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MMM 22

A Rumination On Wars Ahead

Remarks to the Military Testing Association
Washington, D.C.

26 October 1981

Lt. Gen. P. F. Gorman, U.S. Army

Slide 1

A RUMINATION ON WARS AHEAD

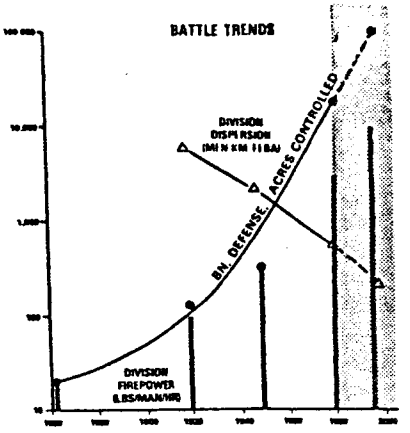
I will be talking forecasting with you, but let me make it clear that mine is not a Schweitzerian prediction of inevitable drift towards war, but rather the sort of concern that all of us in the Pentagon have to direct toward the future in order to do our job. Bob Schweitzer aside, I would have you note that Jimmy "the Greek" Snyder quotes odds of ten to one that there will be a war involving our forces within the coming decade. As the present Secretary of Defense has stated, it is the business of his Department to prepare for future wars. Wars and rumors of war are problems with which we must seriously contend. Let me begin by reading you a quotation from the Defense Guidance, which as some of you may know, is a document wherein the Secretary of Defense instructs the members of his own staff and the Joint Chiefs of Staff on how he wants them to prepare for the future. The time frame for planning in the current draft Defense Guidance is the fiscal years 1984 through 1988. Thereby you can see we are already conceptually far into the future. I will quote from a section of the guidance which deals with our using to advantage those elements of the American system wherein we might be able to enjoy some edge over the competition:

> "An inherent advantage of our system is the ability to combine managerial skills and technology to solve difficult problems. Getting serious about competing with the Soviets will require that the U.S. use its advantages to develop an overall strategy with several areas of primary emphasis: (1) developing first-rate weapons and eliminating some of the reliabilty problems we have recently experienced; (2) expanding the competition into other areas where the Soviets find it difficult to compete; (3) designing innovative forces and operational tactics and procedures that act against the Soviet control system and frustrate, disrupt, and defeat Soviet attempts to achieve political/military objectives; and (4) developing cost imposing strategies whose basic aim is to obsolesce past Soviet investments."

Now, that guidance is a tall order. The purpose of my discussion is to present considerations which someone in your line of work, as well as mine, might bring to bear upon an attempt to comply, either from '84 to '88, or in

the years beyond. Let me start by laying out for you some of the trends in warfare of which I am aware, and which you may want to take into account.

Slide 2



First of all, the long sweeping line ascending from the year 1860, the time of our Civil War, to the 1990's in the upper right-hand side of the chart traces the amount of area that a battalion--a group of 600-800 men--was expected to control given the firepower and mobility means available to them at any given point in time. The fundamental reason for having military forces at all is to control land and people, and the trends are all in the direction of doing more militarily with fewer soldiers. As you can see, I have extrapolated, like most futurists, control trends beyond the present. I would also call to your attention that, like most futurists, I have used a logarithmic scale on the ordinate. The bars graph firepower, for which the measure of merit is the pounds of projectiles that a division, a large assemblage of battalions, could hurl at an enemy in the course of an hour, all guns firing maximum rate, for each soldier engaged. You will note that the bar graph heights do not keep pace with the extention of the area of control, and that lack of direct correlation is a function of both the superior mobility means that we have made available to our land warfare organizations--large quantities of tracked vehicles, and helicopters, plus advanced communications--as well as the efficiency of modern ordnance--one need not project as much ordnance in terms of poundage for greater lethality, given more efficient conventional munitions, and the so-called "smart" weaponry in the force. Finally, on the slide, slashing down diagonally over the trends just described, is a measure that I have called "division dispersion." Here I have taken an amount of the forward edge of the battle area (FEBA) that the division is responsible for in normal disposition, and computed a measure of men per kilometer of FEBA. And as you can see, those trends plunge linearly downward, and my projections suggest to you that they will keep going down through the 1990's. What that line tells you is that we have multiplied the ability of each soldier on the battlefield, or that the density of men on the battlefield will be going down, and going down dramatically, continuing the trends that we have observed as technology has been applied to battle in recent years. Each soldier in battle will count for more toward accomplishing the basic mission of control of the earth's surface.

Slide 3

NOW	FUTURE
• LARGE SURFACE COMBATANTS • RINGS AROUND-CORE DEPLOYMENTS	
• LARGE FIXED AIRFIELDS • INDUSTRIAL-MODEL OPERATIONS	• DISTRIBUTED FORCE
• LARGE ARMOR/MECHANIZED MASS MANEUVER • CONVEYOR-BELT LOGISTICS	

I believe that it is possible, looking into the future, to conclude that, almost certainly, a technolgically advanced combatant in future warfare will be able to see all elements of an opposing forces in real time, and will have at his disposal firepower means for reaching out to strike throughout the depth of the opponent's war-waging apparatus from his theater forces all the way back to his strategic reserves. Some naval officers have found it reasonable to say, vis-a-vis naval warfare, that it will be difficult if not impossible to steam around the seas with forces centered on a large-decked carrier, with protective rings of specialized air and submarine defense ships around that carrier. Some air officers have found it possible to say that we will have to find alternatives to the operation of air forces from large fixed airfields, whereon aircraft are processed for high sortie generation rates on something like an assembly line basis. I can assert for land warfare that the day will soon be gone when massed formations of armored vehicles will be able to swarm over the surface of the earth, trailing behind elaborate logistic tails. Instead we are going to have to move toward something like "distributed force," meaning that in order to provide protection we will have to disperse more broadly and thoroughly than ever before, and thus confuse the enemy as to which elements of the target array before them are particularly significant as threat. Our tactical dispositions will have to confront our foe with a large complex of target elements, each of which is potentially able to deliver punishing firepower, and each element of which could be capable of developing the intelligence requisite to the accurate delivery of that firepower.

