 17 IS N, PROGRAM GOES TO STEP 19
3 IF STEP 18 IS Y, PROGRAM GOES TO STEP 10
4 IF STEP 18 IS N, PROGRAM GOES TO STEP 3
5 TWO INTERSECTION PROBLEMS CAN BE RECORDED PER FORM
6 ENTER FIELD DATA IN BLOCKS MARKED ▶.

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	(O1) NAME	(O1) NAME
1		CALL PROGRAM 12	(O2) NAME	(O2) NAME
2	INTERSECTION			
3	EAST 01: 0.00	ENTER EASTING OF O1	EASTING O1	EASTING O1
4	NORTH 01: 0.00	ENTER NORTHING OF O1	NORTHING O1	NORTHING O1
5	HT 01: 0.0	ENTER HEIGHT OF O1	HEIGHT O1 (METERS)	HEIGHT O1 (METERS)
6	EAST 02: 0.00	ENTER EASTING OF O2	EASTING O2	EASTING O2
7	NORTH 02: 0.00	ENTER NORTHING OF O2	NORTHING O2	NORTHING O2
8	^DIST 01/02: 0.000	RECORD DISTANCE FROM O1 TO O2	DISTANCE O1 TO O2 (METERS)	DISTANCE O1 TO O2 (METERS)
9	AZ 01/02: 0.000	RECORD AZIMUTH FROM O1 TO O2	AZIMUTH O1 TO O2 (MILS)	AZIMUTH O1 TO O2 (MILS)
10	AZ 01/TGT: 0.000	ENTER AZIMUTH FROM O1 TO TARGET	▶ AZIMUTH O1 TO TARGET (MILS)	▶ AZIMUTH O1 TO TARGET (MILS)
11	VA 01/TGT: 0.000	ENTER VERTICAL ANGLE FROM O1 TO TARGET	▶ VERTICAL ANGLE O1 TO TARGET (MILS) + -	▶ VERTICAL ANGLE O1 TO TARGET (MILS) + -
12	AZ 02/TGT: 0.000	ENTER AZIMUTH FROM O2 TO TARGET	▶ AZIMUTH O2 TO TARGET (MILS)	▶ AZIMUTH O2 TO TARGET (MILS)
13	^TARGET #: _	RECORD TARGET NUMBER	TARGET NUMBER	TARGET NUMBER
14	EAST: 0.00	RECORD EASTING OF TARGET	EASTING	EASTING
15	NORTH: 0.00	RECORD NORTHING OF TARGET	NORTHING	NORTHING
16	HT: 0.0	RECORD HEIGHT OF TARGET	HEIGHT (METERS)	HEIGHT (METERS)
17	ADD TGTS (Y/N):	ENTER Y OR N		
18	SAME OPS (Y/N):	ENTER Y OR N		
19	END OF MSN (Y/N):	ENTER Y OR N		

REMARKS:

DA FORM 5604-R, DEC 86

COMPUTATION OF STAR IDENTIFICATION (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

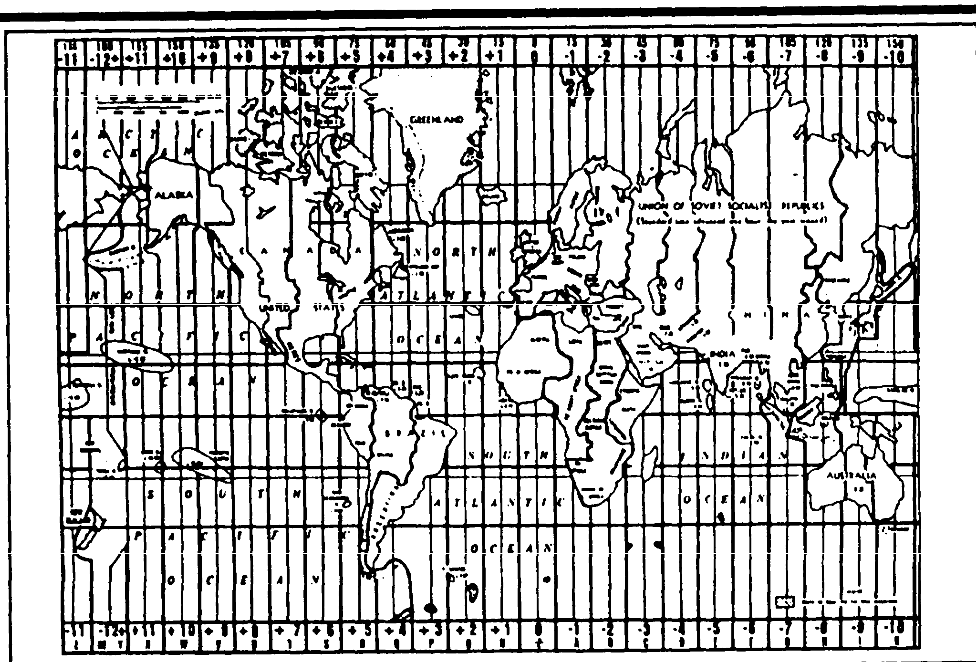
COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET____OF____SHEETS

INSTRUCTIONS				DATA RECORD	
STEP	PROMPT	PROCEDURE			
1		CALL PROGRAM:		STATION:	STATION:
2	STAR ID				
3	SPHEROID CODE: 1 = CLARKE 1866: 2 = INTERNATIONAL: 3 = CLARKE 1880: 4 = EVEREST: 5 = BESSEL: 6 = AUSTRALIAN: 7 = WORLD GEO SYS-72: 8 = GRS-80:	ENTER SPHEROID CODE		SPHEROID:	SPHEROID:
4	EAST: 0.00	ENTER EASTING		EAST:	EAST:
5	NORTH: 0.00	ENTER NORTHING		NORTH:	NORTH:
6	LATITUDE (N/S):	ENTER N OR S			
7	GRID ZONE: 00	ENTER GRID ZONE		GRID ZONE:	GRID ZONE:
8	OBS DATE (DD.MMYY):	ENTER DATE OF OBSERVATION (LOCAL DATE)		DATE: dd . | mm | yy	DATE: dd . | mm | yy
9	OBS TIME (HH.MMSS):	ENTER TIME OF OBSERVATION (LOCAL TIME)		TIME: hh . | mm | ss	TIME: hh . | mm | ss
10	TIME ZONE LETTER:	ENTER TIME ZONE LETTER		TZ LTR:	TZ LTR:
11	DAYLT SV TIME(Y/N):	ENTER Y OR N			
12	LST (DEGREES): - - -.-	RECORD LST		LST: degrees	LST degrees
13	STAR #: 00	ENTER STAR NO		STAR NO-STAR NAME:	STAR NO-STAR NAME:
14	AZ TO STAR: 0.000	RECORD AZIMUTH TO STAR		AZIMUTH (MILS):	AZIMUTH (MILS):
15	ALT TO STAR: 0.000	RECORD ALTITUDE TO STAR		ALTITUDE (MILS):	ALTITUDE (MILS):
16	NEW STAR (Y/N):	ENTER Y OR N		STAR NO-STAR NAME:	STAR NO-STAR NAME:
17	NEW OBS TIME (Y/N):	ENTER Y OR N		AZIMUTH (MILS):	AZIMUTH (MILS):
18	END OF MSN (Y/N):	ENTER Y OR N		ALTITUDE (MILS):	ALTITUDE (MILS):
				STAR NO-STAR NAME:	STAR NO-STAR NAME:
				AZIMUTH (MILS):	AZIMUTH (MILS):
				ALTITUDE (MILS):	ALTITUDE (MILS):

NOTES:
1. IN STEP 8, ENTER DAY, MONTH AND YEAR.
2. IN STEP 9, ENTER HOURS, MINUTES, AND SECONDS.
3. IN STEP 10, SEE BACK OF FORM FOR TIME ZONE LETTERS.
4. IN STEP 13, SEE BACK OF FORM FOR STAR LIST.
5. IN STEP 16, Y RESPONSE RETURNS YOU TO STEP 13.
6. IN STEP 17, Y RESPONSE RETURNS YOU TO STEP 9.

DA FORM 7284-R, SEP 93

TIME ZONE CHART



LONGITUDE OF MERIDIAN	TIME ZONE LETTER
EAST LONGITUDE	
0	Z
15	A
30	B
45	C
60	D
75	E
90	F
105	G
120	H
135	I
150	K
165	L
180	M
WEST LONGITUDE	
0	Z
-15	N
-30	O
-45	P
-60	Q
-75	R
-90	S
-105	T
-120	U
-135	V
-150	W
-165	X
-180	Y

ALPHABETICAL STAR LIST

Star	No.	
ACAMAR	12	
ACHERNAR	9	
ACRUX	42	*
ADHARA	26	
ALDEBARAN	15	*
ALHENA	24	
ALIOTH	45	
ALKAID	48	
AL NA'IR	71	
ALNILAM	20	
ALNITAK	21	
ALPHARD	35	
ALPHECCA	55	
ALPHERATZ	1	*
ALTAIR	66	*
ANKAA	4	
ANTARES	57	*
ARCTURUS	51	*
ATRIA	58	
AVIOR	32	
BELLATRIX	18	
BETA HYDRUS	3	
BETELGEUSE	22	
CANOPUS	23	
CAPELLA	17	
CAPH	2	
CASTOR	28	
DENEB	68	
DENEBOLA	39	
DIPHDA	6	
DSCHUBBA	56	
DUBHE	38	
ELNATH	19	
ELTANIN	62	
ENIF	70	
FOMALHAUT	72	
GACRUX	43	
GAMMA CASSIOPEIAE	7	
GAMMA VELORUM	31	
GIENAH	41	
HADAR	49	
HAMAL	11	
KAUS AUSTRALIS	63	
KOCHAB	54	*
MARKAB	73	
MENKAR	13	
MENKENT	50	
MERAK	37	
MISPLACIDUS	34	
MIMOSA	44	
MIRFAK	14	
MIZAR	46	
NUNKI	65	
NU	69	
PEACOCK	67	
PHECDA	40	
POLARIS	10	*
POLLUX	30	
PROCYON	29	
RASALHAGUE	61	
REGULUS	36	*
RIGEL	16	
RIGIL KENTAURUS	52	
RUCHBAH	8	
SABIK	59	
SCAULA	60	
SCHEDAR	5	
SIRIUS	25	*
SPICA	47	
SUHAIL	33	
VEGA	64	
WEZEN	27	
ZEBENELGENUBI	53	

* INDCATES THE PREFERRED STARS FOR HASTY ASTRO.

COMPUTATION OF ARTY ASTRO (SUN/STAR) (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET____OF____SHEETS

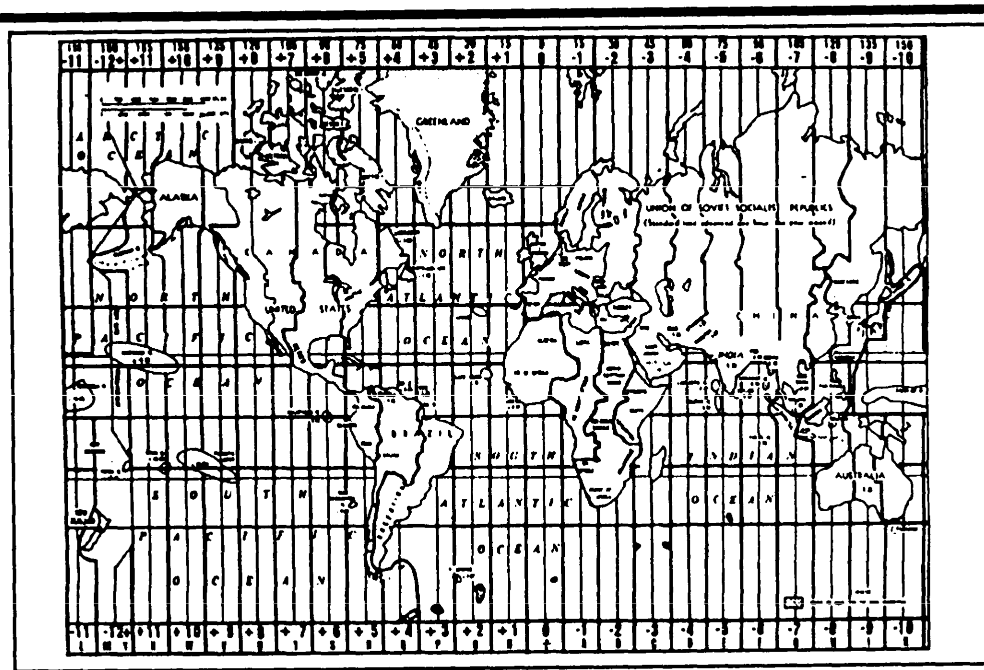
INSTRUCTIONS			DATA RECORD		
STEP	PROMPT	PROCEDURE	STATION:	AZ MARK:	
1		CALL PROGRAM	STAR NAME:	APPROX AZ TO AZMK:	
2	ARTY ASTRO		SPHEROID:		
3	SPHEROID CODE: 0 1 = CLARKE 1866: 2 = INTERNATIONAL: 3 = CLARKE 1880: 4 = EVEREST: 5 = BESSEL: 6 = AUSTRALIAN: 7 = WORLD GEO SYS-72: 8 = GRS-80:	ENTER SPHEROID CODE		REMARKS:	
4	EAST: 0.00	ENTER EASTING	EAST:		
5	NORTH: 0.00	ENTER NORTHING	NORTH:		
6	LATITUDE (N/S):	ENTER N OR S			
7	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE:		
8	4TH/5TH ORDER (4/5):	ENTER 4 OR 5			
9	USE SUN (Y/N):	ENTER Y OR N			
9a	STAR #:	ENTER STAR NO	STAR NO:		
10	TIME MODULE (Y/N):	ENTER Y OR N			
11	TIME ZONE LETTER:	ENTER TME ZONE LETTER	TZ LTR:		
12	DAYLT SV TIME (Y/N):	ENTER Y OR N			
13	(D)RDG AZMK: 0.000	ENTER DIRECT RDG TO AZMK	(D) RDG AZMK:		
(14)	PRESS ENDLINE AT TIP:	PRESS END LINE	SET NO___	SET NO___	SET NO___
15	OBS DATE (DD,MMYY):	RECORD AND/OR ENTER DATE	DATE: dd . mm yy	DATE: dd . mm yy	DATE: dd . mm yy
16	OBS TIME (HH,MMSS):	RECORD AND/OR ENTER TIME	YEAR: hh . mm ss	YEAR: hh . mm ss	YEAR: hh . mm ss
16a	TRL/LDG/CTR (TR/L/C):	ENTER TR, L, OR C			
17	HZ RDG (D): 0.000	ENTER (D) HZ READING	HZ RDG (D) (MILS):	HZ RDG (D) (MILS):	HZ RDG (D) (MILS):
18	GRID AZ/MK: 0.000	RECORD GRID AZIMUTH	GRID AZ (MILS):		
19	END OF MSN (Y/N):	ENTER Y OR N			

NOTES:

1. IN STEP 9, Y RESPONSE RETURNS YOU TO STEP 10.
2. IN STEP 9, N RESPONSE RETURNS YOU TO STEP 9a.
3. IN STEP 10, Y RESPONSE ALLOWS ACCESS TO INTERNAL TIMER AT TIP.
4. IN STEP 10 IF RESPONSE IS N, SKIP STEP 14 AND ENTER LOCAL DATE AND TIME IN STEPS 15 AND 16.
5. STEP 16a WILL APPEAR FOR SUN OBSERVATIONS ONLY.
   TR = TRAILING EDGE OF SUN.
   L = LEADING EDGE OF SUN.
   C = CENTER OF SUN.
6. SEE BACK OF FORM FOR TIME ZONE LETTER AND STAR NUMBER.