Now, there are enormous impediments both technological and cultural to achieving such a capability. But I am convinced that that nation who is first able to achieve the desiderata that I have sketched will exert an enormous superiority over potential adversaries, and I suggest that the excerpt of the Defense Guidance that I just read you is quite right: it would be important for the United States, and any other nations of the free world who wish to assist in the competition with the Soviet Union, to bend their efforts to field first-rate weapons, and invent new tactics and techniques for using them.

Slide 4

LAND WARFARE POST-1990

- CONFLICT MORE ANALOGOUS TO SOCCER THAN FOOTBALL
  - CONTINUOUS ACTION VS "DOWNS"
  - OFFENSE AND DEFENSE VS SPECIALISTS
  - FLUID CONDITIONS VS FIXED PLAYS
- MAJOR CONCENTRATION OF TROOPS AND EQUIPMENT MAY NOT BE PRACTICAL
  - TACTICAL NUCLEAR WEAPONS AND WIDE-AREA MUNITIONS
  - SURFACE-TO-SURFACE AND AIR-TO-SURFACE MISSILES
  - PRECISION EMITTER LOCATION
- NEW TRADE-OFFS AMONG MOBILITY, AGILITY, AND FIREPOWER

Here is a description of future land warfare which I have drawn from a presentation made to the Secretary of Defense just this past summer by the Defense Science Board, which as many of you may know is a group of prestigious scientists who provide advice to the Secretary on problems of particular significance. This summer he asked several DSB Panels to look into the future of warfare, and to advise him what technologies might be relevant to the Department of Defense as it sought to implement the guidance that I read at the outset of my remarks. Here you can see the notion of "distributed force" in an athletic analog, a way of describing warfare which is always more comfortable for Americans than most.

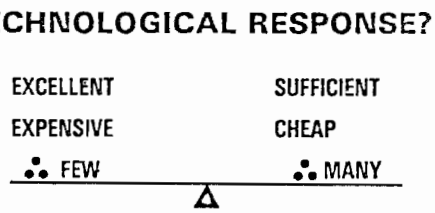
Slide 5

- THE NEED TO CONDUCT SUSTAINED OPERATIONS (DAYS NOT HOURS)
- THE NEED TO LOCATE AND TRACK MAJOR ENEMY FORCES CONTINUOUSLY
- THE NEED FOR REAL-TIME INFORMATION MANAGEMENT
- THE NEED TO COUNTER ENEMY TARGET ACQUISITION SYSTEMS
- THE NEED TO MORE CLOSELY INTEGRATE THE "EYEBALL AND THE TRIGGER"
- THE NEED FOR SECURE, JAM-RESISTANT, FAIL-SOFT, MOBILE COMMUNICATIONS
- THE NEED FOR DISPERSED, SMALL UNIT CAPABILITY
- THE NEED FOR "TRANSPARENT" COMPLEXITY
- THE NEED FOR EQUIPMENT AVAILABILITY AS WELL AS RELIABILITY
- THE NEED FOR SYSTEMS THAT CAN OPERATE IN EXTREME ENVIRONMENTS (CB/RADIATION/TEMP.)

But such amorphous warfare will generate a series of new needs or requirements, of which the Defense Science Board cited these. In other words, these needs are problems that technology has to solve in order for us to have the capability to compete in land warfare as just described. The red signals on the right indicate needs which I submit are as much sociological as they are technological, as much a demand for cultural evolution as they are matters for advanced science and materials. And it is to the needs for cultural leaps that I will eventually direct our attention here today.

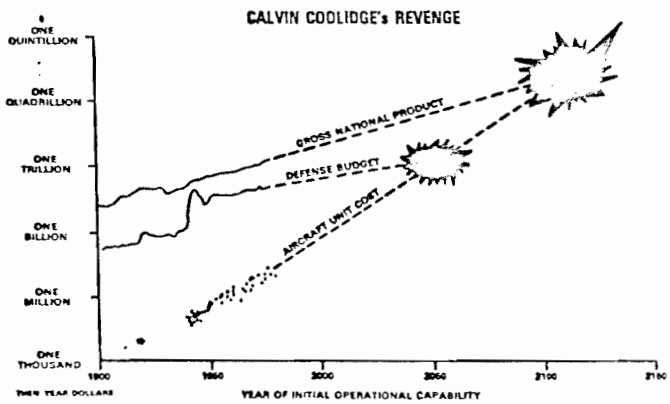
But before I do so, let me quickly walk you through some of the technological responses to these needs that the DSB Panel cited for the Secretrary of Defense.

Slide 6



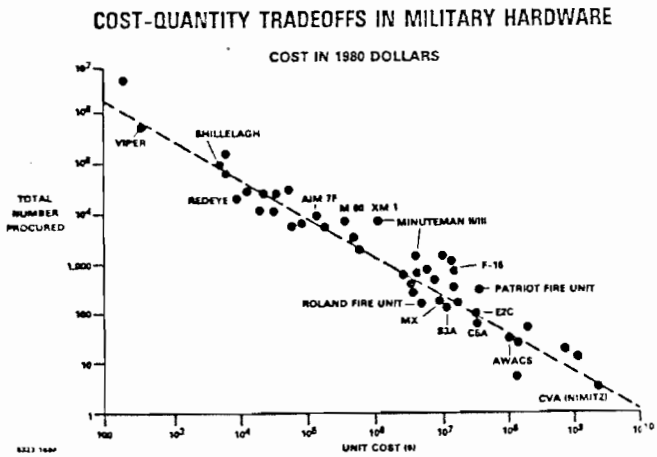
In the first place, they pointed out the United States faces a very difficult choice, as indicated here: Shall we, as many advocate, settle for less complicated, less technologically advanced weapon systems, systems of only sufficient capability, and, since their price will be lower, thereby assure that we can purchase more weapons? Or shall we rather take the ocurse advocated by the Defense Guidance and reach for excellence, knowing full well that, if we do, we thereby expose ourselves to high expense, and concomitantly have to settle for relatively few of those weapon systems? All pertinent trends are depressing:

Slide 7



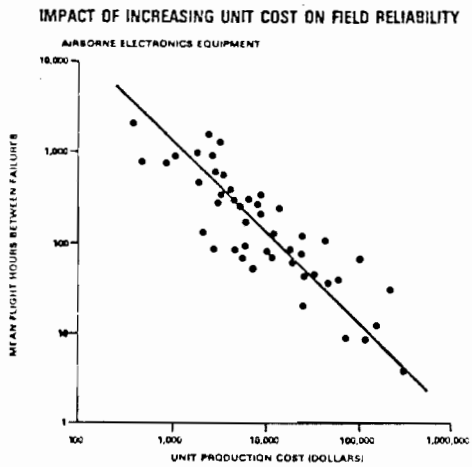
Here is a slide used by Norman Augustine, Chairman of the Defense Science Board. He calls it "Calvin Coolidge's Revenge" because President Coolidge, when presented military budget for 1928, is reported to have said, anent an item of some $25,000 for the purchase of a squadron of airplanes, "Why can't we buy just one airplane and let the aviators take turns?" Mr. Augustine's chart makes it evident that by the year 2054 the entire Defense Budget of the United States will be able to purchase just one airplane, so we will have to let the Navy use it 3-1/2 days each week and the Air Force the remainder. And, of course, by the year 2100, it predicts that the entire gross national product of the United States will buy just one airplane, and we will have unification of the services at last.

Slide 8



Not only are cost trends up, but as the systems become more expensive, the trends are to buy fewer of them: whether it's carriers of the NIMITZ class, down on the bottom right, the AWACS, or various advanced air defense systems, the more expensive the system is, the fewer that you will see in inventory. Hence, we are indeed very much in a numbers quandry.

Slide 9



Moreover, as the complexity and costs of systems increase, reliability seems to decrease. Here is a plot Mr. Augustine has put together comparing costs of various items of recent aviation electronic equipment to hours between failure. This chart, he says, illustrates that if you are willing to pay enough for a given avionic apparatus, you can guarantee that it won't work at all.

Slide 10

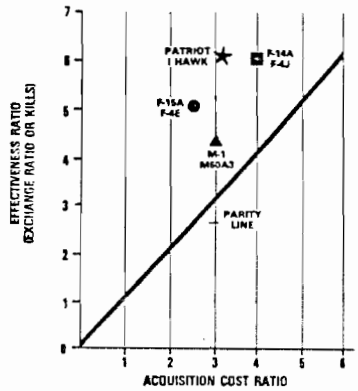
WE FIND NO GENERAL EVIDENCE THAT HIGH PERFORMANCE LEADS AUTOMATICALLY TO LOW READINESS

DEFENSE SCIENCE BOARD SUMMER STUDY PANAL 1981

However, this summer the Defense Science Board, after examining just such trends and propositions, came to this rather opposite conclusion. Why?

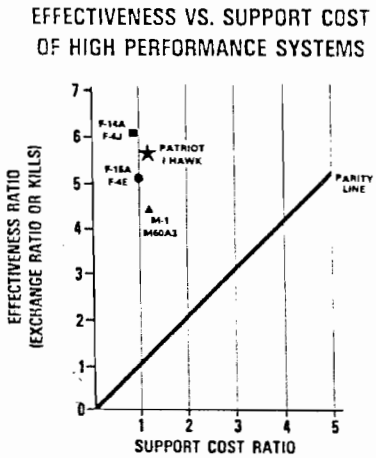
Slide 11

EFFECTIVENESS VS. ACQUISITION COST OF HIGH PERFORMANCE SYSTEMS



Well, among other things they looked at pairings of advanced systems with older counterparts. For example, here the F-14 and the F-4J, a Naval fighter new and old; Patriot and Improved Hawk, SAM air defense systems new and old; the F-15 and F-4E, Air Force fighter aircraft, new and old; and the M-1 and M-60 A3, Army tanks, new and old. The values on the ordinate express effectiveness in terms of ratio of kill potential, new to old (you'll just have to take the DSB Panel's word that these are reduced to some kind of common base for comparison). And on the abscissa is plotted the ratio of acquisition costs, new to old. The parity line represents the break even point, system for system. As you can see, the very much increased effectiveness of the new systems drives all of these pairings well up into a win area of much better than parity: 3, 4, 6 to 1.

Slide 12



The same thing is true in terms of support costs, which get at the issue of keeping systems available or ready for use in the force. Support costs include the costs of parts, training the operator and the maintainers to keep the system operating, and the costs of requisite basing. Again, the picture here is favorable for the new systems. So it is possible, according to the DSB, to build into new systems both high availability rates and very high effectiveness, and thereby to compensate for reduced numbers of systems. In fact, as you can see, with effectiveness ratios of 5 to 1 or so over systems they are replacing, one can operate with significantly fewer elements in the force.

Slide 13

THE CASE FOR HIGH TECHNOLOGY WEAPON SYSTEMS

- SOVIETS BUILD MANY OF SAME
- 24 HRS/DAY, MORE "SORTIES" OVERALL
- HUMAN COSTS LOWER
- SUPPORT COSTS LOWER
- LESS STRAIN ON BASING

Indeed, one DSB panel made for the Secretary of Defense this kind of a case for high performance or high technology systems. We might buy twice as many "half-performance systems," but the panel noted that the Soviets are building a very large, very high performance force, against which a smaller lower performance force would do very badly. Half-performance systems could not defeat Soviet systems built on advanced technology, such as we see in their tanks or in their titanium hull submarine. Moreover, high performance systems give us for the first time the ability to operate at night, in adverse weather, and under the electronic warfare conditions which will be typical of the future.