DA FORM 7285-R, SEP 93

TIME ZONE CHART



LONGITUDE OF MERIDIAN	TIME ZONE LETTER
EAST LONGITUDE	
0	Z
15	A
30	B
45	C
60	D
75	E
90	F
105	G
120	H
135	I
150	K
165	L
180	M
WEST LONGITUDE	
0	Z
-15	N
-30	O
-45	P
-60	Q
-75	R
-90	S
-105	T
-120	U
-135	V
-150	W
-165	X
-180	Y

ALPHABETICAL STAR LIST

Star	No.	
ACAMAR	12	
ACHERNAR	9	
ACRUX	42	*
ADHARA	26	
ALDEBARAN	15	*
ALHENA	24	
ALIOTH	45	
ALKAID	48	
AL NA'IR	71	
ALNILAM	20	
ALNITAK	21	
ALPHARD	35	
ALPHECCA	55	
ALPHERATZ	1	*
ALTAIR	66	*
ANKAA	4	
ANTARES	57	*
ARCTURUS	51	*
ATRIA	58	
AVIOR	32	
BELLATRIX	18	
BETA HYDRUS	3	
BETELGEUSE	22	
CANOPUS	23	
CAPELLA	17	
CAPH	2	
CASTOR	28	
DENEB	68	
DENEBOLA	39	
DIPHDA	6	
DSCHUBBA	56	
DUBHE	38	
ELNATH	19	
ELTANIN	62	
ENIF	70	
FOMALHAUT	72	
GACRUX	43	
GAMMA CASSIOPEIAE	7	
GAMMA VELORUM	31	
GIENAH	41	
HADAR	49	
HAMAL	11	
KAUS AUSTRALIS	63	
KOCHAB	54	*
MARKAB	73	
MENKAR	13	
MENKENT	50	
MERAK	37	
MISPLACIDUS	34	
MIMOSA	44	
MIRFAK	14	
MIZAR	46	
NUNKI	65	
NU	69	
PEACOCK	67	
PHECDA	40	
POLARIS	10	*
POLLUX	30	
PROCYON	29	
RASALHAGUE	61	
REGULUS	36	*
RIGEL	16	
RIGIL KENTAURUS	52	
RUCHBAH	8	
SABIK	59	
SCAULA	60	
SCHEDAR	5	
SIRIUS	25	*
SPICA	47	
SUHAIL	33	
VEGA	64	
WEZEN	27	
ZEBENELGENUBI	53	

* INDCATES THE PREFERRED STARS FOR HASTY ASTRO.

COMPUTATION OF HASTY ASTRO (BUCS)

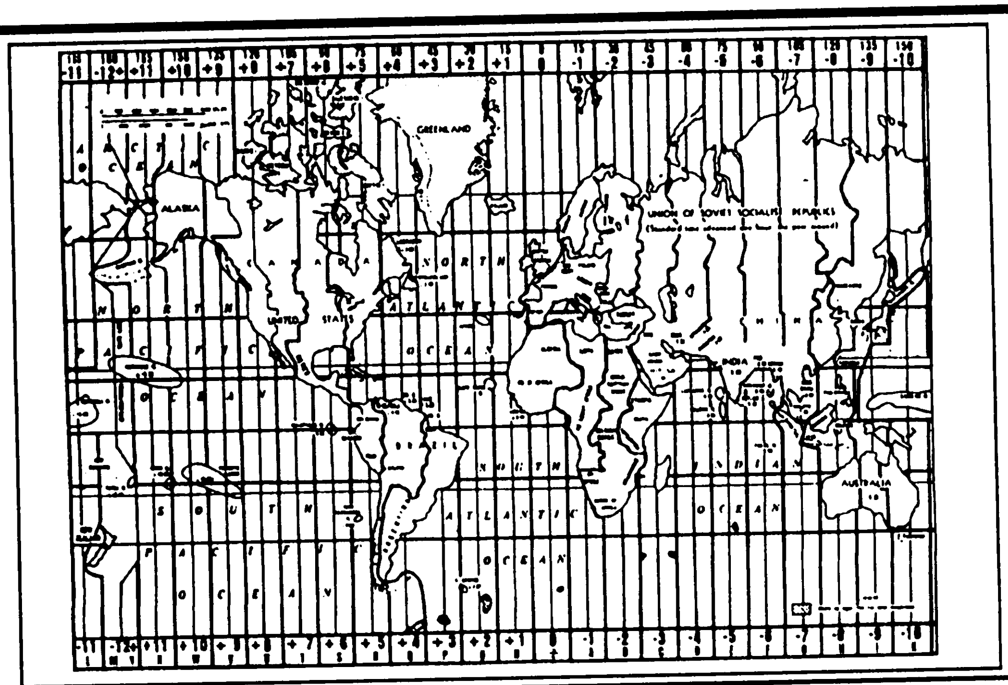
(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET___OF___SHEETS

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE		
1		CALL PROGRAM	STATION:	APPROX AZ TO AZMK (MILS):
3	SPHEROID CODE: 0 1 = CLARKE 1866: 2 = INTERNATIONAL: 3 = CLARKE 1880: 4 = EVEREST: 5 = BESSEL: 6 = AUSTRALIAN: 7 = WORLD GEO SYS-72: 8 = GRS-80:	ENTER SPHEROID CODE	SPHEROID:	REMARKS:
4	EAST: 0.00	ENTER EASTING	EAST:	
5	NORTH: 0.00	ENTER NORTHING	NORTH:	
6	LATITUDE (N/S):	ENTER N OR S		
7	GRID ZONE: 00	ENTER GRID ZONE	GRID ZONE:	
8	USE SUN (Y/N):	ENTER Y OR N		
8a	STAR #: 00	ENTER STAR NO	STAR NO:	
9	TIME MODULE (Y/N):	ENTER Y OR N		
10	TIME ZONE LETTER:	ENTER TIME ZONE LETTER	TZ LTR:	NOTES:
11	DAYLT SV TIME (Y/N):	ENTER Y OR N		1. IN STEP 8, Y RESPONSE RETURNS YOU TO STEP 9.
(12)	PRESS ENDLINE AT TIP	PRESS END LINE		2. IN STEP 8, N RESPONSE RETURNS YOU TO STEP 8a.
13	OBS DATE (DD.MMYY):	RECORD OR ENTER LOCAL DATE	DATE: dd . | mm | yy	3. IN STEP 9, Y RESPONSE WILL ALLOW ACCESS TO INTERNAL TIMER AT TIP.
14	OBS TIME (HH.MMSS):	RECORD OR ENTER LOCAL TIME	TIME: hh . | mm | ss	4. IN STEP 9 IF RESPONSE IS N, SKIP STEPS 12 AND 16. ENTER LOCAL DATE IN STEP 13 AND LOCAL TIME IN STEPS 14 AND 17.
14a	TRL/LDG/CTR (TR/L/C):	ENTER TR, L, OR C		5. STEPS 14a AND 17a WILL APPEAR FOR SUN OBSERVATIONS ONLY. TR = TRAILING EDGE OF SUN. L = LEADING EDGE OF SUN. C = CENTER OF SUN.
15	GRID AZ: 0.000	RECORD GRID AZIMUTH	GRID AZ (MILS):	
(16)	PRESS ENDLINE AT TIP	PRESS END LINE		
17	OBS TIME (HH.MMSS)	RECORD OR ENTER LOCAL TIME	TIME: hh . | mm | ss	6. SEE BACK OF FORM FOR TIME ZONE LETTER AND STAR NUMBER.
17a	TRL/LDG/CTR (TR/L/C):	ENTER TR, L, OR C		7. CHECK ANGLE COMPARISON: M2 (AC): ± 2.0 MILS T16: ± 0.3 MIL
18	CK ANGLE: 0.000	RECORD CHECK ANGLE	CK ANGLE (MILS):	
19	ANOTHER OBS (Y/N):	ENTER Y OR N		
20	END OF MSN (Y/N):	ENTER Y OR N		

DA FORM 7286-R, SEP 93

TIME ZONE CHART



LONGITUDE OF MERIDIAN	TIME ZONE LETTER
EAST LONGITUDE	
0	Z
15	A
30	B
45	C
60	D
75	E
90	F
105	G
120	H
135	I
150	K
165	L
180	M
WEST LONGITUDE	
0	Z
-15	N
-30	O
-45	P
- 60	Q
-75	R
-90	S
-105	T
-120	U
-135	V
-150	W
-165	X
-180	Y

ALPHABETICAL STAR LIST

STAR	NO.	
ACAMAR	12	
ACHERNAR	9	
ACRUX	42	*
ADHARA	26	
ALDEBARAN	15	*
ALHENA	24	
ALIOTH	45	
ALKAID	48	
AL NA'IR	71	
ALNILAM	20	
ALNITAK	21	
ALPHARD	35	
ALPHECCA	55	
ALPHERATZ	1	*
ALTAIR	66	*
ANKAA	4	
ANTARES	57	*
ARCTURUS	51	*
ATRIA	58	
AVIOR	32	
BELLATRIX	18	
BETA HYDRUS	3	
BETELGEUSE	22	
CANOPUS	23	
CAPELLA	17	
CAPH	2	
CASTOR	28	
DENEB	68	
DENEBOLA	39	
DIPHDA	6	
DSCHUBBA	56	
DUBHE	38	
ELNATH	19	
ELTANIN	62	
ENIF	70	
FOMALHAUT	72	
GACRUX	43	
GAMMA CASSIOPEIAE	7	
GAMMA VELORUM	31	
GIENAH	41	
HADAR	49	
HAMAL	11	
KAUS AUSTRALIS	63	
KOCHAB	54	*
MARKAB	73	
MENKAR	13	
MENKENT	50	
MERAK	37	
MISPLACIDUS	34	
MIMOSA	44	
MIRFAK	14	
MIZAR	46	
NUNKI	65	
NU	69	
PEACOCK	67	
PHECDA	40	
POLARIS	10	*
POLLUX	30	
PROCYON	29	
RASALHAGUE	61	
REGULUS	36	*
RIGEL	16	
RIGIL KENTAURUS	52	
RUCHBAH	8	
SABIK	59	
SCAULA	60	
SCHEDAR	5	
SIRIUS	25	*
SPICA	47	
SUHAIL	33	
VEGA	64	
WEZEN	27	
ZEBENELGENUBI	53	

* INDCATES THE PREFERRED STARS FOR HASTY ASTRO.

COMPUTATION OF DATUM-TO-DATUM COORDINATE TRANSFORMATION (PROGRAM 14—LISTED DATUMS) (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET____OF____SHEETS

NOTES: 1. IF PRINTER NOT CONNECTED, SKIP STEPS 5 AND 6.
2. DATUM CODES FOR STEPS 7 AND 8 ARE ON BACK OF FORM.
3. AFTER STEP 9, GO TO STEP 15 IF FUNCTION CODE IS 3 OR 4.

INSTRUCTIONS				DATA RECORD	
STEP	PROMPT		PROCEDURE	STATION:	STATION:
1			RUN DDCT		
2	DDCT REV .#0 90/06/25				
3	MODULE DESIRED:	00	CALL PROGRAM 14		
4	LISTED DATUMS:				
5	PRINT FORM (Y/N):		ENTER Y OR N (SEE NOTE 1)		
6	DATUM LIST (Y/N):		ENTER Y OR N (SEE NOTE 1)		
7	FROM DATUM:	00	ENTER DATUM CODE (SEE BACK OF FORM)	FROM DATUM:	FROM DATUM:
8	TO DATUM:	00	ENTER DATUM CODE (SEE BACK OF FORM)	TO DATUM:	TO DATUM:
9	FUNCTION CODE: 1 = UTM TO UTM 2 = UTM TO GEO 3 = GEO TO UTM 4 = GEO TO GEO	0	ENTER FUNCTION CODE IF FUNCTION = 1 OR 2, GO TO STEP 10. IF FUNCTION = 3 OR 4, GO TO STEP 15.	FUNCTION: [] UTM TO UTM [] UTM TO GEO [] GEO TO UTM [] GEO TO GEO	FUNCTION: [] UTM TO UTM [] UTM TO GEO [] GEO TO UTM [] GEO TO GEO
10	EAST:	000000.00	ENTER EASTING	EASTING:	EASTING:
11	NORTH:	0000000.00	ENTER NORTHING	NORTHING:	NORTHING:
12	GRID ZONE (-:S):	00	ENTER GRID ZONE (IF FUNCTION = 2, GO TO STEP 22)	GRID ZONE:	GRID ZONE:
13	ZONE TO ZONE (Y/N):		ENTER Y OR N (IF NO, GO TO STEP 18)		
14	ENDING GRID ZONE (-:S):		ENTER ENDING GRID ZONE (GO TO STEP 18)	ENDING GRID ZONE:	ENDING GRID ZONE:
15	LAT (-:S):	00.0000000	ENTER LATITUDE OF STATION	LAT: + – ° ' "N S	LAT: + – ° ' "N S
16	LG (-:W):	000.0000000	ENTER LONGITUDE OF STATION	LNG: + – ° ' "N W	LNG: + – ° ' "E W
17	GRID ZONE (-:S):	00	ENTER GRID ZONE OF STATION (IF FUNCTION = 4, GO TO STEP 22)	GRID ZONE:	GRID ZONE:
18	EAST:	000000.00	RECORD EASTING OF STATION	EASTING:	EASTING:
19	NORTH:	0000000.00	RECORD NORTHING OF STATION	NORTHING:	NORTHING:
20	GRID ZONE (-:S):	00	RECORD GRID ZONE OF STATION	GRID ZONE:	GRID ZONE:
21	ELPS:		RECORD ELLIPSOID (GO TO STEP 26)	ELLIPSOID:	ELLIPSOID:
22	_LAT:	00.0000000	RECORD LATITUDE OF STATION	LAT: + – ° ' "N S	LAT: + – ° ' "N S
23	_LNG:	000.0000000	RECORD LONGITUDE OF STATION	LNG: + – ° ' "E W	LNG: + – ° ' "E W
24	GRID ZONE:	00	RECORD GRID ZONE OF STATION	GRID ZONE:	GRID ZONE:
25	ELPS:		RECORD ELLIPSOID	ELLIPSOID:	ELLIPSOID:
26	END OF MSN (Y/N):		ENTER Y OR N		

REMARKS:

DA FORM 7287-R, SEP 93

USE THE FOLLOWING DATUM CODES FOR STEPS 8 AND 18.

DATUM NAME	CODE	DISPLAYED NAME
Adindan[1]	1	ADINDAN
Afgooye	2	AFG
Ain el Abd 1970	3	AIN EL ABD 1970
Anna 1 Astro 1965	4	ANNA 1 ASTRO 1965
Arc 1950	5	ARC 1950
Arc 1960	6	ARC 1960
Ascension Island 1958	7	ASCENSION ISLAND' 58
Astro Beacon E	8	ASTRO BEACON "E"
Astro Tern Island (FRIG) 1961[2]	9	ASTRO B4 SOR. ATOLL
Astro DOS[2]	10	ASTRO POS 71/4
Astronomic Station 1952	11	ASTRONOMIC STA. 52
Australian Geodetic 1966	12	AUSTRALIAN GEO 1966
Australian Geodetic 1984	13	AUSTRALIAN GEO 1984
Bellevue (IGN)	14	BELLEVUE (IGN)
Bermuda 1957	15	BERMUDA 1957
Bogota Observatory	16	BOGOTA OBSERVATORY
Campo Inchauspe	17	CAMPO INCHAUSPE
Canton Astro 1966[2]	18	CANTON ISLAND 1966
Cape	19	CAPE
Cape Canaveral	20	CAPE CANAVERAL
Carthage	21	CARTHAGE
Chatham 1971	22	CHATHAM 1971
Chua Astro	23	CHUA ASTRO
Corrego Alegre	24	CORREGO ALEGRE
Djakarta (Batavia)	25	DJAKARTA (BATAVIA)
DOS 1968	26	DOS 1968
Easter Island 1967	27	EASTER ISLAND 1967
European 1950	28	EUROPEAN 1950
European 1979	29	EUROPEAN 1979
Gandajika Base	30	GANDAJIKA BASE
Geodetic Datum 1949	31	GEODETIC DATUM 1949
Guam 1963	32	GUAM 1963
Gux 1 Astro	33	GUX 1 ASTRO
Hjorsey 1955	34	HJORSEY 1955
Hong Kong 1963	35	HONG KONG 1963
Indian 1 (Thailand, Vietnam)	36	INDIAN 1 (Thai/Viet)
Indian 2 (Bangladesh, India, Nepal)	37	INDIAN 2
Ireland 1965	38	IRELAND 1965
ISTS 073 Astro 1969	39	ISTS 073 ASTRO 1969
Johnston Island 1961	40	JOHNSTON ISLAND 61
Kandawala	41	KANDAWALA
Kerguelen Island	42	KERGUELEN ISLAND
Kertau 1948	43	KERTAU 1948
Reunion[2]	44	LA REUNION
L.C. 5 ASTRO	45	L.C. 5 ASTRO
Liberia 1964	46	LIBERIA 1964
Luzon 1 (Philippines)	47	LUZON 1 (Philippine)
Luzon 2 (Mindanao Island)	48	LUZON 2 (Mindanao)
Mahe 1971	49	MAHE 1971
Selvagem Grande 1938[2]	50	MARCO ASTRO
Massawa	51	MASSAWA
Merchich	52	MERCHICH
Midway Astro 1961	53	MIDWAY ASTRO 1961
Minna	54	MINNA
Nahrwan 1 (Masirah Island [Oman])	55	NAHRWAN 1 (Oman)
Nahrwan 2 (United Arab Emirates)	56	NAHRWAN 2 (UAE)
Nahrwan 3 (Saudi Arabia)	57	NAHRWAN 3 (Saudi)
Schwarzech (Namibia)	58	NAMIBIA
Naparima, BWI	59	NAPARIMA BWI
North American 1927 (Continental United States)	60	NAD'27 (CONUS)
North American 1927 (Alaska)	61	NAD'27 (Alaska)
North American 1927 (Bahamas, excluding San Salvador Island)	62	NAD'27 (Bahamas)
North American 1927 (San Salvador Island)	63	NAD'27 (Salvador)
North American 1927 (Canada)	64	NAD'27 (Canada)
North American 1927 (Canal Zone)	65	NAD'27 Canal Zone)
North American 1927 (Caribbean)	66	NAD'27 (Caribbean)
North American 1927 (Central America)	67	NAD'27 (Cent.Amer.)
North American 1927 (Cuba)	68	NAD'27 (Cuba)
North American 1927 (Greenland)	69	NAD'27(Greenland)
North American 1927 (Mexico)	70	NAD'27(Mexico)
North American 1983	71	NORTH AMERICAN 1983
Meteorologico 1939[2]	72	OBSERVATORIO 1966
Old Egyptian 1907[2]	73	OLD EGYPTIAN 1930
Old Hawaiian	74	OLD HAWAIIAN
Oman	75	OMAN
Ordnance Survey of Great Britain 1936	76	ORD.SURV.GR.BRIT '36
Pico de Las Nieves	77	PICO DE LAS NIEVES
Pitcairn Astro 1967	78	PITCAIRN ASTRO 1967
Provisional South Chilean 1963 or Hito XVIII 1963[2]	79	PROV. SO.CHILEAN'63
Provisional South American 1956	80	PROV. S.AMERICAN'56
Puerto Rico	81	PUERTO RICO
Qatar National	82	QATAR NATIONAL
Qornoq	83	QORNOQ
Rome 1940	84	ROME 1940
São Braz[2]	85	SANTA BRAZ
Santa (DOS)	86	SANTA (DOS)
Sapper Hill 1943	87	SAPPER HILL 1943
South American 1969	88	SO. AMERICAN 1969
South Asia	89	SOUTH ASIA
Porto Santo 1936[2]	90	SOUTHEAST BASE
Graciosa Base SW End 1948[2]	91	SOUTHWEST BASE
Timbalai 1948	92	TIMBALAI 1948
Tokyo	93	TOKYO
Tristan Astro 1968	94	TRISTAN ASTRO 1968
Viti Levu 1916	95	VITI LEVU 1916
Wake-Eniwetok 1960	96	WAKE-ENIWETOK 1960
World Geodetic System 1972	97	WGS 1972
World Geodetic System 1984	98	WGS 1984
Zanderij	99	ZANDERIJ