Moreover, we can get more "sorties" out of such equipment than has been possible in the past. (Incidentally, for those of you who have been following the dialogue in Congress over whether some particular fighter aircraft is better than the one it is replacing, should note that very frequently critics of our latest airplanes will contend that the sortie rate of the new is below that of a plane we had in World War II or Korea. You have to remember that sortie rates for the present peacetime force are programmed by flying hours and parts, and we don't fly these airplanes more often because we didn't have funds to do so. But our new fighters, in tests under field maneuver conditions in Europe and elsewhere, have demonstrated a capability to produce sortie rates two and three times what we have had in wars past.) Perhaps more importantly, to accept lower performance systems would be simply to accept higher, avoidable U.S. casualties. And if we went the low-performance route, we would need to increase our intake of military manpower overall not only to compensate for losses, but to operate the increased numbers of systems in the force. True, these could conceivably be less demanding systems in terms of skill requirements. But higher numbers of systems would increase our already high support costs, and--the point needs to be made again and again--human costs, manpower costs, will dominate the life cycle cost of virtually every system that the Department of Defense presently has under procurement or under research and development. And then finally, of course, maintenance support for larger numbers of systems in the force would increase the strain on a force which is already stressed in providing for its large logistic tail, its training base, its management, housing for dependents, personnel services, and headquarters overhead. The last line on the slide, basing, makes the additional point that whether you are talking about aircraft carrier decks, or airfields, or tank parks, we today have a constrained basing system for the American armed forces; putting a lot more systems into the field could create problems of basing for us.

Slide 14

TECHNOLOGIES THAT COULD MAKE AN ORDER OF MAGNITUDE DIFFERENCE

	OPPORTUNITY/RISK
1. VERY HIGH-SPEED INTEGRATED CIRCUITS	63/13.5 = 4.7
2. STEALTH	65.5/22 = 3.0
3. ADVANCED SOFTWARE/ALGORITHM DEVELOPMENT	71/29.8 = 2.4
4. MICROPROCESSOR-BASED PERSONAL LEARNING AIDS	41/17 = 2.4
5. FAIL-SOFT/FAULT-TOLERANT ELECTRONICS	55.5/25 = 2.2
6. RAPID SOLIDIFICATION TECHNOLOGY	46/21 = 2.1
7. MACHINE INTELLIGENCE	65.5/31.7 = 2.1
8. SUPERCOMPUTERS	62.5/24.[illegible] = 2.1
9. ADVANCED COMPOSITES	43/21.[illegible] = 2.0

Well, what high technology should we reach for to acquire high performance systems, pursuant to the Defense Guidance? Here is a list of technologies which the Defense Science Board believes could make an order of magnitude difference in our capability to meet the exegencies of future warfare. What you are looking at are results of a Delphi technique, in which the panelists assigned measures of merit to various technologies in order to assess relative

opportunity and relative risks, from which they derived the numerical rating on the right, a function of both opportunity and risk.

I am going to talk about a number of these particular technologies in a moment, but note that overall the Defense Science Board commended some 17 technologies to the Secretary. I have deliberately avoided having to discuss some of the more arcane--such as "high density monolithic focal plan arrays"--in order to focus on some of the technologies which I find, interestingly enough, are both at the top of the list and prominent for their sociological or cultural dimensions.

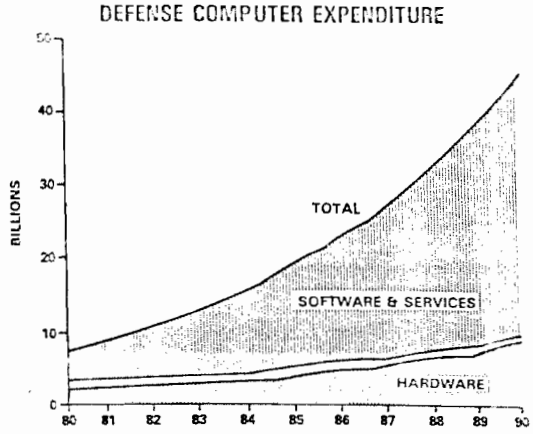
Slide 15

TECHNOLOGY	OPPORTUNITY/RISK	INVESTMENT STATUS
SYSTEMS APPLICATIONS	NATURE OF IMPACT*	
3. ADVANCED SOFTWARE/ ALGORITHM DEVELOPMENT	71/29.2–2.4	$7M
• CRYPTOGRAPHY	• PORTABILITY OF SOFTWARE	• BADLY UNDERFUNDED GIVEN IMPACT POTENTIAL
• TARGET ACQUISITION	• FASTER SOFTWARE DESIGN/TESTING/ MAINTENANCE*	• POORLY COORDINATED AND CONCEIVED
• SOFTWARE MAINTENANCE	• LESS EXPENSIVE ALTERNATIVES TO HARDWARE	• FRAGMENTED
• PERVASIVE ACROSS DOD SYSTEMS		• BEHIND STATE OF THE ART

* ORDER OF MAGNITUDE IMPROVEMENT

For example, this one. On the right you see the investment posture in the Defense Research and Development budget at the moment, and elsewhere on the slide, an indication of what Defense might do by way of applications: what kinds of opportunities the technology could provide. I would have you note that the Defense Science Board panel identified computer software as the highest risk undertaking among all Defense development undertakings.

Slide 16



This chart, rather startling to some, indicates the problem that we face unless we are able to find ways of producing computer software more efficiently than we have in the past. Without some technological intervention, we simply are

not going to be able to exploit the promise of smaller, smarter processors. The United States is facing very severe shortages of system analysts, computer scientists, and programmers. The research into advanced software methods to which I just alluded, does not hold out promise for relief for many years, but it is hopeful, and we should pursue it.