[1] The transformation parameters for the Adindan datum have been updated by the Defense Mapping Agency. Use Program 16 (user-defined) with the following transformation parameters:

Semimajor Axis	Flattening	X-Shift	Y-Shift	Z-Shift
6378249.145	293.465	-166	-15	204

[2] Datum names were incorrect in DMA Technical Report (TR) 8350.2, 1 Dec 87, but are correct above. The BUCS-displayed names for these datums differ from the correct name.

COMPUTATION OF DATUM-TO-DATUM COORDINATE TRANSFORMATION (PROGRAM 15—GAUSS-KRUGER [GK]) (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET____OF____SHEETS

NOTES:
1. IF PRINTER IS NOT CONNECTED, SKIP STEPS 5 AND 6.
2. DATUM CODES FOR STEPS 8 AND 9 ARE ON BACK OF FORM.
3. AFTER STEP 9, GO TO STEP 13 IF FUNCTION CODE IS 2 OR 4.

WARNING FOR SOUTHERN HEMISPHERE ONLY:
STEP 14A - MANUALLY SUBTRACT 4,000 FROM UTM NORTHING *BEFORE* ENTERING.
STEP 21A - MANUALLY ADD 4,000 TO COMPUTED GK NORTHING.

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	STATION:	STATION:
1		RUN DDCT		
2	DDCT REV .#0 90/06/25			
3	MODULE DESIRED: 00	CALL PROGRAM 15		
4	GAUSS-KRUGER			
5	PRINT FORM (Y/N):	ENTER Y OR N (SEE NOTE 1)		
6	DATUM LIST (Y/N):	ENTER Y OR N (SEE NOTE 1)		
7	FUNCTION CODE: 0 1 = KRASSOVSKY TO UTM 2 = UTM TO KRASSOVSKY 3 = BESSEL TO UTM 4 = UTM TO BESSEL	ENTER FUNCTION CODE	FUNCTION CODE: [] = KRASSOVSKY TO UTM [] = UTM TO KRASSOVSKY [] = BESSEL TO UTM [] = UTM TO BESSEL	FUNCTION CODE: [] = KRASSOVSKY TO UTM [] = UTM TO KRASSOVSKY [] = BESSEL TO UTM [] = UTM TO BESSEL
8	FROM DATUM: 00	ENTER DATUM CODE (SEE REVERSE)	FROM DATUM:	FROM DATUM:
9	TO DATUM: 00	ENTER DATUM CODE (IF FUNCTION = 2 OR 4, GO TO STEP 13)	TO DATUM:	TO DATUM:
10	EAST: 000000.00	ENTER GK EASTING	GK EASTING:	GK EASTING:
11	NORTH: 0000000.00	ENTER GK NORTHING	GK NORTHING:	GK NORTHING:
12	GRID ZONE (-:S): 00	ENTER GK GRID ZONE (GO TO STEP 20)	GK GRID ZONE:	GK GRID ZONE:
13	EAST: 000000.00	ENTER UTM EASTING	UTM EASTING:	UTM EASTING:
14	NORTH: 0000000.00	ENTER UTM NORTHING (SEE WARNING)	UTM NORTHING:	UTM NORTHING:
14A	**SEE WARNING FOR SOUTHERN HEMISPHERE**	SOUTHERN HEMISPHERE ONLY MANUALLY SUBTRACT 4,000 BEFORE ENTERING	SOUTHERN HEMISPHERE ONLY -4,000.00	SOUTHERN HEMISPHERE ONLY -4,000.00
15	GRID ZONE (-:S): 00	ENTER UTM GRID ZONE	UTM GRID ZONE:	UTM GRID ZONE:
16	EAST: 000000.00	RECORD GK EASTING	GK EASTING:	GK EASTING:
17	NORTH: 0000000.00	RECORD GK NORTHING	GK NORTHING:	GK NORTHING:
18	GRID ZONE (-:S): 00	RECORD GK GRID ZONE	GK GRID ZONE:	GK GRID ZONE:
19	ELPS:	RECORD ELLIPSOID (GO TO STEP 24)	ELLIPSOID:	ELLIPSOID:
20	EAST: 000000.00	RECORD UTM EASTING	UTM EASTING:	UTM EASTING:
21	NORTH: 0000000.00	RECORD UTM NORTHING (SEE WARNING)	UTM NORTHING:	UTM NORTHING:
21A	**SEE WARNING FOR SOUTHERN HEMISPHERE**	SOUTHERN HEMISPHERE ONLY MANUALLY ADD 4,000 TO COMPUTED GK NORTHING	SOUTHERN HEMISPHERE ONLY +4,000.00	SOUTHERN HEMISPHERE ONLY +4,000.00
22	GRID ZONE (-:S): 00	RECORD UTM GRID ZONE	UTM GRID ZONE:	UTM GRID ZONE:
23	ELPS:	RECORD ELLIPSOID	ELLIPSOID:	ELLIPSOID:
24	END OF MSN (Y/N):	ENTER Y OR N		

REMARKS:

COMPUTATION—ZONE-TO-ZONE TRANSFORMATION—UTM GRID COORDINATES AND UTM GRID AZIMUTH (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

NOTES: 1. IF STEP 14 IS Y, PROGRAM GOES TO STEP 2

2. IF STEP 14 IS N, PROGRAM GOES TO STEP 15

3. TWO TRANSFORMATION PROBLEMS CAN BE RECORDED PER FORM

INSTRUCTIONS			DATA RECORD	
STEP	PROMPT	PROCEDURE	STATION:	STATION:
1		CALL PROGRAM 10		
2	GEO/UTM/ZONE-ZONE			
3	SPHEROID CODE: 0 1=CLARKE 1866 2=INTERNATIONAL 3=CLARKE 1880 4=EVEREST 5=BESSEL 6=AUSTRALIAN 7=WGS-72 8=GRS-80	ENTER SPHEROID CODE	SPHEROID:	SPHEROID:
4	FUNCTION CODE: 0 1=GEO TO UTM 2=UTM TO GEO 3=ZONE TO ZONE	ENTER 3		
5	STARTING GRID: 00	ENTER STARTING GRID ZONE	STARTING GRID ZONE:	STARTING GRID ZONE:
6	ENDING GRID: 00	ENTER ENDING GRID ZONE	ENDING GRID ZONE:	ENDING GRID ZONE:
7	E IN __: 0.00	ENTER EASTING OF STATION	EASTING:	EASTING:
8	N IN __: 0.00	ENTER NORTHING OF STATION	NORTHING:	NORTHING:
9	LATITUDE (N/S):	ENTER N OR S		
10	AZ IN __: 0.000	ENTER AZIMUTH IN STARTING GRID ZONE	AZIMUTH (MILS):	AZIMUTH (MILS):
11	E IN __: 0.00	RECORD EASTING IN ENDING GRID ZONE	EASTING:	EASTING:
12	N IN __: 0.00	RECORD NORTHING IN ENDING GRID ZONE	NORTHING:	NORTHING:
13	AZ IN __: 0.000	RECORD AZIMUTH IN ENDING GRID ZONE	AZIMUTH (MILS):	AZIMUTH (MILS):
14	ANOTHER CONV (Y/N):	ENTER Y OR N		
15	END OF MSN (Y/N):	ENTER Y OR N		

REMARKS:

DA FORM 5602-R, DEC 86

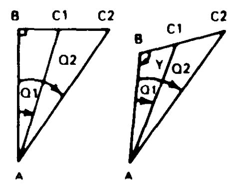
COMPUTATION OF TRIG TRAVERSE/SUBTENSE (BUCS)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER	NOTEBOOK REFERENCE	DATE
CHECKER	AREA	SHEET OF SHEETS

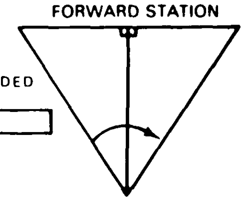
TRIG TRAVERSE

NOTES:
1. IF STEP 7 IS Y, PROGRAM GOES TO STEP 8
2. IF STEP 7 IS N, PROGRAM GOES TO STEP 9
3. STEP 12, CHECK SPECIFICATIONS
4. IF STEP 13 IS Y, PROGRAM GOES TO STEP 2
5. IF STEP 13 IS N, PROGRAM GOES TO STEP 14
6. TWO TRIG-TRAVERSE PROBLEMS CAN BE RECORDED PER FORM
7. ENTER FIELD DATA IN BLOCKS MARKED ▶



SUBTENSE

NOTES:
1. IF STEP 7 IS Y, PROGRAM GOES TO STEP 2
2. IF STEP 7 IS N, PROGRAM GOES TO STEP 8
3. TWO SUBTENSE PROBLEMS CAN BE RECORDED PER FORM
4. ENTER FIELD DATA IN BLOCKS MARKED ▶



TRIG-TRAVERSE INSTRUCTIONS

STEP	PROMPT		PROCEDURE
1			CALL PROGRAM 11
2	TRIG TRAV (Y/N):		ENTER Y
3	ANGLE Q1:	0.000	ENTER ANGLE Q1
4	ANGLE Q2:	0.000	ENTER ANGLE Q2
5	BASE B/C1:	0.000	ENTER BASE B TO C1
6	BASE B/C2:	0.000	ENTER BASE B TO C2
7	PERPENDICULAR (Y/N):		ENTER Y OR N
8	ANGLE Y:	0.000	ENTER ANGLE Y
9	DIST#1:	0.000	RECORD DISTANCE #1
10	DIST#2:	0.000	RECORD DISTANCE #2
11	MN DIST:	0.000	RECORD MEAN DISTANCE
12	CA:1/		RECORD COMPARATIVE ACCURACY
13	ANOTHER TRIG (Y/N):		ENTER Y OR N
14	END OF MSN (Y/N):		ENTER Y OR N

TRIG-TRAVERSE DATA RECORD

ANGLE Q1 (MILS): ▶	ANGLE Q1 (MILS): ▶
ANGLE Q2 (MILS): ▶	ANGLE Q2 (MILS): ▶
BASE B TO C1 (METERS): ▶	BASE B TO C1 (METERS): ▶
BASE B TO C2 (METERS): ▶	BASE B TO C2 (METERS): ▶
ANGLE Y (MILS): ▶	ANGLE Y (MILS): ▶
DISTANCE NUMBER 1 (METERS):	DISTANCE NUMBER 1 (METERS):
DISTANCE NUMBER 2 (METERS):	DISTANCE NUMBER 2 (METERS):
MEAN DISTANCE (METERS):	MEAN DISTANCE (METERS):
COMPARATIVE ACCURACY: 1/	COMPARATIVE ACCURACY: 1/

SUBTENSE INSTRUCTIONS

STEP	PROMPT		PROCEDURE
1			CALL PROGRAM 11
2	TRIG TRAV (Y/N):		ENTER N
3	SUBTENSE		
4	SUBTENDED <:	0.000	ENTER SUBTENDED ANGLE
5	SUBT BASE:	0.000	ENTER SUBTENDED BASE
6	HZ DIST:	0.000	RECORD HORIZONTAL DISTANCE
7	ANOTHER SUBT (Y/N):		ENTER Y OR N
8	END OF MSN (Y/N):		ENTER Y OR N

SUBTENSE DATA RECORD

SUBTENDED ANGLE (MILS): ▶	SUBTENDED ANGLE (MILS): ▶
SUBTENDED BASE (METERS): ▶	SUBTENDED BASE (METERS): ▶
HORIZONTAL DISTANCE (METERS):	HORIZONTAL DISTANCE (METERS):

REMARKS

DA FORM 5603-R, DEC 86

USE THE FOLLOWING DATUM CODES FOR STEPS 8 AND 18.

DATUM NAME	CODE	DISPLAYED NAME
Adindan[1]	1	ADINDAN
Afgooye	2	AFG
Ain el Abd 1970	3	AIN EL ABD 1970
Anna 1 Astro 1965	4	ANNA 1 ASTRO 1965
Arc 1950	5	ARC 1950
Arc 1960	6	ARC 1960
Ascension Island 1958	7	ASCENSION ISLAND' 58
Astro Beacon E	8	ASTRO BEACON "E"
Astro Tern Island (FRIG) 1961[2]	9	ASTRO B4 SOR. ATOLL
Astro DOS[2]	10	ASTRO POS 71/4
Astronomic Station 1952	11	ASTRONOMIC STA. 52
Australian Geodetic 1966	12	AUSTRALIAN GEO 1966
Australian Geodetic 1984	13	AUSTRALIAN GEO 1984
Bellevue (IGN)	14	BELLEVUE (IGN)
Bermuda 1957	15	BERMUDA 1957
Bogota Observatory	16	BOGOTA OBSERVATORY
Campo Inchauspe	17	CAMPO INCHAUSPE
Canton Astro 1966[2]	18	CANTON ISLAND 1966
Cape	19	CAPE
Cape Canaveral	20	CAPE CANAVERAL
Carthage	21	CARTHAGE
Chatham 1971	22	CHATHAM 1971
Chua Astro	23	CHUA ASTRO
Corrego Alegre	24	CORREGO ALEGRE
Djakarta (Batavia)	25	DJAKARTA (BATAVIA)
DOS 1968	26	DOS 1968
Easter Island 1967	27	EASTER ISLAND 1967
European 1950	28	EUROPEAN 1950
European 1979	29	EUROPEAN 1979
Gandajika Base	30	GANDAJIKA BASE
Geodetic Datum 1949	31	GEODETIC DATUM 1949
Guam 1963	32	GUAM 1963
Gux 1 Astro	33	GUX 1 ASTRO
Hjorsey 1955	34	HJORSEY 1955
Hong Kong 1963	35	HONG KONG 1963
Indian 1 (Thailand, Vietnam)	36	INDIAN 1 (Thai/Viet)
Indian 2 (Bangladesh, India, Nepal)	37	INDIAN 2
Ireland 1965	38	IRELAND 1965
ISTS 073 Astro 1969	39	ISTS 073 ASTRO 1969
Johnston Island 1961	40	JOHNSTON ISLAND 61
Kandawala	41	KANDAWALA
Kerguelen Island	42	KERGUELEN ISLAND
Kertau 1948	43	KERTAU 1948
Reunion[2]	44	LA REUNION
L.C. 5 ASTRO	45	L.C. 5 ASTRO
Liberia 1964	46	LIBERIA 1964
Luzon 1 (Philippines)	47	LUZON 1 (Philippine)
Luzon 2 (Mindanao Island)	48	LUZON 2 (Mindanao)
Mahe 1971	49	MAHE 1971
Selvagem Grande 1938[2]	50	MARCO ASTRO
Massawa	51	MASSAWA
Merchich	52	MERCHICH
Midway Astro 1961	53	MIDWAY ASTRO 1961
Minna	54	MINNA
Nahrwan 1 (Masirah Island [Oman])	55	NAHRWAN 1 (Oman)
Nahrwan 2 (United Arab Emirates)	56	NAHRWAN 2 (UAE)
Nahrwan 3 (Saudi Arabia)	57	NAHRWAN 3 (Saudi)
Schwarzech (Namibia)	58	NAMIBIA
Naparima, BWI	59	NAPARIMA BWI
North American 1927 (Continental United States)	60	NAD'27 (CONUS)
North American 1927 (Alaska)	61	NAD'27 (Alaska)
North American 1927 (Bahamas, excluding San Salvador Island)	62	NAD'27 (Bahamas)
North American 1927 (San Salvador Island)	63	NAD'27 (Salvador)
North American 1927 (Canada)	64	NAD'27 (Canada)
North American 1927 (Canal Zone)	65	NAD'27 Canal Zone)
North American 1927 (Caribbean)	66	NAD'27 (Caribbean)
North American 1927 (Central America)	67	NAD'27 (Cent.Amer.)
North American 1927 (Cuba)	68	NAD'27 (Cuba)
North American 1927 (Greenland)	69	NAD'27(Greenland)
North American 1927 (Mexico)	70	NAD'27(Mexico)
North American 1983	71	NORTH AMERICAN 1983
Meteorologico 1939[2]	72	OBSERVATORIO 1966
Old Egyptian 1907[2]	73	OLD EGYPTIAN 1930
Old Hawaiian	74	OLD HAWAIIAN
Oman	75	OMAN
Ordnance Survey of Great Britain 1936	76	ORD.SURV.GR.BRIT '36
Pico de Las Nieves	77	PICO DE LAS NIEVES
Pitcairn Astro 1967	78	PITCAIRN ASTRO 1967
Provisional South Chilean 1963 or Hito XVIII 1963[2]	79	PROV. SO.CHILEAN'63
Provisional South American 1956	80	PROV. S.AMERICAN'56
Puerto Rico	81	PUERTO RICO
Qatar National	82	QATAR NATIONAL
Qornoq	83	QORNOQ
Rome 1940	84	ROME 1940
Sâo Braz[2]	85	SANTA BRAZ
Santa (DOS)	86	SANTA (DOS)
Sapper Hill 1943	87	SAPPER HILL 1943
South American 1969	88	SO. AMERICAN 1969
South Asia	89	SOUTH ASIA
Porto Santo 1936[2]	90	SOUTHEAST BASE
Graciosa Base SW End 1948[2]	91	SOUTHWEST BASE
Timbalai 1948	92	TIMBALAI 1948
Tokyo	93	TOKYO
Tristan Astro 1968	94	TRISTAN ASTRO 1968
Viti Levu 1916	95	VITI LEVU 1916
Wake-Eniwetok 1960	96	WAKE-ENIWETOK 1960
World Geodetic System 1972	97	WGS 1972
World Geodetic System 1984	98	WGS 1984
Zanderij	99	ZANDERIJ

[1] The transformation parameters for the Adindan datum have been updated by the Defense Mapping Agency. Use Program 16 (user-defined) with the following transformation parameters:

Semimajor Axis	Flattening	X-Shift	Y-Shift	Z-Shift
6378249.145	293.465	-166	-15	204

[2] Datum names were incorrect in DMA Technical Report (TR) 8350.2, 1 Dec 87, but are correct above. The BUCS-displayed names for these datums differ from the correct name.

COMPUTATION OF DATUM-TO-DATUM COORDINATE TRANSFORMATION
(PROGRAM 16—USER-DEFINED) (BUCS)

(For use of this form, see FM 6-2; the proponent agency is TRADOC.)

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET____OF____SHEETS

NOTES: 1. IF PRINTER IS NOT CONNECTED, SKIP STEPS 5 AND 6.
2. IF STEP 7 IS Y, GO TO STEP 9.
3. DATUM CODES FOR STEPS 8 AND 18 ARE ON BACK OF FORM.

INSTRUCTIONS				DATA RECORD	
STEP	PROMPT		PROCEDURE	STATION:	STATION:
1			RUN DDCT		
2	DDCT REV .#0 90/06/25:				
3	MODULE DESIRED:	00	CALL PROGRAM 16		
4	USER DEFINED:				
5	PRINT FORM (Y/N):		ENTER Y OR N (SEE NOTE 1)		
6	DATUM LIST (Y/N):		ENTER Y OR N (SEE NOTE 1)		
7	FROM USER DEF (Y/N):		ENTER Y OR N (IF Y, GO TO STEP 9)		
8	FROM DATUM:	00	ENTER DATUM CODE (GO TO STEP 16)	FROM DATUM:	FROM DATUM:
9	X-SHIFT:	0000	ENTER X-SHIFT	X-SHIFT:	X-SHIFT:
10	Y-SHIFT:	0000	ENTER Y-SHIFT	Y-SHIFT:	Y-SHIFT:
11	Z-SHIFT:	0000	ENTER Z-SHIFT	Z-SHIFT:	Z-SHIFT:
12	MAJOR:	0000000.00	ENTER SEMIMAJOR AXIS	SEMIMAJOR AXIS:	SEMIMAJOR AXIS:
13	FLAT OR MINOR (F/M):		ENTER F OR M (IF M, GO TO STEP 15)		
14	FLAT:	000.000000000	ENTER FLATTENING (GO TO STEP 17)	FLATTENING:	FLATTENING:
15	MINOR:	0000000.00	ENTER SEMIMINOR AXIS (GO TO STEP 17)	SEMIMINOR AXIS:	SEMIMINOR AXIS:
16	TO DATUM (USER DEF):		GO TO STEP 19		
17	TO USER DEF (Y/N):		ENTER Y OR N (IF Y, GO TO STEP 19)		
18	TO DATUM:	00	ENTER DATUM CODE (GO TO STEP 26)	TO DATUM:	TO DATUM:
19	X-SHIFT:	0000	ENTER X-SHIFT	X-SHIFT:	X-SHIFT:
20	Y-SHIFT	0000	ENTER Y-SHIFT	Y-SHIFT:	Y-SHIFT:
21	Z-SHIFT:	0000	ENTER Z-SHIFT	Z-SHIFT:	Z-SHIFT:
22	MAJOR:	0000000.00	ENTER SEMIMAJOR AXIS	SEMIMAJOR AXIS:	SEMIMAJOR AXIS:
23	FLAT OR MINOR (F/M):		ENTER F OR M (IF M, GO TO STEP 25)		
24	FLAT:	000.000000000	ENTER FLATTENING (GO TO STEP 26)	FLATTENING:	FLATTENING:
25	MINOR:	0000000.00	ENTER SEMIMINOR AXIS	SEMIMINOR AXIS:	SEMIMINOR AXIS:
26	EAST:	000000.00	ENTER EASTING	EASTING:	EASTING:
27	NORTH:	0000000.00	ENTER NORTHING	NORTHING:	NORTHING:
28	GRID ZONE (-:S):	00	ENTER GRID ZONE	GRID ZONE:	GRID ZONE:
29	ZONE TO ZONE (Y/N):		ENTER Y OR N (IF N, GO TO STEP 31)		
30	ENDING GRID ZONE (-:S):	00	ENTER GRID ZONE	GRID ZONE:	GRID ZONE:
31	EAST:	000000.00	RECORD EASTING OF STATION	EASTING:	EASTING:
32	NORTH:	0000000.00	RECORD NORTHING OF STATION	NORTHING:	NORTHING:
33	GRID ZONE: (-:S):	00	RECORD GRID ZONE OF STATION	GRID ZONE:	GRID ZONE:
34	ELPS:		RECORD ELLIPSOID	ELLIPSOID:	ELLIPSOID:
35	END OF MSN (Y/N):		ENTER Y OR N		

REMARKS:

DA FORM 7289-R, SEP 93

USE THE FOLLOWING DATUM CODES FOR STEPS 8 AND 18.

DATUM NAME	CODE	DISPLAYED NAME
Adindan[1]	1	ADINDAN
Afgooye	2	AFG
Ain el Abd 1970	3	AIN EL ABD 1970
Anna 1 Astro 1965	4	ANNA 1 ASTRO 1965
Arc 1950	5	ARC 1950
Arc 1960	6	ARC 1960
Ascension Island 1958	7	ASCENSION ISLAND' 58
Astro Beacon E	8	ASTRO BEACON "E"
Astro Tern Island (FRIG) 1961[2]	9	ASTRO B4 SOR. ATOLL
Astro DOS[2]	10	ASTRO POS 71/4
Astronomic Station 1952	11	ASTRONOMIC STA. 52
Australian Geodetic 1966	12	AUSTRALIAN GEO 1966
Australian Geodetic 1984	13	AUSTRALIAN GEO 1984
Bellevue (IGN)	14	BELLEVUE (IGN)
Bermuda 1957	15	BERMUDA 1957
Bogota Observatory	16	BOGOTA OBSERVATORY
Campo Inchauspe	17	CAMPO INCHAUSPE
Canton Astro 1966[2]	18	CANTON ISLAND 1966
Cape	19	CAPE
Cape Canaveral	20	CAPE CANAVERAL
Carthage	21	CARTHAGE
Chatham 1971	22	CHATHAM 1971
Chua Astro	23	CHUA ASTRO
Corrego Alegre	24	CORREGO ALEGRE
Djakarta (Batavia)	25	DJAKARTA (BATAVIA)
DOS 1968	26	DOS 1968
Easter Island 1967	27	EASTER ISLAND 1967
European 1950	28	EUROPEAN 1950
European 1979	29	EUROPEAN 1979
Gandajika Base	30	GANDAJIKA BASE
Geodetic Datum 1949	31	GEODETIC DATUM 1949
Guam 1963	32	GUAM 1963
Gux 1 Astro	33	GUX 1 ASTRO
Hjorsey 1955	34	HJORSEY 1955
Hong Kong 1963	35	HONG KONG 1963
Indian 1 (Thailand, Vietnam)	36	INDIAN 1 (Thai/Viet)
Indian 2 (Bangladesh, India, Nepal)	37	INDIAN 2
Ireland 1965	38	IRELAND 1965
ISTS 073 Astro 1969	39	ISTS 073 ASTRO 1969
Johnston Island 1961	40	JOHNSTON ISLAND 61
Kandawala	41	KANDAWALA
Kerguelen Island	42	KERGUELEN ISLAND
Kertau 1948	43	KERTAU 1948
Reunion[2]	44	LA REUNION
L.C. 5 ASTRO	45	L.C. 5 ASTRO
Liberia 1964	46	LIBERIA 1964
Luzon 1 (Philippines)	47	LUZON 1 (Philippine)
Luzon 2 (Mindanao Island)	48	LUZON 2 (Mindanao)
Mahe 1971	49	MAHE 1971
Selvagem Grande 1938[2]	50	MARCO ASTRO
Massawa	51	MASSAWA
Merchich	52	MERCHICH
Midway Astro 1961	53	MIDWAY ASTRO 1961

DATUM NAME	CODE	DISPLAYED NAME
Minna	54	MINNA
Nahrwan 1 (Masirah Island [Oman])	55	NAHRWAN 1 (Oman)
Nahrwan 2 (United Arab Emirates)	56	NAHRWAN 2 (UAE)
Nahrwan 3 (Saudi Arabia)	57	NAHRWAN 3 (Saudi)
Schwarzech (Namibia)	58	NAMIBIA
Naparima, BWI	59	NAPARIMA BWI
North American 1927 (Continental United States)	60	NAD'27 (CONUS)
North American 1927 (Alaska)	61	NAD'27 (Alaska)
North American 1927 (Bahamas, excluding San Salvador Island)	62	NAD'27 (Bahamas)
North American 1927 (San Salvador Island)	63	NAD'27 (Salvador)
North American 1927 (Canada)	64	NAD'27 (Canada)
North American 1927 (Canal Zone)	65	NAD'27 Canal Zone)
North American 1927 (Caribbean)	66	NAD'27 (Caribbean)
North American 1927 (Central America)	67	NAD'27 (Cent.Amer.)
North American 1927 (Cuba)	68	NAD'27 (Cuba)
North American 1927 (Greenland)	69	NAD'27(Greenland)
North American 1927 (Mexico)	70	NAD'27(Mexico)
North American 1983	71	NORTH AMERICAN 1983
Meteorologico 1939[2]	72	OBSERVATORIO 1966
Old Egyptian 1907[2]	73	OLD EGYPTIAN 1930
Old Hawaiian	74	OLD HAWAIIAN
Oman	75	OMAN
Ordnance Survey of Great Britain 1936	76	ORD.SURV.GR.BRIT '36
Pico de Las Nieves	77	PICO DE LAS NIEVES
Pitcairn Astro 1967	78	PITCAIRN ASTRO 1967
Provisional South Chilean 1963 or Hito XVIII 1963[2]	79	PROV. SO.CHILEAN'63
Provisional South American 1956	80	PROV. S.AMERICAN'56
Puerto Rico	81	PUERTO RICO
Qatar National	82	QATAR NATIONAL
Qornoq	83	QORNOQ
Rome 1940	84	ROME 1940
Sâo Braz[2]	85	SANTA BRAZ
Santa (DOS)	86	SANTA (DOS)
Sapper Hill 1943	87	SAPPER HILL 1943
South American 1969	88	SO. AMERICAN 1969
South Asia	89	SOUTH ASIA
Porto Santo 1936[2]	90	SOUTHEAST BASE
Graciosa Base SW End 1948[2]	91	SOUTHWEST BASE
Timbalai 1948	92	TIMBALAI 1948
Tokyo	93	TOKYO
Tristan Astro 1968	94	TRISTAN ASTRO 1968
Viti Levu 1916	95	VITI LEVU 1916
Wake-Eniwetok 1960	96	WAKE-ENIWETOK 1960
World Geodetic System 1972	97	WGS 1972
World Geodetic System 1984	98	WGS 1984
Zanderij	99	ZANDERIJ

[1] The transformation parameters for the Adindan datum have been updated by the Defense Mapping Agency. Use Program 16 (user-defined) with the following transformation parameters:

Semimajor Axis	Flattening	X-Shift	Y-Shift	Z-Shift
6378249.145	293.465	-166	-15	204

[2] Datum names were incorrect in DMA Technical Report (TR) 8350.2, 1 Dec 87, but are correct above. The BUCS-displayed names for these datums differ from the correct name.