Slide 17

TECHNOLOGY	OPPORTUNITY/RISK	INVESTMENT STATUS
SYSTEMS/APPLICATIONS	NATURE OF IMPACT*	
6. FAIL SOFT/FAULT TOLERANT (SELF POLICING") ELECTRONICS	55.5/25 = 2.2	$5M (NO CENTRAL PROGRAM)
• PERVASIVE IMPACT ON SYSTEM AVAILABILITY	• ELECTRONIC SYSTEM AVAILABILITY AND RELIABILITY* • LIFE CYCLE COSTS* • SIMPLIFIED TEST	• NO COHERENT PROGRAM FOCUS • POOR TRANSITION OF PROMISING TECHNOLOGY ALTERNATIVES

* ORDER OF MAGNITUDE IMPROVEMENT

And then you have a possibility of improving the inherent capability of materiel with respect to its availability or reliability in the field. In commending this particular technology to the Secretary of Defense, the Defense Science Board stated as follows:

> "Reliability standards must be raised significantly--the technology to support such increases is available--the adherence to these standards the first time around is the most economical approach in the long run. Front-end costs will be higher....Times and funds must be programmed in the development cycle to accommodate necessary redesign iterations after test and before Initial Operating Capability for critical reliability, maintainability and producibility problems (as well as performance problems)."

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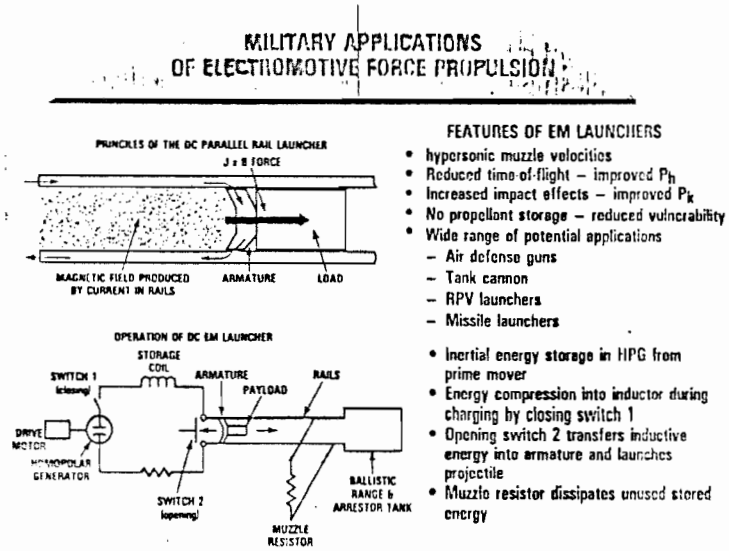
TECHNOLOGY	OPPORTUNITY/RISK	INVESTMENT STATUS
SYSTEMS/APPLICATIONS	NATURE OF IMPACT*	
7. MACHINE INTELLIGENCE	65.5/31.7 = 2.1	$13.2M
• CRISES MANAGEMENT • AUTONOMOUS WEAPONS • "INTELLIGENT" DATA BASES	• PERVASIVE DEPLOYMENT OF COMPUTERS* • DISTRIBUTED INFORMATION • RECOGNITION AND CORRELATION* • NATURAL INTERFACING* • TRANSPARENT COMPLEXITY* • AUTOMATIC PROGRAMMING	• PREDOMINATELY DARPA • SLOW SERVICE PICKUP • APPLICATIONS LAGGING • UNDERFUNDED BUT TALENT LIMITED

* ORDER OF MAGNITUDE IMPROVEMENT

And then lastly, for the moment at least, this particular technology. A number of recent publications have made it evident that by the end of the decade of the 1980's there will be available machines, computers or processors, which will be comparable in size and in weight to the human brain, and will

have comparable requirements for input and energy, and which will have quite comparable capabilities for output. Now what that means for the weapon system developer is obvious.

Slide 19



Here is a technology which was not cited by the DSB, but one I picked to highlight further the human dimension of the problem. This is a mechanism for propelling a projectile using electro-motive vice chemical energy, exploiting the so called Lorentz force. By the end of this calendar year, 1981, in the Westinghouse R&D Center at Pittsburgh, Pennsylvania, the Defense Advanced Research Projects Agency and the Army's Development and Readiness Command hopes to have operational a laboratory device which will be able to propel a 300-gram mass to a speed of 3 kilometers per second, yielding a muzzle energy on the order of 1.35 megajoules. In effect, this laboratory device will shoot a bullet about 3 times faster than present rifles or tank guns, and opens a whole new realm of physical possibilities with respect to antiaircraft guns, tank guns, and that sort of thing--Tom Swift's Electric Gun at last. Such weapons, if they ever become practical, could field a division's firepower with about 1/3 less weapon weight and 1/2 less logistic tonnage. But such weapons will also propel us into a whole new realm of difficulties with that most intransigent, stultified, subculture within military sociology, the artillery.

Slide 20

8 INCH PROJECTILES

- STORED ON GROUND INDIVIDUALLY
- LIFTED TO TRUCK BED ONE-BY-ONE, BY HAND
- LIFTED TO GROUND ONE-BY-ONE, BY HAND
- LIFTED TO TRUCK BED ONE-BY-ONE, BY HAND
- TRANSFERRED TO HOWITZER ONE-BY-ONE, BY HAND
- LOADED ONE-BY-ONE, BY HAND

In 1977 when I took command of the 8th Division in Germany, I found this state of affairs in my division artillery. I found that my artillerymen adhered

to their manpower-intensive ways of doing business as assiduously as their forefathers had clung to horsepower. Application of high school physics--levers and pulleys, inclined planes--could have bettered the situation, let alone buying materiel handling equipment, or looking to robotics to solve the problem. Let me read to you from a recent Army War College pamphlet on the Army in the year 2000.