COMPUTATION OF AZIMUTH AND DISTANCE FROM COORDINATES (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select AZIMUTH/DISTANCE (option A) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the AZIMUTH/DISTANCE SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶ . 3. Four computations can be recorded on this form. 4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OCC STA: ?	NAME OCC STA:	NAME OCC STA:
ENTER EASTING: ?	EASTING: ▶	EASTING: ▶
ENTER NORTHING: ?	NORTHING: ▶	NORTHING: ▶
ENTER NAME AZMK: ?	NAME AZMK:	NAME AZMK:
ENTER EASTING: ?	EASTING: ▶	EASTING: ▶
ENTER NORTHING: ?	NORTHING: ▶	NORTHING: ▶
RECORD AZ OCC STA TO AZMK: ?	AZ (MILS):	AZ (MILS):
RECORD DIST OCC STA TO AZMK: ?	DIST (METERS):	DIST (METERS):

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OCC STA: ?	NAME OCC STA:	NAME OCC STA:
ENTER EASTING: ?	EASTING: ▶	EASTING: ▶
ENTER NORTHING: ?	NORTHING: ▶	NORTHING: ▶
ENTER NAME AZMK: ?	NAME AZMK:	NAME AZMK:
ENTER EASTING: ?	EASTING: ▶	EASTING: ▶
ENTER NORTHING: ?	NORTHING: ▶	NORTHING: ▶
RECORD AZ OCC STA TO AZMK: ?	AZ (MILS):	AZ (MILS):
RECORD DIST OCC STA TO AZMK: ?	DIST (METERS):	DIST (METERS):

REMARKS:

COMPUTATION OF COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE, AND VERTICAL ANGLE (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select TRAVERSE (option B) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the TRAVERSE SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶ . 3. Step MAIN/OFFSET is not required for first leg. 4. Remove window of legal entries by pressing ENTER before pressing the **C** key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME REAR STA: ?	NAME REAR STA:	NAME REAR STA:
ENTER NAME OCC STA: ?	NAME OCC STA: NUMBER:	NAME OCC STA: NUMBER:
ENTER EAST OCC STA: ?	EASTING:	EASTING:
ENTER NORTH OCC STA: ?	NORTHING:	NORTHING:
ENTER HEIGHT OCC STA: ?	HEIGHT:	HEIGHT:
ENTER AZIMUTH TO REAR: ?	AZ TO REAR (MILS):	AZ TO REAR (MILS):

REQUIRED FIELDS	DATA RECORD	
ENTER NAME FWD STA: ?	NAME FWD STA:	NAME FWD STA:
MAIN/OFFSET: ? (SEE NOTE 3)	(MAIN) (OFFSET)	(MAIN) (OFFSET)
ENTER HORZ ANGLE TO FWD STA: ?	▶ HORZ ANGLE (MILS):	▶ HORZ ANGLE (MILS):
ENTER VERT ANGLE TO FWD STA: ?	▶ VERT ANGLE (MILS): ±	▶ VERT ANGLE (MILS): ±
RECIPROCAL VERT ANGLE (Y/N)	(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
HORZ OR SLOPE DIST: ?	▶ DISTANCE: (HORZ) (SLOPE)	▶ DISTANCE: (HORZ) (SLOPE)

REQUIRED FIELDS	DATA RECORD	
RECORD NAME REAR STA: ?	NAME REAR STA:	NAME REAR STA:
RECORD NAME OCC STA: ?	NAME OCC STA: NUMBER:	NAME OCC STA: NUMBER:
RECORD EAST OCC STA: ?	EASTING:	EASTING:
RECORD NORTH OCC STA: ?	NORTHING:	NORTHING:
RECORD HEIGHT OCC STA: ?	HEIGHT:	HEIGHT:
RECORD AZIMUTH TO REAR: ?	AZ TO REAR (MILS):	AZ TO REAR (MILS):

REQUIRED FIELDS	DATA RECORD	
ENTER NAME FWD STA: ?	NAME FWD STA:	NAME FWD STA:
MAIN/OFFSET: ? (SEE NOTE 3)	(MAIN) (OFFSET)	(MAIN) (OFFSET)
ENTER HORZ ANGLE TO FWD STA: ?	▶ HORZ ANGLE (MILS):	▶ HORZ ANGLE (MILS):
ENTER VERT ANGLE TO FWD STA: ?	▶ VERT ANGLE (MILS): ±	▶ VERT ANGLE (MILS): ±
RECIPROCAL VERT ANGLE (Y/N)	(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
HORZ OR SLOPE DIST: ?	▶ DISTANCE: (HORZ) (SLOPE)	▶ DISTANCE: (HORZ) (SLOPE)

REMARKS:

DA FORM 7357-R, SEP 96

CLOSURE/ADJUSTMENT

INSTRUCTIONS	NOTES
	1. Observe closure screen by pressing the T key. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate. 3. Press the T key when in the completed closure screen to view adjusted traverse data.

REQUIRED FIELDS	DATA RECORD	
	CLOSURE DATA	ADJUSTED DATA
ENTER CLOSING ANGLE: ?	CLOSING ANGLE (MILS):	STATION NAME:
ENTER AZIMUTH FWD STA: ?	KNOWN AZ FORWARD (MILS):	EASTING:
ENTER HEIGHT CLOSING STA: ?	KNOWN HEIGHT (METERS):	NORTHING:
ENTER EAST CLOSING STA:	KNOWN EASTING:	HEIGHT (METERS):
ENTER NORTH CLOSING STA: ?	KNOWN NORTHING:	ADJUSTED AZ TO REAR (MILS):
ENTER 4TH/5TH ORDER: ?	4 OR 5	
PRESS ENTER THEN C KEY TO CALCULATE		

REQUIRED FIELDS	DATA RECORD	
RECORD CMPT AZ FWD:	CMPT AZ FORWARD (MILS):	STATION NAME:
RECORD TOTAL AZ CORRECTION:	TOTAL AZ CORRECTION (MILS):	EASTING:
RECORD TOTAL HEIGHT CORRECTION:	TOTAL HEIGHT CORRECTION (METERS):	NORTHING:
RECORD TOTAL TRAVERSE LENGTH:	TOTAL TRAVERSE LENGTH (METERS):	HEIGHT (METERS):
RECORD RADIAL ERROR:	RADIAL ERROR (METERS):	ADJUSTED AZ TO REAR (MILS):
RECORD ACCURACY RATIO:	ACCURACY RATIO:	

ADJUSTED DATA

REQUIRED FIELDS	DATA RECORD	
RECORD STATION NAME:	STATION NAME:	STATION NAME:
RECORD STATION EASTING:	EASTING:	EASTING:
RECORD STATION NORTHING:	NORTHING:	NORTHING:
RECORD STATION HEIGHT:	HEIGHT (METERS):	HEIGHT (METERS):
RECORD AZ TO REAR:	ADJUSTED AZ TO REAR (MILS):	ADJUSTED AZ TO REAR (MILS):

REMARKS:

COMPUTATION OF PLANE TRIANGLE COORDINATES AND HEIGHT FROM ONE SIDE, THREE ANGLES, AND VERTICAL ANGLE (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS

1. Select SURVEY CALC (option B) from the MODE MENU.
2. Select TRIANGULATION (option C) from the SURVEY CALCULATIONS MENU.
3. Select the desired record from the TRIANGULATION SUMMARY LIST.
4. Observe the required fields, and enter the desired data.

NOTES

1. Press ENTER to display the window of legal entries.
2. Enter field data in blocks marked ▶.
3. Two triangles can be recorded on this form.
4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

SKETCH: (DRAW SKETCH, AND LABEL STATIONS BY NAME AND NUMBER.)

NOTES

1. Draw a diagram of the triangle scheme, and label starting base, required side(s), interior angles, and stations by name.
2. Number the stations in the order that the stations are computed. The starting station is Number 1.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME REAR STA: ?	NAME REAR STA:	NAME REAR STA:
ENTER NAME START POINT/ B OR C: ?	NAME OCC STA (B OR C): NUMBER:	NAME OCC STA (B OR C): NUMBER:
ENTER/RECORD EAST START POINT: ?	EASTING:	EASTING:
ENTER/RECORD NORTH START POINT: ?	NORTHING:	NORTHING:
ENTER/RECORD HEIGHT START POINT: ?	HEIGHT:	HEIGHT:
ENTER/RECORD AZ START POINT TO REAR: ?	AZ OF BASE (MILS):	AZ OF BASE (MILS):
ENTER/RECORD BASE DISTANCE: ?	BASE DISTANCE (METERS):	BASE DISTANCE (METERS):
GRID OR HORZ BASE: ?	(GRID) (HORIZONTAL)	(GRID) (HORIZONTAL)

REQUIRED FIELDS	DATA RECORD	
ENTER NAME FWD STA: ?	NAME FWD STA:	NAME FWD STA:
ENTER INTERIOR ANGLE POINT A: ?	▶ ANGLE A (MILS):	▶ ANGLE A (MILS):
ENTER INTERIOR ANGLE POINT B: ?	▶ ANGLE B (MILS):	▶ ANGLE B (MILS):
ENTER INTERIOR ANGLE POINT C: ?	▶ ANGLE C (MILS):	▶ ANGLE C (MILS):
ENTER VERTICAL ANGLE TO FWD STA: ?	▶ VERTICAL ANGLE (MILS): ±	▶ VERTICAL ANGLE (MILS): ±
RECIP VERT ANGLE (Y/N): ?	(RECIPROCAL) (NONRECIPROCAL)	(RECIPROCAL) (NONRECIPROCAL)
NEXT TRI BASE BA/CA: ?	(BA) (CA)	(BA) (CA)

REMARKS:

CLOSURE ON KNOWN POINT OR CHECK BASE

INSTRUCTIONS	NOTES
	1. Observe closure screen by pressing the T key. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate. 3. Enter K for known point or C for check base.

REQUIRED FIELDS (Known Point)	DATA RECORD	
ENTER CLOSING ANGLE: ?	CLOSING ANGLE (MILS):	
ENTER AZ CLOSING STA TO AZMK: ?	KNOWN AZ FORWARD (MILS):	
ENTER HEIGHT CLOSING STA: ?	KNOWN HEIGHT (METERS):	
ENTER EAST CLOSING STA: ?	KNOWN EASTING:	
ENTER NORTH CLOSING STA: ?	KNOWN NORTHING:	
PRESS ENTER THEN C KEY TO CALCULATE		

REQUIRED FIELDS	DATA RECORD	
RECORD CMPTD AZ TO AZMK:	CMPTD AZ TO AZMK:	
RECORD TOTAL AZ ERROR:	TOTAL AZ ERROR (MILS):	
RECORD TOTAL HEIGHT ERROR:	TOTAL HEIGHT ERROR (METERS):	
RECORD TOTAL DISTANCE OF SCHEME:	TOTAL DISTANCE OF SCHEME:	
RECORD RADIAL ERROR:	RADIAL ERROR (METERS):	
RECORD ACCURACY RATIO:	ACCURACY RATIO: (CHECK SPECIFICATIONS)	

REQUIRED FIELDS (Check Base)	DATA RECORD	
ENTER MEASURED AZIMUTH OF CHECK BASE: ?	MEASURED AZIMUTH (MILS):	
ENTER MEASURED BASE DISTANCE: ?	MEASURED BASE (METERS):	
RECORD AZIMUTH ERROR:	AZ ERROR (MILS):	
RECORD COMPARATIVE ACCURACY:	COMPARATIVE RATIO: (CHECK SPECIFICATIONS)	

REMARKS:

COMPUTATION OF COORDINATES AND HEIGHT BY THREE–POINT RESECTION (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select RESECTION (option D) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶ .
3. Select the desired record from the RESECTION SUMMARY LIST.	3. Two resection computations can be recorded on this form.
4. Observe the required fields, and enter the desired data.	4. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
	5. Sums between 2845-3555 provide NO VALID SOLUTION.

REQUIRED FIELDS	DATA RECORD	
ENTER EAST LEFT STA: ?	EASTING OF LEFT:	EASTING OF LEFT:
ENTER NORTH LEFT STA: ?	NORTHING OF LEFT:	NORTHING OF LEFT:
ENTER EAST CENTER STA: ?	EASTING OF CENTER:	EASTING OF CENTER:
ENTER NORTH CENTER STA: ?	NORTHING OF CENTER:	NORTHING OF CENTER:
ENTER HEIGHT CENTER STA: ?	HEIGHT OF CENTER:	HEIGHT OF CENTER:
ENTER EAST RIGHT STA: ?	EASTING OF RIGHT:	EASTING OF RIGHT:
ENTER NORTH RIGHT STA: ?	NORTHING OF RIGHT:	NORTHING OF RIGHT:

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OCC STA: ?	NAME OCC STA:	NAME OCC STA:
ENTER HORZ ANGLE LEFT TO CENTER: ?	HORZ ANGLE P1 (MILS): ▶	HORZ ANGLE P1 (MILS): ▶
ENTER HORZ ANGLE CENTER TO RIGHT: ?	HORZ ANGLE P2 (MILS): ▶	HORZ ANGLE P2 (MILS): ▶
ENTER VERT ANGLE OCC STA TO CENTER: ?	VERT ANGLE FROM P TO CENTER: ▶ ±	VERT ANGLE FROM P TO CENTER: ▶ ±
ENTER TARGET HEIGHT AT CENTER: ?	HEIGHT OF TARGET (METERS):	HEIGHT OF TARGET (METERS):
ENTER INSTRUMENT HEIGHT AT OCC STA: ?	HEIGHT OF INSTRUMENT (METERS):	HEIGHT OF INSTRUMENT (METERS):

REQUIRED FIELDS	DATA RECORD	
SUM OF ANGLES: CHECK SPECIFICATIONS: (NOTE 5)	SUM OF ANGLES:	SUM OF ANGLES:
RECORD EAST OCC STA:	EASTING OF P:	EASTING OF P:
RECORD NORTH OCC STA:	NORTHING OF P:	NORTHING OF P:
RECORD HEIGHT OCC STA:	HEIGHT OF P (METERS):	HEIGHT OF P (METERS):
RECORD AZ FROM OCC STA TO CENTER:	AZ FROM P TO CENTER (MILS):	AZ FROM P TO CENTER (MILS):

REMARKS/SKETCH:

DA FORM 7359-R, SEP 96

COMPUTATION OF ASTRONOMIC AZIMUTH BY ALTITUDE METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select ALTITUDE METHOD SUN (option E) or STAR (option F) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the ALTITUDE METHOD SUN/STAR SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶ . 3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD		
NAME AZIMUTH MARK: ?	NAME AZ MK:	APPROX AZIMUTH TO AZIMUTH MARK (MILS):	
		STAR POSITION: ? EAST WEST	
NAME OBS STATION: ?	NAME OBS STA:	STAR NO/NAME:	
		4TH/5TH ORDER: ? 4TH 5TH	
ENTER GRID ZONE: ?	GRID ZONE:	TEMPERATURE:	
ENTER LATITUDE: ?	LATITUDE: °	'	" N S
ENTER LONGITUDE: ?	LONGITUDE: °	'	" E W
ENTER DECLINATION: ?	DECLINATION: + - °	'	"
ENTER DAILY CHANGE OF DECLN: ?	DAILY CHANGE (SECONDS): + - (SUN ONLY)		
ENTER WATCH CORRECTION: ?	WATCH CORRECTIONS: HOURS (SLOW) + (SUN ONLY) (FAST) -	MINUTES	SECONDS
ENTER TIME ZONE CORRECTION: ?	TIME ZONE CORRECTION: + - (SUN ONLY)		W E
DAYLIGHT SAVINGS TIME (Y/N): ?	ENTER Y OR N (SUN ONLY)		

	SET ___	SET ___	SET ___
ENTER MEAN WATCH TIME: ? (SUN ONLY)	HOURS , MINUTES , SECONDS ▶	HOURS , MINUTES , SECONDS ▶	HOURS , MINUTES , SECONDS ▶
ENTER VERT ANGLE TO SUN/STAR: ?	VERT ANGLE (MILS): ▶	VERT ANGLE (MILS): ▶	VERT ANGLE (MILS): ▶
ENTER REFRACTION: ?	ENTER AS + : MILS	ENTER AS + : MILS	ENTER AS + : MILS
ENTER HORZ AZMK TO SUN/STAR: ?	HORZ ANGLE (MILS): ▶	HORZ ANGLE (MILS): ▶	HORZ ANGLE (MILS): ▶

RECORD OBS 1 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS):	REMARKS:
RECORD OBS 2 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS):	
RECORD OBS 3 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS):	
RECORD MEAN ASTRO AZ TO AZMK: ?	MEAN ASTRONOMIC AZ (MILS):	
RECORD GRID AZ TO AZMK: ?	GRID AZIMUTH (MILS):	

DA FORM 7360-R, SEP 96

ALPHABETICAL STAR LIST

STAR NAME	NO	MAG	STAR NAME	NO	MAG	STAR NAME	NO	MAG
ACAMAR	12	3.4	CAPH	2	2.4	MIRFAK	14	1.9
ACHERNAR	9	0.5	CASTOR	28	1.5	MIZAR	46	2.4
ACRUX	42	1.0	DENEB	68	1.3	NUNKI	65	2.1
ADHARA	26	1.6	DENEBOLA	39	2.2	NU	69	3.7
ALDEBARAN	15	1.1	DIPHDA	6	2.2	PEACOCK	67	2.1
ALHENA	24	1.9	DSCHUBBA	56	2.5	PHECDA	40	2.5
ALIOTH	45	1.7	DUBHE	38	1.9	POLARIS	10	2.1
ALKAID	48	1.9	ELNATH	19	1.8	POLLUX	30	1.2
AL NA 'IR	71	2.2	ELTANIN	62	2.4	PROCYON	29	0.5
ALNILAM	20	1.7	ENIF	70	2.5	RASALHAGUE	51	2.1
ALNITAK	21	2.0	FORMALHAUT	72	1.3	REGULUS	35	1.3
ALPHARD	35	2.2	GACRUX	43	1.6	RIGEL	16	0.3
ALPHECCA	55	2.3	GAMMA CASSIOPEIAE	7	1.6-2.8	RIGIL KENTAURUS	52	0.1
ALPHERATZ	1	2.1	GAMMA VELORUM	31	1.9	RUCHBUH	8	2.8
ALTAIR	66	0.9	GIENAH	41	2.8	SABIK	59	2.6
ANKAA	4	2.4	HADAR	49	0.8	SCAULA	60	1.7
ANTARES	57	1.2	HAMAL	11	2.2	SCHEDAR	5	2.3
ARCTURUS	51	0.2	KAUS AUSTRALIS	63	1.9	SIRIUS	25	-1.6
ATRIA	58	1.9	KOCHAB	54	2.2	SPICA	47	1.2
AVIOR	32	1.7	MARKAB	73	2.6	SUHAIL	33	2.2
BELLATRIX	18	1.7	MENKAR	13	2.8	VEGA	64	0.1
BETA HYDRUS	3	2.9	MENKENT	50	2.3	WEZEN	27	2.0
BETELGEUSE	22	0.1	MEPAK	37	2.4	ZEBENELGENUBI	53	2.9
CANOPUS	23	-0.9	MISPLACIDUS	34	1.8			
CAPELLA	17	0.2	MIMOSA	44	1.5			

REMARKS:

COMPUTATION OF ASTRONOMIC AZIMUTH BY THE HASTY ASTRO METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select HASTY ASTRO (SUN) (option G) or STAR (option H) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶ .
3. Select the desired record from the HASTY ASTRO SUN/STAR SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	4. Two observation computations can be recorded on this form.

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OBS STATION: ?	NAME OBS STATION:	NAME OBS STATION:
ENTER EAST OBS STATION: ?	EASTING OBS STATION:	EASTING OBS STATION:
ENTER NORTH OBS STATION: ?	NORTHING OBS STATION:	NORTHING OBS STATION:
ENTER APPROX AZ TO AZMK: ?	APPROX AZ TO AZMK:	APPROX AZ TO AZMK:
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID:	SPHEROID:

REQUIRED FIELDS	DATA RECORD	
HEMISPHERE (N/S): ?	ENTER N or S	ENTER N or S
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:
ENTER STAR NO/NAME: ?	STAR NO: / STAR NAME:	STAR NO: / STAR NAME:
DAYLT SAVINGS TIME (Y/N): ?	ENTER Y or N	ENTER Y or N
ENTER TIME ZONE LETTER: ?	TIME ZONE LETTER:	TIME ZONE LETTER:
USE TIME MODULE (Y/N): ?	ENTER Y or N	ENTER Y or N
ENTER/RECORD OBS DATE: ?	▶ DATE: dd / mm / yy	▶ DATE: dd / mm / yy
ENTER/RECORD OBS 1 TIME: ?	▶ TIME: hh / mm / ss	▶ TIME: hh / mm / ss
ENTER OBS 1 POSITION AT TIP: ? A = TRAILING EDGE B = LEADING EDGE C = CENTER	ENTER A, B, or C:	ENTER A, B, or C:
ENTER/RECORD OBS 2 TIME: ?	▶ TIME: hh / mm / ss	▶ TIME: hh / mm / ss
ENTER OBS 2 POSITION AT TIP: ? A = TRAILING EDGE B = LEADING EDGE C = CENTER	ENTER A, B, or C:	ENTER A, B, or C:
RECORD GRID AZIMUTH:	GRID AZIMUTH:	GRID AZIMUTH:
RECORD CHECK ANGLE:	CHECK ANGLE:	CHECK ANGLE:

REMARKS:

DA FORM 7361-R, SEP 96

ALPHABETICAL STAR LIST

STAR NAME	NO	MAG	STAR NAME	NO	MAG	STAR NAME	NO	MAG
ACAMAR	12	3.4	CAPH	2	2.4	MIRFAK	14	1.9
ACHERNAR	9	0.5	CASTOR	28	1.5	MIZAR	46	2.4
ACRUX	42	1.0	DENEB	68	1.3	NUNKI	65	2.1
ADHARA	26	1.6	DENEBOLA	39	2.2	NU	69	3.7
ALDEBARAN	15	1.1	DIPHDA	6	2.2	PEACOCK	67	2.1
ALHENA	24	1.9	DSCHUBBA	56	2.5	PHECDA	40	2.5
ALIOTH	45	1.7	DUBHE	38	1.9	POLARIS	10	2.1
ALKAID	48	1.9	ELNATH	19	1.8	POLLUX	30	1.2
AL NA 'IR	71	2.2	ELTANIN	62	2.4	PROCYON	29	0.5
ALNILAM	20	1.7	ENIF	70	2.5	RASALHAGUE	51	2.1
ALNITAK	21	2.0	FORMALHAUT	72	1.3	REGULUS	35	1.3
ALPHARD	35	2.2	GACRUX	43	1.6	RIGEL	16	0.3
ALPHECCA	55	2.3	GAMMA CASSIOPEIAE	7	1.6-2.8	RIGIL KENTAURUS	52	0.1
ALPHERATZ	1	2.1	GAMMA VELORUM	31	1.9	RUCHBUH	8	2.8
ALTAIR	66	0.9	GIENAH	41	2.8	SABIK	59	2.6
ANKAA	4	2.4	HADAR	49	0.8	SCAULA	60	1.7
ANTARES	57	1.2	HAMAL	11	2.2	SCHEDAR	5	2.3
ARCTURUS	51	0.2	KAUS AUSTRALIS	63	1.9	SIRIUS	25	-1.6
ATRIA	58	1.9	KOCHAB	54	2.2	SPICA	47	1.2
AVIOR	32	1.7	MARKAB	73	2.6	SUHAIL	33	2.2
BELLATRIX	18	1.7	MENKAR	13	2.8	VEGA	64	0.1
BETA HYDRUS	3	2.9	MENKENT	50	2.3	WEZEN	27	2.0
BETELGEUSE	22	0.1	MEPAK	37	2.4	ZEBENELGENUBI	53	2.9
CANOPUS	23	-0.9	MISPLACIDUS	34	1.8			
CAPELLA	17	0.2	MIMOSA	44	1.5			

REMARKS:

(BACK) DA FORM 7361-R, SEP 96

COMPUTATION OF AZIMUTH AND VERTICAL ANGLE TO SELECTED STAR (STAR ID) (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select STAR ID (option I) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the STAR ID SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER OBS STATION: ?	NAME OBS STATION:	NAME OBS STATION:
ENTER EAST OBS STATION: ?	EASTING:	EASTING:
ENTER NORTH OBS STATION: ?	NORTHING:	NORTHING:
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID:	SPHEROID:

REQUIRED FIELDS	DATA RECORD	
HEMISPHERE (N/S): ?	ENTER N or S	ENTER N or S
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:
ENTER OBS DATE: ?	DATE: dd mm yy	DATE: dd mm yy
ENTER OBS TIME: ?	TIME: hh mm	TIME: hh mm
ENTER TIME ZONE LETTER: ?	TZ LTR:	TZ LTR:
DAYLT SAVINGS TIME (Y/N): ?	ENTER Y or N	ENTER Y or N
ENTER/RECORD STAR NO/NAME:	STAR NO: STAR NAME:	STAR NO: STAR NAME:
RECORD LOCAL SIDEREAL TIME:	LST: degrees	LST: degrees
RECORD AZIMUTH TO STAR:	AZIMUTH:	AZIMUTH:
RECORD ALTITUDE TO STAR:	ALTITUDE:	ALTITUDE:

REMARKS:

ALPHABETICAL STAR LIST

STAR NAME	NO	MAG	STAR NAME	NO	MAG	STAR NAME	NO	MAG
ACAMAR	12	3.4	CAPH	2	2.4	MIRFAK	14	1.9
ACHERNAR	9	0.5	CASTOR	28	1.5	MIZAR	46	2.4
ACRUX	42	1.0	DENEB	68	1.3	NUNKI	65	2.1
ADHARA	26	1.6	DENEBOLA	39	2.2	NU	69	3.7
ALDEBARAN	15	1.1	DIPHDA	6	2.2	PEACOCK	67	2.1
ALHENA	24	1.9	DSCHUBBA	56	2.5	PHECDA	40	2.5
ALIOTH	45	1.7	DUBHE	38	1.9	POLARIS	10	2.1
ALKAID	48	1.9	ELNATH	19	1.8	POLLUX	30	1.2
AL NA 'IR	71	2.2	ELTANIN	62	2.4	PROCYON	29	0.5
ALNILAM	20	1.7	ENIF	70	2.5	RASALHAGUE	51	2.1
ALNITAK	21	2.0	FORMALHAUT	72	1.3	REGULUS	35	1.3
ALPHARD	35	2.2	GACRUX	43	1.6	RIGEL	16	0.3
ALPHECCA	55	2.3	GAMMA CASSIOPEIAE	7	1.6-2.8	RIGIL KENTAURUS	52	0.1
ALPHERATZ	1	2.1	GAMMA VELORUM	31	1.9	RUCHBUH	8	2.8
ALTAIR	66	0.9	GIENAH	41	2.8	SABIK	59	2.6
ANKAA	4	2.4	HADAR	49	0.8	SCAULA	60	1.7
ANTARES	57	1.2	HAMAL	11	2.2	SCHEDAR	5	2.3
ARCTURUS	51	0.2	KAUS AUSTRALIS	63	1.9	SIRIUS	25	-1.6
ATRIA	58	1.9	KOCHAB	54	2.2	SPICA	47	1.2
AVIOR	32	1.7	MARKAB	73	2.6	SUHAIL	33	2.2
BELLATRIX	18	1.7	MENKAR	13	2.8	VEGA	64	0.1
BETA HYDRUS	3	2.9	MENKENT	50	2.3	WEZEN	27	2.0
BETELGEUSE	22	0.1	MEPAK	37	2.4	ZEBENELGENUBI	53	2.9
CANOPUS	23	-0.9	MISPLACIDUS	34	1.8			
CAPELLA	17	0.2	MIMOSA	44	1.5			

REMARKS:

COMPUTATION OF ASTRONOMIC AZIMUTH BY POLARIS TABULAR METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select POLARIS TABULAR METHOD (option J) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the POLARIS TABULAR METHOD SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶ . 3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD			
NAME AZIMUTH MARK: ?	NAME AZ MK:	APPROX AZIMUTH TO AZIMUTH MARK (MILS):		
NAME OBS STATION: ?	NAME OBS STA:			
ENTER LATITUDE: ?	LATITUDE: °	'	" N / S	
ENTER LONGITUDE: ?	LONGITUDE: °	'	" E / W	
ENTER GRID ZONE: ?	GRID ZONE:			
ENTER TIME ZONE CORRECTION: ?	TIME ZONE CORRECTION: + / -		W / E	
ENTER SIDEREAL TIME: ? (FM 6-300, TABLE 2)	SIDEREAL TIME: + HOURS	MINUTES	SECONDS	
ENTER WATCH CORRECTION: ?	WATCH CORRECTIONS: (SLOW) + (FAST) - HOURS	MINUTES	SECONDS	
4TH/5TH ORDER: ?	ENTER 4 OR 5			

	SET ___	SET ___	SET ___
ENTER MEAN WATCH TIME: ?	▶ HOURS / MINUTES / SECONDS	▶ HOURS / MINUTES / SECONDS	▶ HOURS / MINUTES / SECONDS
ENTER HORZ ANGLE AZMK TO STAR: ?	▶ HORZ ANGLE (MILS):	▶ HORZ ANGLE (MILS):	▶ HORZ ANGLE (MILS):
RECORD LOCAL SIDEREAL TIME: (hrs/min)	HOURS / MINUTES	HOURS / MINUTES	HOURS / MINUTES
ENTER B /B_0 /B_1 :B_2 (FM 6-300, TABLE 12):	▶ B_0 / B_1 / B_2	▶ B_0 / B_1 / B_2	▶ B_0 / B_1 / B_2

RECORD OBS 1 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS):	REMARKS:
RECORD OBS 2 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS):	
RECORD OBS 3 ASTRO AZ TO AZMK: ?	ASTRONOMIC AZ (MILS):	
RECORD MEAN ASTRO AZ TO AZMK: ?	MEAN ASTRONOMIC AZ (MILS):	
RECORD GRID AZ TO AZMK: ?	GRID AZIMUTH (MILS):	

DA FORM 7363-R, SEP 96

COMPUTATION – CONVERGENCE OF TRUE AZIMUTH TO GRID AZIMUTH (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select GRID CONVERGENCE (option K) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶ .
3. Select the desired record from the GRID CONVERGENCE SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	4. Four convergence computations can be recorded on this form.

REQUIRED FIELDS	DATA RECORD	
NAME AZIMUTH MARK: ?	NAME AZ MK:	NAME AZ MK:
NAME OCC STATION: ?	NAME OCC STA:	NAME OCC STA:
ENTER LATITUDE: ?	LATITUDE: ° ' " N S	LATITUDE: ° ' " N S
ENTER LONGITUDE: ?	LONGITUDE: ° ' " E W	LONGITUDE: ° ' " E W
ENTER TRUE AZIMUTH: ?	TRUE AZIMUTH (MILS): ▶	TRUE AZIMUTH (MILS): ▶
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	
RECORD CONVERGENCE: ?	CONVERGENCE (MILS):	CONVERGENCE (MILS):
RECORD GRID AZIMUTH: ?	GRID AZIMUTH (MILS):	GRID AZIMUTH (MILS):

REQUIRED FIELDS	DATA RECORD	
NAME AZIMUTH MARK: ?	NAME AZ MK:	NAME AZ MK:
NAME OCC STATION: ?	NAME OCC STA:	NAME OCC STA:
ENTER LATITUDE: ?	LATITUDE: ° ' " N S	LATITUDE: ° ' " N S
ENTER LONGITUDE: ?	LONGITUDE: ° ' " E W	LONGITUDE: ° ' " E W
ENTER TRUE AZIMUTH: ?	TRUE AZIMUTH (MILS): ▶	TRUE AZIMUTH (MILS): ▶
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	
RECORD CONVERGENCE: ?	CONVERGENCE (MILS):	CONVERGENCE (MILS):
RECORD GRID AZIMUTH: ?	GRID AZIMUTH (MILS):	GRID AZIMUTH (MILS):

REMARKS:

COMPUTATION OF TRIG TRAVERSE (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU. 2. Select TRIG TRAVERSE (option L) from the SURVEY CALCULATIONS MENU. 3. Select the desired record from the TRIG TRAVERSE SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Enter field data in blocks marked ▶ . 3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate. 4. Four trig traverse computations can be recorded on this form. 5. If the response to PERPENDICULAR (Y/N) is Y, no data are required for ANGLE Y.

REQUIRED FIELDS	DATA RECORD	
4TH OR 5TH ORDER: ?	ENTER 4 OR 5	ENTER 4 OR 5
ENTER HORZ ANGLE Q1: ?	▶ ANGLE Q1 (MILS):	▶ ANGLE Q1 (MILS):
ENTER HORZ ANGLE Q2: ?	▶ ANGLE Q2 (MILS):	▶ ANGLE Q2 (MILS):
ENTER BASE DIST B TO C1: ?	▶ BASE B TO C1 (METERS):	▶ BASE B TO C1 (METERS):
ENTER BASE DIST B TO C2: ?	▶ BASE B TO C2 (METERS):	▶ BASE B TO C2 (METERS):
PERPENDICULAR BASE (Y/N): ?	ENTER Y OR N	ENTER Y OR N
ENTER ANGLE Y: ? (IF NONPERP)	▶ ANGLE Y (MILS):	▶ ANGLE Y (MILS):

REQUIRED FIELDS	DATA RECORD	
RECORD DIST AB FROM BASE B/C1:	DIST NO 1 (METERS):	DIST NO 1 (METERS):
RECORD DIST AB FROM BASE B/C2:	DIST NO 2 (METERS):	DIST NO 2 (METERS):
RECORD MEAN HORZ DISTANCE:	MEAN DIST (METERS):	MEAN DIST (METERS):
RECORD COMPARATIVE ACCURACY:	COMPARATIVE ACCURACY: 1/	COMPARATIVE ACCURACY: 1/

REQUIRED FIELDS	DATA RECORD	
4TH OR 5TH ORDER: ?	ENTER 4 OR 5	ENTER 4 OR 5
ENTER HORZ ANGLE Q1: ?	▶ ANGLE Q1 (MILS):	▶ ANGLE Q1 (MILS):
ENTER HORZ ANGLE Q2: ?	▶ ANGLE Q2 (MILS):	▶ ANGLE Q2 (MILS):
ENTER BASE DIST B TO C1: ?	▶ BASE B TO C1 (METERS):	▶ BASE B TO C1 (METERS):
ENTER BASE DIST B TO C2: ?	▶ BASE B TO C2 (METERS):	▶ BASE B TO C2 (METERS):
PERPENDICULAR BASE (Y/N): ?	ENTER Y OR N	ENTER Y OR N
ENTER ANGLE Y: ? (IF NONPERP)	▶ ANGLE Y (MILS):	▶ ANGLE Y (MILS):

REQUIRED FIELDS	DATA RECORD	
RECORD DIST AB FROM BASE B/C1:	DIST NO 1 (METERS):	DIST NO 1 (METERS):
RECORD DIST AB FROM BASE B/C2:	DIST NO 2 (METERS):	DIST NO 2 (METERS):
RECORD MEAN HORZ DISTANCE:	MEAN DIST (METERS):	MEAN DIST (METERS):
RECORD COMPARATIVE ACCURACY:	COMPARATIVE ACCURACY: 1/	COMPARATIVE ACCURACY: 1/

REMARKS:

COMPUTATION OF COORDINATES AND HEIGHT BY INTERSECTION (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select INTERSECTION (option N) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶ .
3. Select the desired record from the INTERSECTION SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	4. Two intersection computations can be recorded on this form.