> "In considering technology the Army must look introspectively at its ability to use advanced technology and its past performance in this area. For over 20 years there has been the technological capability to have a Howitzer that could be electronically laid (directed), fuzes automatically set, rounds automatically rammed, muzzle velocity (for future corrections) electronically measured and firing data electronically computed from an electronic sensing. The actual condition is that there are many artillery commanders taking great pride in the fact that they never fire their Howitzers using only the FADAC (a very old computer which is dependent on mobile generators usually in short supply). These commanders insist on checking the FADAC by manual means or they check the manual using the FADAC. One could imagine the confusion resulting from the introduction of the modern artillery systems which we should have."

I can attest to that. I sent back from Germany a young oficer to the Army Materiel Systems Analysis Agency where, working with ballistic experts, he developed a chip for a Texas Instruments programmable hand-held calculator incorporating the firing tables for our medium howitzers. The device proved both reliable and quick. But I can vividly recall walking into a fire direction center of a battalion firing at Grafenwohr to find three tiers of firing data calculators in operation. On tier one of a football-bleacher like set-up there were three plotters producing data for the guns using the graphic techniques that had been used in World War I and World War II. On tier two were not one but two FADAC operators checking the graphic data. And in the back at the top of the pyramid was a lad with the Texas Instrument device, invariably producing his data faster and as accurately as anybody else, but whose data would not be independently accepted by any self-respecting fire control officer, you may rest assured.

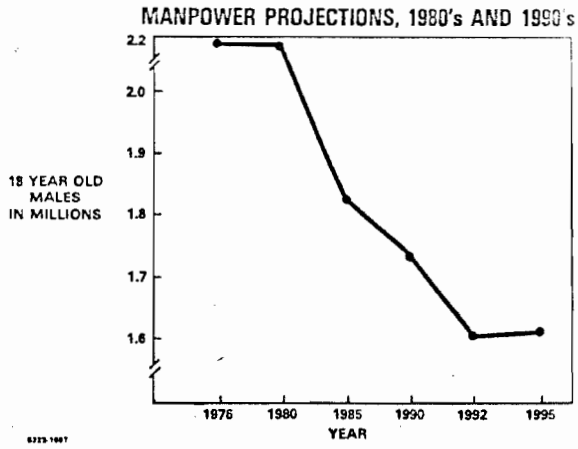
What I am suggesting is that a technology like electric guns, which could eliminate chemical energy as a way of propelling projectiles, could also eliminate an enormous amount of that manpower intensive logistic tail to which I alluded at the outset, and may make it possible for us to have a genuinely distributed force. In future wars we will have to dispense with specialization. I do not believe that it will be possible to maintain through the 1990's an arm dedicated, as we now dedicate the artillery, exclusively to the delivery of indirect firepower. I think all elements of the force are going to have to be capable of contributing to both direct and indirect firepower, to anti-aircraft and anti tank defenses, and to reconnaissance. Hence, our present specialized, manpower-intensive artillery has got to yield place to multi-purpose weapons systems.

Slide 21

This is a cartoon suggesting such a future weapon, by William Coulter of the Washington Post. It is not, I assure you, genuinely classified. It depicts a device which I admire if only because it operates by ingesting its own technical documentation. I believe, as the data I am about to show will illustrate, that such a feature in a weapon may be the only hope for the Army of the future. But I want to use this slide to make a more serious point about the dilemma that we face: here the artist caricatures one of those omnipotent machines we might have to develop. I would say that the principal obstacle to our fielding to such a machine is the fellow portrayed sitting on the seat there on the left: the commander, operator, maintainer of the device. Here again, a quotation from a Defense Science Board report to the Secretary this summer:

> "The division of tasks between the man and the machine becomes increasingly critical in two dimensions. First, there is the problem of personnel skill potential (quality). Average reading levels and aptitudes come into play. Secondly, there is the complexity issue. To the extent that complexity can be engineered away from the man-machine interface so much the better, if it can be afforded, and if it is not translated into insoluable problems somewhere back in their maintenance sequence. More human research and man-machine technology development is required. The current problems with Built-In Test Equipment (BITE) illustrate the doubtful state of the art. The division of maintenance tasks between the diagnostic equipment and the mechanic or repairman has been tilted too far toward the machine and they have generally failed to live up to their advanced billing. In the meanwhile, the people must interact realistically with the engineers at the outset. This is an art not yet fully developed. Testing at the man-machine interface must be conducted and room for corrective design interactions provided in the development program."

Slide 22



I would be remiss if I did not immediately, of course, acknowledge, that in addition to the issue of the quality of the men manning weapon systems, we have a quantity problem in this country. The Soviet Union faces a similar quantity problem, and so too, I believe, do most developed countries.

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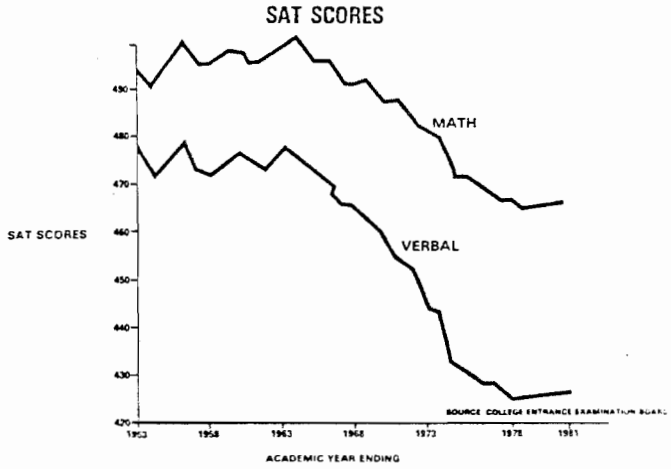

But we also have a quality problem, and it may be societal in scope, as illustrated by the decline in Scholastic Aptitude Test results nationwide.