REQUIRED FIELDS	DATA RECORD	
NAME OF OB POST 1: ?	NAME 01:	NAME 01:
ENTER EAST OF OB POST 1: ?	EASTING 01:	EASTING 01:
ENTER NORTH OF OB POST 1: ?	NORTHING 01:	NORTHING 01:
ENTER HEIGHT OF OB POST 1: ?	HEIGHT 01 (METERS):	HEIGHT 01 (METERS):
NAME OF OB POST 2: ?	NAME 02:	NAME 02:
ENTER EAST OF OB POST 2: ?	EASTING 02:	EASTING 02:
ENTER NORTH OF OB POST 2: ?	NORTHING 02:	NORTHING 02:
RECORD DIST OB POST 1/OB POST 2:	DIST 01 TO 02 (METERS):	DIST 01 TO 02 (METERS):
RECORD AZ OB POST 1/OB POST 2:	AZIMUTH 01 TO 02 (MILS):	AZIMUTH 01 TO 02 (MILS):
ENTER AZ OB POST 1/TARGET: ?	AZ 01 TO TARGET (MILS): ▶	AZ 01 TO TARGET (MILS): ▶
ENTER VERT ANGLE OB POST 1/TARGET: ?	VERT ANGLE 01 TO TARGET (MILS): ▶ ±	VERT ANGLE 01 TO TARGET (MILS): ▶ ±
ENTER AZ OB POST 2/TARGET: ?	AZ 02 TO TARGET (MILS): ▶	AZ 02 TO TARGET (MILS): ▶
RECORD TARGET NO:	TGT NO:	TGT NO:
RECORD TGT EASTING:	EASTING OF TGT:	EASTING OF TGT:
RECORD TGT NORTHING:	NORTHING OF TGT:	NORTHING OF TGT:
RECORD TGT HEIGHT:	HEIGHT OF TGT:	HEIGHT OF TGT:

REMARKS/SKETCH:

COMPUTATION OF OF ASTRONOMIC AZIMUTH BY THE ARTY ASTRO METHOD (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select SURVEY CALC (option B) from the MODE MENU.	1. Press ENTER to display the window of legal entries.
2. Select ARTY ASTRO (SUN) (option O) or STAR (option P) from the SURVEY CALCULATIONS MENU.	2. Enter field data in blocks marked ▶ .
3. Select the desired record from the ARTY ASTRO SUN/STAR SUMMARY LIST.	3. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.
4. Observe the required fields, and enter the desired data.	

REQUIRED FIELDS	DATA RECORD	
ENTER NAME OBS STATION: ?	NAME OBS STATION:	APPROX AZIMUTH TO AZIMUTH MARK:
ENTER EAST OBS STATION: ?	EASTING OBS STATION:	
ENTER NORTH OBS STATION: ?	NORTHING OBS STATION:	
ENTER NAME AZIMUTH MARK: ?	NAME AZ MK:	
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID:	

REQUIRED FIELDS	DATA RECORD		
HEMISPHERE (N/S): ?	ENTER N OR S		
ENTER/RECORD STAR NO/NAME: ?	STAR NO: STAR NAME:		
ENTER GRID ZONE: ?	GRID ZONE:		
DAYLT SAVINGS TIME (Y/N): ?	ENTER Y OR N		
ENTER TIME ZONE LETTER: ?	TIME ZONE LETTER:		
USE TIME MODULE (Y/N): ?	ENTER Y OR N		
4TH OR 5TH ORDER: ?	ENTER 4 OR 5		
ENTER DIRECT READ TO AZMK: ?	▶ (D) RDG AZMK:		
ENTER/RECORD OBS DATE: ?	▶ DATE: dd mm yy	▶ DATE: dd mm yy	▶ DATE: dd mm yy
ENTER/RECORD OBS TIME: ?	▶ TIME: hh mm ss	▶ TIME: hh mm ss	▶ TIME: hh mm ss
ENTER OBS POSITION AT TIP: ? A = TRAILING EDGE B = LEADING EDGE C = CENTER	ENTER A, B, or C:	ENTER A, B, or C:	ENTER A, B, or C:
ENTER DIRECT HORZ READING AT TIP: ?	▶ HORZ RDG (D):	▶ HORZ RDG (D):	▶ HORZ RDG (D):
RECORD GRID AZ TO AZ MK:	GRID AZ:		

REMARKS:

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ALPHABETICAL STAR LIST

STAR NAME	NO	MAG	STAR NAME	NO	MAG	STAR NAME	NO	MAG
ACAMAR	12	3.4	CAPH	2	2.4	MIRFAK	14	1.9
ACHERNAR	9	0.5	CASTOR	28	1.5	MIZAR	46	2.4
ACRUX	42	1.0	DENEB	68	1.3	NUNKI	65	2.1
ADHARA	26	1.6	DENEBOLA	39	2.2	NU	69	3.7
ALDEBARAN	15	1.1	DIPHDA	6	2.2	PEACOCK	67	2.1
ALHENA	24	1.9	DSCHUBBA	56	2.5	PHECDA	40	2.5
ALIOTH	45	1.7	DUBHE	38	1.9	POLARIS	10	2.1
ALKAID	48	1.9	ELNATH	19	1.8	POLLUX	30	1.2
AL NA 'IR	71	2.2	ELTANIN	62	2.4	PROCYON	29	0.5
ALNILAM	20	1.7	ENIF	70	2.5	RASALHAGUE	51	2.1
ALNITAK	21	2.0	FORMALHAUT	72	1.3	REGULUS	35	1.3
ALPHARD	35	2.2	GACRUX	43	1.6	RIGEL	16	0.3
ALPHECCA	55	2.3	GAMMA CASSIOPEIAE	7	1.6-2.8	RIGIL KENTAURUS	52	0.1
ALPHERATZ	1	2.1	GAMMA VELORUM	31	1.9	RUCHBUH	8	2.8
ALTAIR	66	0.9	GIENAH	41	2.8	SABIK	59	2.6
ANKAA	4	2.4	HADAR	49	0.8	SCAULA	60	1.7
ANTARES	57	1.2	HAMAL	11	2.2	SCHEDAR	5	2.3
ARCTURUS	51	0.2	KAUS AUSTRALIS	63	1.9	SIRIUS	25	-1.6
ATRIA	58	1.9	KOCHAB	54	2.2	SPICA	47	1.2
AVIOR	32	1.7	MARKAB	73	2.6	SUHAIL	33	2.2
BELLATRIX	18	1.7	MENKAR	13	2.8	VEGA	64	0.1
BETA HYDRUS	3	2.9	MENKENT	50	2.3	WEZEN	27	2.0
BETELGEUSE	22	0.1	MEPAK	37	2.4	ZEBENELGENUBI	53	2.9
CANOPUS	23	-0.9	MISPLACIDUS	34	1.8			
CAPELLA	17	0.2	MIMOSA	44	1.5			

REMARKS:

COMPUTATION – CONVERSION UTM TO GEO COORDINATE, GEO TO UTM COORDINATE, ZONE-TO-ZONE TRANSFORMATION (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select UTM TO GEO COORD (option A), GEO TO UTM COORD (option B), or ZONE TO ZONE (option C) from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD		
	UTM TO GEO	GEO TO UTM	ZONE TO ZONE
ENTER STATION NAME: ?	STATION NAME:	STATION NAME:	STATION NAME:
ENTER SPHEROID CODE/NAME: ? 1 = CLARKE 1866 2 = INTERNATIONAL 3 = CLARKE 1880 4 = EVEREST 5 = BESSEL 6 = AUSTRALIAN 7 = WGS-72 8 = GRS-80	SPHEROID (NAME/NUMBER):	SPHEROID (NAME/NUMBER):	SPHEROID (NAME/NUMBER):
ENTER STARTING GRID ZONE: ?			STARTING GRID ZONE:
ENTER EASTING: ?	EASTING:		EASTING:
ENTER NORTHING: ?	NORTHING:		NORTHING:
ENTER LATITUDE: ?		LATITUDE: ° ' " N S	
ENTER LONGITUDE: ?		LONGITUDE: ° ' " E W	
HEMISPHERE (N/S): ?	ENTER N OR S		ENTER N OR S
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:	
ENTER AZIMUTH: ?			AZIMUTH:
ENTER ENDING GRID ZONE: ?			ENDING GRID ZONE:

REQUIRED FIELDS	DATA RECORD		
ENTER EASTING: ?		EASTING:	EASTING:
ENTER NORTHING: ?		NORTHING:	NORTHING:
ENTER AZIMUTH: ?			AZIMUTH:
ENTER LATITUDE: ?	LATITUDE: ° ' " N S		
ENTER LONGITUDE: ?	LONGITUDE: ° ' " E W		

REMARKS:

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COMPUTATION—DATUM-TO-DATUM COORDINATE TRANSFORMATION
LISTED DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select UTM TO UTM DATUM (option D), UTM TO GEO DATUM (option E), GEO TO UTM DATUM (option F), or GEO TO GEO DATUM (option G) from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER STATION NAME: ?	STATION NAME:	STATION NAME:
ENTER FROM UTM/GEO DATUM: ?	FROM DATUM:	FROM DATUM:
ENTER EASTING: ?	EASTING:	EASTING:
ENTER NORTHING: ?	NORTHING:	NORTHING:
ENTER LATITUDE: ?	LATITUDE: ° ' " N S	LATITUDE: ° ' " N S
ENTER LONGITUDE: ?	LONGITUDE: ° ' " E W	LONGITUDE: ° ' " E W
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:
ENTER FROM UTM/GEO DATUM: ?	TO DATUM:	TO DATUM:
ZONE TO ZONE:	ENTER Y OR N	ENTER Y OR N
ENTER ENDING GRID ZONE: ?	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	
RECORD EASTING: ?	EASTING:	EASTING:
RECORD NORTHING: ?	NORTHING:	NORTHING:
RECORD LATITUDE: ?	LATITUDE: ° ' " N S	LATITUDE: ° ' " N S
RECORD LONGITUDE: ?	LONGITUDE: ° ' " E W	LONGITUDE: ° ' " E W
RECORD GRID ZONE: ?	GRID ZONE:	GRID ZONE:
RECORD ELLIPSOID: ?	ELLIPSOID:	ELLIPSOID:

REMARKS:

KRASSOVSKY DATUMS			BESSEL DATUMS		
DATUM NAME	CODE	DISPLAYED NAME	DATUM NAME	CODE	DISPLAYED NAME
Afgooye	1	AFGOOYE	Potsdam	1	POTSDAM
Herat North	2	HERAT NORTH	Tokyo	2	TOKYO
Peking 1954	3	PEKING 1954			
Pulkovo 1942	4	PULKOVO 1942			

UTM DATUMS

DATUM NAME	CODE	DISPLAYED NAME	DATUM NAME	CODE	DISPLAYED NAME
Adindan[1]	1	ADINDAN	Massawa	51	MASSAWA
Afgooye	2	AFG	Merchich	52	MERCHICH
Ain el Abd 1970	3	AIN EL ABD 1970	Midway Astro 1961	53	MIDWAY AST 1961
Anna 1 Astro 1965	4	ANNA 1 AST 1965	Minna	54	MINNA
Arc 1950	5	ARC 1950	Nahrwan 1 (Masirah Island [Oman])	55	NAHRWAN 1 OMAN
Arc 1960	6	ARC 1960	Nahrwan 2 (United Arab Emirates)	56	NAHRWAN 2 UAE
Ascension Island 1958	7	ASCENSION IL 1958	Nahrwan 3 (Saudi Arabia)	57	NAHRWAN 3 SAUDI
Astro Beacon E	8	ASTRO BEACON E	Schwarzech (Namibia)	58	NAMIBIA
Astro Tern Island (FRIG) 1961[2]	9	AST B4 SOR ATOL	Naparima, BWI	59	NAPARIMA BWI
Astro DOS[2]	10	ASTRO POS 71 4	North American 1927 (Continental United States)	60	NAD 27 CONUS
Astronomic Station 1952	11	ASTRO STA 52	North American 1927 (Alaska)	61	NAD 27 ALASKA
Australian Geodetic 1966	12	AUSTRL GEO 1966	North American 1927 (Bahamas, excluding San Salvador Island)	62	NAD 27 BAHAMAS
Australian Geodetic 1984	13	AUSTRL GEO 1984	North American 1927 (San Salvador Island)	63	NAD 27 SALVADOR
Bellevue (IGN)	14	BELLEVUE IGN	North American 1927 (Canada)	64	NAD 27 CANADA
Bermuda 1957	15	BERMUDA 1957	North American 1927 (Canal Zone)	65	NAD 27 CANAL ZO
Bogota Observatory	16	BOGOTA OBSERVY	North American 1927 (Caribbean)	66	NAD 27 CARIBEAN
Compo Inchauspe	17	COMPO INCHAUSPE	North American 1927 (Central America)	67	NAD 27 CENT AM
Canton Astro 1966[2]	18	CANTON IL 1966	North American 1927 (Cuba)	68	NAD 27 CUBA
Cape	19	CAPE	North American 1927 (Greenland)	69	NAD 27 GREENLD
Cape Canaveral	20	CAPE CANAVERAL	North American 1927 (Mexico)	70	NAD 27 MEXICO
Carthage	21	CARTHAGE	North American 1983	71	NORTH AMER 1983
Chatham 1971	22	CHATHAM 1971	Meteorologico 1983[2]	72	OBSERVATOR 1966
Chua Astro	23	CHUA ASTRO	Old Egyptian 1907[2]	73	OLD EGYPT 1930
Corrego Alegre	24	CORREGO ALEGRE	Old Hawaiian	74	OLD HAWAIIAN
Djakarta (Batavia)	25	DJAKARTA BATAV	Oman	75	OMAN
DOS 1968	26	DOS 1968	Ordnance Survey of Great Britain 1936	76	ORD SV GR BR 36
Easter Island 1967	27	EASTER IL 1967	Pico de Las Nieves	77	PICO DE LAS NVS
European 1950	28	EUROPEAN 1950	Pitcairn Astro 1967	78	PITCRN AST 1967
European 1979	29	EUROPEAN 1979	Provisional South Chilean 1963 or Hito XVIII 1963[2]	79	PROV S CHIL 63
Gandajika Base	30	GANDAJIKA BASE	Provisional South American 1956	80	PROV S AMER 56
Geodetic Datum 1949	31	GEO DATUM 1949	Puerto Rico	81	PUERTO RICO
Guam 1963	32	GUAM 1963	Qatar National	82	QATAR NATIONAL
Gux 1 Astro	33	GUX 1 ASTRO	Qornoq	83	QORNOQ
Hjorsey 1955	34	HJORSEY 1955	Rome 1940	84	ROME 1940
Hong Kong 1963	35	HONG KONG 1963	Sao Braz[2]	85	SANTA BRAZ
Indian 1 (Thailand, Vietnam)	36	IND 1 THAI VIET	Santa (DOS)	86	SANTA (DOS)
Indian 2 (Bangladesh, India, Nepal)	37	INDIAN 2	Sapper Hill 1943	87	SAPPR HILL 1943
Ireland 1965	38	IRELAND 1965	South American 1969	88	SOUTH AMERICAN
ISTS 073 Astro 1969	39	IST 73 AST 1969	South Asia	89	SOUTH ASIA
Johnston Island 1961	40	JOHNSTON IL 61	Porto Santo 1936[2]	90	SOUTHEAST BASE
Kandawala	41	KANDAWALA	Graciosa Base SW End 1948[2]	91	SOUTHWEAST BASE
Kerguelen Island	42	KERGUELEN IL	Timbalai 1948	92	TIMBALAI 1948
Kertau 1948	43	KERTAU 1948	Tokyo	93	TOKYO
Reunion[2]	44	LA REUNION	Tristan Astro 1968	94	TRISTN AST 1968
L. C. 5 ASTRO	45	L. C. 5 ASTRO	Viti Levu 1916	95	VITI LEVU 1916
Liberia 1964	46	LIBERIA 1964	Wake-Eniwetok 1960	96	WK ENIWETK 1960
Luzon 1 (Philippines)	47	LUZON 1 PHILIP	World Geodetic System 1972	97	WORLD GEO 1972
Luzon 2 (Mindanao Island)	48	LUZON 2 MINDAN	World Geodetic System 1984	98	WORLD GEO 1984
Mahe 1971	49	MAHE 1971	Zanderij	99	ZANDERIJ
Selvagem Grande 1938[2]	50	MARCO ASTRO			

[1] The transformation parameters for the Adindan datum have been updated by the Defense Mapping Agency. Use Program 16 (user-defined) with the following transformation parameters:

Semimajor Axis	Flattening	X-Shift	Y-Shift	Z-Shift
6378249.145	293.465	-166	-15	204

[2] Datum names were incorrect in DMA Technical Report (TR) 83501, 2 Dec 87, but are correct above. The FED-displayed names for these datums differ from the correct name.