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SOVIET VS U.S. SECONDARY SCHOOL GRADUATE

	SOV (YEARS)
ALGEBRA	+1.5
GEOMETRY	+8.0
CALCULUS	+1.5
PHYSICS	+4.0
CHEMISTRY	+3.0
BIOLOGY	+3.5
ASTRONOMY	+1.0
MECHANICAL DRAWING	+3.0
WORKSHOP	+8.0

NSF REPORT, 1979

But even more disturbingly, recognizing that we are in a serious competition with the USSR, our high school graduates, compared with Soviet high school graduates of the past decade, have had far less disciplining in mathematics, science and other technologically supportive subjects in the course of their schooling.

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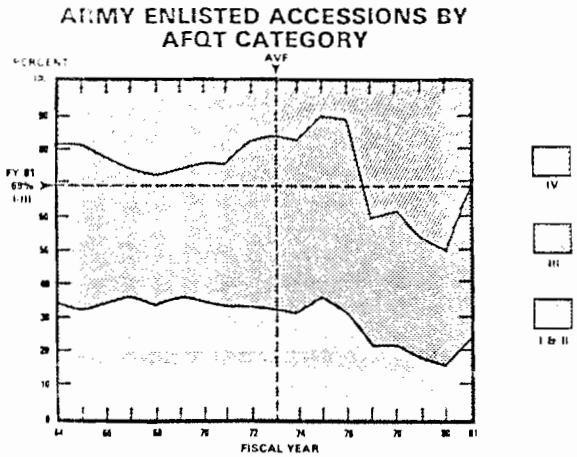
NSF, 1979

"THE DISPARITY BETWEEN THE LEVEL OF TRAINING IN SCIENCE AND MATHEMATICS OF AN AVERAGE SOVIET SKILLED WORKER OR MILITARY RECRUIT...AND AN AVERAGE MEMBER OF OUR ALL-VOLUNTEER ARMY IS SO GREAT THAT COMPARISONS ARE MEANINGLESS."

I quote here from Dr. Isaak Wirzup, Professor of Mathematics at the University of Chicago, and Director of the East European Survey of Mathematical Literature for the National Science Foundation, and also the NSF's Director of its program on Soviet Applications of Computers to Management. In a letter to the National Science Foundation, Dr. Wirzup said this:

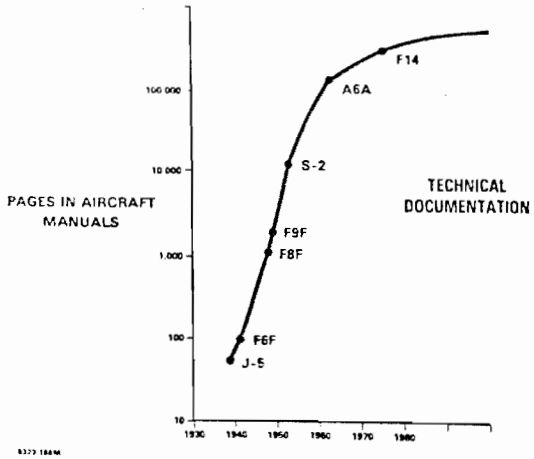
> "The Soviet Union's tremendous investment in human resources, unprecedented achievements in the education of the general population, and immense manpower pool in science and technology will have an immeasurable impact on that country's scientific, industrial and military strength. It is my considered opinion that the recent Soviet educational mobilization, although not as spectacular as the launching of the first Sputnik, poses a formidable challenge to the national security of the United States, one that is far more threatening than any in the past and one that will be much more difficult to meet."

Slide 26



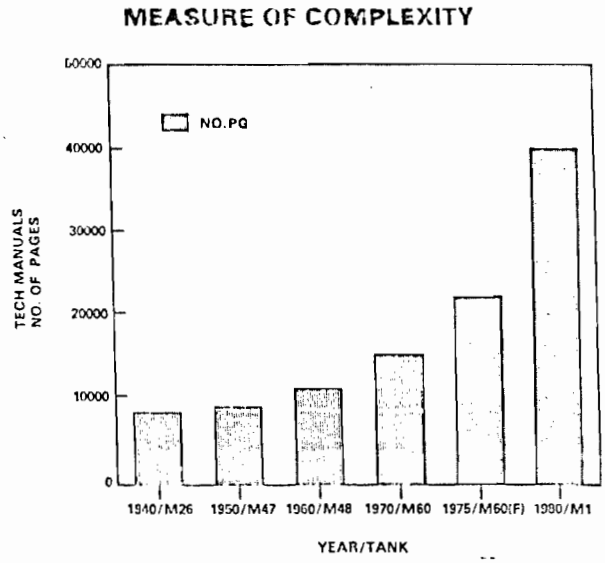
I think you are familiar with these data. Regardless of what you may think of their precision, the trends are plain. The population recruited into the Army recently was different qualitatively from the population that was inducted or recruited in the wanning years of conscription in the United States. This is not to say that the Army cannot work successfully with a large median population. However, it is evident that the Army encounters significant difficulties when attempting to assign masses of such individuals to high technology weapon systems. I am not talking about future difficulties; I am talking about problems that are here and with us today. Reference was made earlier to reading ability.

Slide 27



This is what is happening to technical documentation vis-a-vis airplanes. As you can see, the Navy's F-14 fighter is going into the fleet accompanied by some 300,000 pages of technical information.

Slide 28



And it is not just airplanes, but tanks: here you can see the Army's starting early in World War II with soemthing less than 10,000 pages of technical documentation per tank, and now fielding over 40,000 pages per tank. It is easy to imagine what that means in terms of complexity for the mechanic who has to be able to find his path into his technical documentation for fault isolation, repair, replacement, etc. What such a complication does in terms of slowing the rate of repair, and the reliability of the repair is predictable, and the predictable is happening already in some of our current higher-technology weapons systems.