COMPUTATION—DATUM–TO–DATUM COORDINATE TRANSFORMATION
GAUSS KRUGER (GK) DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select KRASSOVSKY UTM DATUM (option H) UTM TO KRASSOVSKY DATUM (option I), BESSEL TO UTM DATUM (option J), or UTM TO BESSEL DATUM (option K) from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the **C** key to calculate.

REQUIRED FIELDS	DATA RECORD	
ENTER STATION NAME: ?	STATION NAME:	STATION NAME:
ENTER FROM KRASS/UTM/BESSEL DATUM: ?	FROM DATUM:	FROM DATUM:
ENTER GK/UTM EASTING: ?	EASTING:	EASTING:
ENTER GK/UTM NORTHING: ?	NORTHING:	NORTHING:
ENTER GK/UTM GRID ZONE: ?	GRID ZONE:	GRID ZONE:
ENTER TO UTM/KRASS/BESSEL DATUM: ?	TO DATUM:	TO DATUM:

REQUIRED FIELDS	DATA RECORD	
RECORD UTM/GK EASTING:	EASTING:	EASTING:
RECORD UTM/GK NORTHING:	NORTHING:	NORTHING:
RECORD UTM/GK GRID ZONE:	GRID ZONE:	GRID ZONE:
RECORD ELLIPSOID:	ELLIPSOID:	ELLIPSOID:

REQUIRED FIELDS	DATA RECORD	
ENTER STATION NAME: ?	STATION NAME:	STATION NAME:
ENTER FROM KRASS/UTM/BESSEL DATUM: ?	FROM DATUM:	FROM DATUM:
ENTER GK/UTM EASTING: ?	EASTING:	EASTING:
ENTER GK/UTM NORTHING: ?	NORTHING:	NORTHING:
ENTER GK/UTM GRID ZONE: ?	GRID ZONE:	GRID ZONE:
ENTER TO UTM/KRASS/BESSEL DATUM: ?	TO DATUM:	TO DATUM:

REQUIRED FIELDS	DATA RECORD	
RECORD UTM/GK EASTING:	EASTING:	EASTING:
RECORD UTM/GK NORTHING:	NORTHING:	NORTHING:
RECORD UTM/GK GRID ZONE:	GRID ZONE:	GRID ZONE:
RECORD ELLIPSOID:	ELLIPSOID:	ELLIPSOID:

REMARKS:

KRASSOVSKY DATUMS			BESSEL DATUMS		
DATUM NAME	CODE	DISPLAYED NAME	DATUM NAME	CODE	DISPLAYED NAME
Afgooye	1	AFGOOYE	Potsdam	1	POTSDAM
Herat North	2	HERAT NORTH	Tokyo	2	TOKYO
Peking 1954	3	PEKING 1954			
Pulkovo 1942	4	PULKOVO 1942			

UTM DATUMS					
Adindan[1]	1	ADINDAN	Massawa	51	MASSAWA
Afgooye	2	AFG	Merchich	52	MERCHICH
Ain el Abd 1970	3	AIN EL ABD 1970	Midway Astro 1961	53	MIDWAY AST 1961
Anna 1 Astro 1965	4	ANNA 1 AST 1965	Minna	54	MINNA
Arc 1950	5	ARC 1950	Nahrwan 1 (Masirah Island [Oman])	55	NAHRWAN 1 OMAN
Arc 1960	6	ARC 1960	Nahrwan 2 (United Arab Emirates)	56	NAHRWAN 2 UAE
Ascension Island 1958	7	ASCENSION IL 1958	Nahrwan 3 (Saudi Arabia)	57	NAHRWAN 3 SAUDI
Astro Beacon E	8	ASTRO BEACON E	Schwarzech (Namibia)	58	NAMIBIA
Astro Tern Island (FRIG) 1961[2]	9	AST B4 SOR ATOL	Naparima, BWI	59	NAPARIMA BWI
Astro DOS[2]	10	ASTRO POS 71 4	North American 1927 (Continental United States)	60	NAD 27 CONUS
Astronomic Station 1952	11	ASTRO STA 52	North American 1927 (Alaska)	61	NAD 27 ALASKA
Australian Geodetic 1966	12	AUSTRL GEO 1966	North American 1927 (Bahamas, excluding San Salvador Island)	62	NAD 27 BAHAMAS
Australian Geodetic 1984	13	AUSTRL GEO 1984	North American 1927 (San Salvador Island)	63	NAD 27 SALVADOR
Bellevue (IGN)	14	BELLEVUE IGN	North American 1927 (Canada)	64	NAD 27 CANADA
Bermuda 1957	15	BERMUDA 1957	North American 1927 (Canal Zone)	65	NAD 27 CANAL ZO
Bogota Observatory	16	BOGOTA OBSERVY	North American 1927 (Caribbean)	66	NAD 27 CARIBEAN
Compo Inchauspe	17	COMPO INCHAUSPE	North American 1927 (Central America)	67	NAD 27 CENT AM
Canton Astro 1966[2]	18	CANTON IL 1966	North American 1927 (Cuba)	68	NAD 27 CUBA
Cape	19	CAPE	North American 1927 (Greenland)	69	NAD 27 GREENLD
Cape Canaveral	20	CAPE CANAVERAL	North American 1927 (Mexico)	70	NAD 27 MEXICO
Carthage	21	CARTHAGE	North American 1983	71	NORTH AMER 1983
Chatham 1971	22	CHATHAM 1971	Meteorologico 1983[2]	72	OBSERVATOR 1966
Chua Astro	23	CHUA ASTRO	Old Egyptian 1907[2]	73	OLD EGYPT 1930
Corrego Alegre	24	CORREGO ALEGRE	Old Hawaiian	74	OLD HAWAIIAN
Djakarta (Batavia)	25	DJAKARTA BATAV	Oman	75	OMAN
DOS 1968	26	DOS 1968	Ordnance Survey of Great Britain 1936	76	ORD SV GR BR 36
Easter Island 1967	27	EASTER IL 1967	Pico de Las Nieves	77	PICO DE LAS NVS
European 1950	28	EUROPEAN 1950	Pitcairn Astro 1967	78	PITCRN AST 1967
European 1979	29	EUROPEAN 1979	Provisional South Chilean 1963 or Hito XVIII 1963[2]	79	PROV S CHIL 63
Gandajika Base	30	GANDAJIKA BASE	Provisional South American 1956	80	PROV S AMER 56
Geodetic Datum 1949	31	GEO DATUM 1949	Puerto Rico	81	PUERTO RICO
Guam 1963	32	GUAM 1963	Qatar National	82	QATAR NATIONAL
Gux 1 Astro	33	GUX 1 ASTRO	Qornoq	83	QORNOQ
Hjorsey 1955	34	HJORSEY 1955	Rome 1940	84	ROME 1940
Hong Kong 1963	35	HONG KONG 1963	Sao Braz[2]	85	SANTA BRAZ
Indian 1 (Thailand, Vietnam)	36	IND 1 THAI VIET	Santa (DOS)	86	SANTA (DOS)
Indian 2 (Bangladesh, India, Nepal)	37	INDIAN 2	Sapper Hill 1943	87	SAPPR HILL 1943
Ireland 1965	38	IRELAND 1965	South American 1969	88	SOUTH AMERICAN
ISTS 073 Astro 1969	39	IST 73 AST 1969	South Asia	89	SOUTH ASIA
Johnston Island 1961	40	JOHNSTON IL 61	Porto Santo 1936[2]	90	SOUTHEAST BASE
Kandawala	41	KANDAWALA	Graciosa Base SW End 1948[2]	91	SOUTHWEAST BASE
Kerguelen Island	42	KERGUELEN IL	Timbalai 1948	92	TIMBALAI 1948
Kertau 1948	43	KERTAU 1948	Tokyo	93	TOKYO
Reunion[2]	44	LA REUNION	Tristan Astro 1968	94	TRISTN AST 1968
L. C. 5 ASTRO	45	L. C. 5 ASTRO	Viti Levu 1916	95	VITI LEVU 1916
Liberia 1964	46	LIBERIA 1964	Wake-Eniwetok 1960	96	WK ENIWETK 1960
Luzon 1 (Philippines)	47	LUZON 1 PHILIP	World Geodetic System 1972	97	WORLD GEO 1972
Luzon 2 (Mindanao Island)	48	LUZON 2 MINDAN	World Geodetic System 1984	98	WORLD GEO 1984
Mahe 1971	49	MAHE 1971	Zanderij	99	ZANDERIJ
Selvagem Grande 1938[2]	50	MARCO ASTRO			

[1] The transformation parameters for the Adindan datum have been updated by the Defense Mapping Agency. Use Program 16 (user-defined) with the following transformation parameters:

Semimajor Axis	Flattening	X-Shift	Y-Shift	Z-Shift
6378249.145	293.465	-166	-15	204

[2] Datum names were incorrect in DMA Technical Report (TR) 83501, 2 Dec 87, but are correct above. The FED-displayed names for these datums differ from the correct name.

COMPUTATION—DATUM-TO-DATUM COORDINATE TRANSFORMATION
USER-DEFINED DATUMS (FED MSR)

For use of this form, see FM 6-2; the proponent agency is TRADOC.

COMPUTER:	NOTEBOOK REFERENCE:	DATE:
CHECKER:	AREA:	SHEET OF SHEETS

INSTRUCTIONS	NOTES
1. Select TRANSFORMATIONS (option C) from the MODE MENU. 2. Select USER DEF TO USER DEF DATUM (option L), USER DEF TO LISTED DATUM (option M), or LISTED TO USER DEF DATUM from the TRANSFORMATIONS MENU. 3. Select the desired record from the displayed SUMMARY LIST. 4. Observe the required fields, and enter the desired data.	1. Press ENTER to display the window of legal entries. 2. Remove window of legal entries by pressing ENTER before pressing the C key to calculate.

REQUIRED FIELDS	DATA RECORD		
	USER DEF TO USER DEF	USER DEF TO LISTED	LISTED TO USER DEF
ENTER STATION NAME: ?	STATION NAME:	STATION NAME:	STATION NAME:
ENTER FROM LISTED DATUM: ?			FROM DATUM:
ENTER X SHIFT USER DEF1: ?	X SHIFT:	X SHIFT:	
ENTER Y SHIFT USER DEF1: ?	Y SHIFT:	Y SHIFT:	
ENTER Z SHIFT USER DEF1: ?	Z SHIFT:	Z SHIFT:	
ENTER SEMI-MAJOR USER DEF1: ?	SEMI-MAJOR AXIS:	SEMI-MAJOR AXIS:	
ENTER FLAT/MINOR USER DEF1: ?	ENTER F OR M	ENTER F OR M	
ENTER FLATTENING USER DEF1: ?	FLATTENING:	FLATTENING:	
ENTER SEMI-MINOR USER DEF1: ?	SEMI-MINOR AXIS:	SEMI-MINOR AXIS:	
ENTER EASTING: ?	EASTING:	EASTING:	EASTING:
ENTER NORTHING: ?	NORTHING:	NORTHING:	NORTHING:
ENTER GRID ZONE: ?	GRID ZONE:	GRID ZONE:	GRID ZONE:
ENTER TO LISTED DATUM: ?		TO DATUM:	
ENTER X SHIFT USER DEF2: ?	X SHIFT:		X SHIFT:
ENTER Y SHIFT USER DEF2: ?	Y SHIFT:		Y SHIFT:
ENTER Z SHIFT USER DEF2: ?	Z SHIFT:		Z SHIFT:
ENTER SEMI-MAJOR USER DEF2: ?	SEMI-MAJOR AXIS:		SEMI-MAJOR AXIS:
ENTER FLAT/MINOR USER DEF2: ?	ENTER F OR M		ENTER F OR M
ENTER FLATTENING USER DEF2: ?	FLATTENING:		FLATTENING:
ENTER SEMI-MINOR USER DEF2: ?	SEMI-MINOR AXIS:		SEMI-MINOR AXIS:
ZONE TO ZONE: ?	ENTER Y OR N	ENTER Y OR N	ENTER Y OR N
ENTER ENDING GRID ZONE: ?	GRID ZONE:	GRID ZONE:	GRID ZONE:

REQUIRED FIELDS	DATA RECORD	REMARKS:
RECORD EASTING: ?	EASTING:	
RECORD NORTHING: ?	NORTHING:	
RECORD GRID ZONE: ?	GRID ZONE:	
RECORD ELLIPSOID: ?	ELLIPSOID:	

DA FORM 7371-R, SEP 96

KRASSOVSKY DATUMS			BESSEL DATUMS		
DATUM NAME	CODE	DISPLAYED NAME	DATUM NAME	CODE	DISPLAYED NAME
Afgooye	1	AFGOOYE	Potsdam	1	POTSDAM
Herat North	2	HERAT NORTH	Tokyo	2	TOKYO
Peking 1954	3	PEKING 1954			
Pulkovo 1942	4	PULKOVO 1942			
UTM DATUMS					
Adindan[1]	1	ADINDAN	Massawa	51	MASSAWA
Afgooye	2	AFG	Merchich	52	MERCHICH
Ain el Abd 1970	3	AIN EL ABD 1970	Midway Astro 1961	53	MIDWAY AST 1961
Anna 1 Astro 1965	4	ANNA 1 AST 1965	Minna	54	MINNA
Arc 1950	5	ARC 1950	Nahrwan 1 (Masirah Island [Oman])	55	NAHRWAN 1 OMAN
Arc 1960	6	ARC 1960	Nahrwan 2 (United Arab Emirates)	56	NAHRWAN 2 UAE
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Astro Beacon E	8	ASTRO BEACON E	Schwarzech (Namibia)	58	NAMIBIA
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Indian 2 (Bangladesh, India, Nepal)	37	INDIAN 2	Sapper Hill 1943	87	SAPPR HILL 1943
Ireland 1965	38	IRELAND 1965	South American 1969	88	SOUTH AMERICAN
ISTS 073 Astro 1969	39	IST 73 AST 1969	South Asia	89	SOUTH ASIA
Johnston Island 1961	40	JOHNSTON IL 61	Porto Santo 1936[2]	90	SOUTHEAST BASE
Kandawala	41	KANDAWALA	Graciosa Base SW End 1948[2]	91	SOUTHWEAST BASE
Kerguelen Island	42	KERGUELEN IL	Timbalai 1948	92	TIMBALAI 1948
Kertau 1948	43	KERTAU 1948	Tokyo	93	TOKYO
Reunion[2]	44	LA REUNION	Tristan Astro 1968	94	TRISTN AST 1968
L. C. 5 ASTRO	45	L. C. 5 ASTRO	Viti Levu 1916	95	VITI LEVU 1916
Liberia 1964	46	LIBERIA 1964	Wake-Eniwetok 1960	96	WK ENIWETK 1960
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Luzon 2 (Mindanao Island)	48	LUZON 2 MINDAN	World Geodetic System 1984	98	WORLD GEO 1984
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Selvagem Grande 1938[2]	50	MARCO ASTRO			

[1] The transformation parameters for the Adindan datum have been updated by the Defense Mapping Agency. Use Program 16 (user-defined) with the following transformation parameters:

Semimajor Axis	Flattening	X-Shift	Y-Shift	Z-Shift
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[2] Datum names were incorrect in DMA Technical Report (TR) 83501, 2 Dec 87, but are correct above. The FED-displayed names for these datums differ from the correct name.

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By Order of the Secretary of the Army:

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General, United States Army
Chief of Staff

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MILTON H. HAMILTON
Administrative Assistant to the
Secretary of the Army
04922

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