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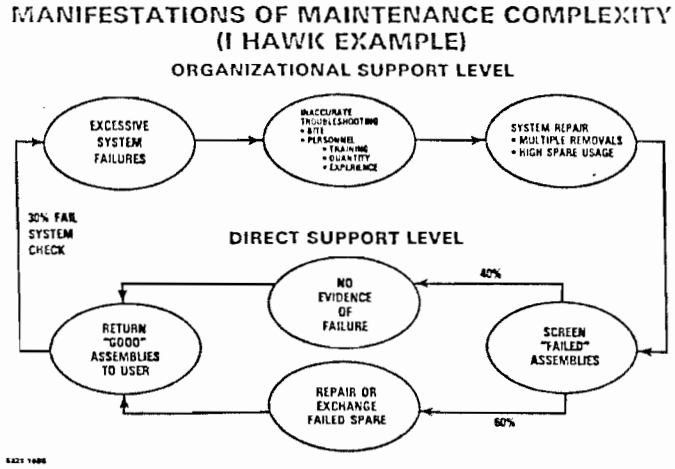

Here is a flow diagram showing the maintenance process for the anti-aircraft missile, the Improved Hawk. Up at the top you see the Hawk unit's own mainten-

ance, and across the bottom the direct support maintenance performed exogenous to the Hawk unit. The highlighted figures suggest that of parts that were sent from the unit back to the direct support level for repair, 40% when examined were found to be faultless; that is to say, almost half the time the Hawk unit removed parts from the weapons system and sent them away to the direct support maintenance unit on a totally unnecessary trip. Moreover, you can see over on the left, when the parts came out of the direct support maintenance unit and were returned to the Hawk unit, 30% of the time they didn't check out when actually refitted to the system. And up at the top, the box in the center suggests that these mishaps are a function of inaccurate trouble shooting, of inadequacies in the built-in test equipment, and of personnel deficiencies in training, quantity or experience.

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IMPACT OF MAINTENANCE COMPLEXITY (I HAWK COMPARISON)

OVERALL CRITERION MEASURES	U.S. ARMY	GERMAN AIR FORCE
NO EVIDENCE-OF-FAILURE RATE	40%	2%
FAILED-SYSTEM-CHECK RATE	30%	UNKNOWN
REPAIR TIME DISTRIBUTION	NOT AVAILABLE	

These data were compared with the I-Hawk experience of the Bundeswehr, at least with respect to the no-evidence-of-failure rate. There was a dramatic difference of over 20 times less maldiagnosis.

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APPARENT COMPLEXITY (I HAWK COMPARISON)

INDICATORS	USA GAF COMPARISON	
MANPOWER AUTHORIZATION BY MOS	SIMILAR	
SKILL LEVELS (GRADE)	USA 2 GRADES LOWER THAN GAF	
SKILL UTILIZATION	SIMILAR DIVERSIONS AND WORKHOURS	
INDIVIDUAL DIFFERENCES • CIVILIAN EDUCATION • READING GRADE LEVEL	USA 67% HIGH SCHOOLGED AVG. 8 TO 9	GAF 100% SEC + VOCATIONAL AVG. 11 TO 12
ACCESSION POPULATION FOR MAINTENANCE MOS	90% 3-YEAR 10% 4-YEAR	8 YEAR OBLIGORS WITH OVER 3 YEARS OPERATOR EXPERIENCE

As you might expect, if an armed force is willing for a technologically advanced system such as the Improved Hawk, to invest individuals with 8-year terms of service, who are all high school graduates, and who have other advantages over what the U.S. Army has been working with on the left, the performance of the weapon system is almost invariably going to look better.

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EL SCORE DISTRIBUTION

		PERCENT OF INVENTORY BY EL CATEGORY		
		EL ≤ 99	100 ≤ EL ≤ 109	EL ≥ 110
TOTAL ACTIVE ARMY		49%	21%	29%
I HAWK	ORG	15%	23%	62%
	DS/GS	2%	24%	74%

Now, it isn't that we are picking less apt soldiers to man the Improved Hawk as a system. These are Electronic Aptitude scores. As you can see, compared with the total force, the I-Hawk system is getting a pretty good cut of the soldiers of higher electronic aptitudes. And, of course, the I-Hawk is but one of many systems that have a demand for soldiers with these high scores. Part of our problem is that the tests which produced these scores are normative. Part of our problem is that even high scoring soldiers may not be up to the maintenance task to which we have put them. Part of our problem is exactly that the weapon system may be too smart, and we need to engineer it some more in order to drive its maintenance back into routines with which we know the soldiers we have can cope. These are all very, very intractable problems, to handle which the Army of the future, or the Air Force of the future, or the Navy of the future, are going to need the skills of you psychometricians far more then ever in the past.

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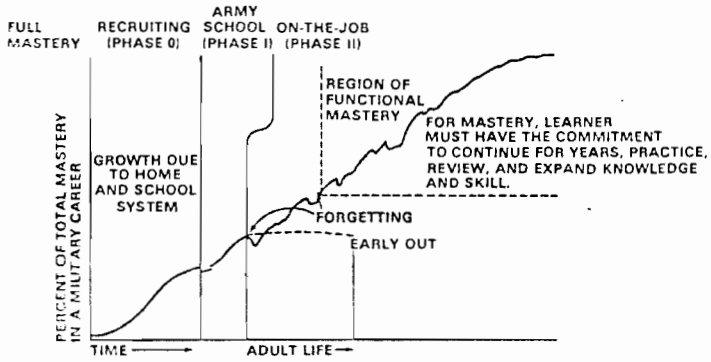
THREE PHASES IN ACHIEVING MASTERY IN A MILITARY CAREER



What to do? I advocate a manpower strategy for the Armed Forces, in complying with the guidance of the Secretary of Defense, which would operate on all three phases or learning regimes of the soldier, sailor or airman. In the past, of course, the services have focused resources on the center phase, labeled here the school, and they will have to keep doing so. They have sort of left it to hope, to chance or to high enlistment bonuses that the Phase 0

of left it to hope, to chance or to high enlistment bonuses that the Phase 0 product would pan out for them: not a sound approach, given what is happening in SAT scores. We are going to have to do something about finding individuals in Phase 0 who are fit to become stellar performers both in Phase I and Phase II. But it is equally important to devise a plan for Phase II--On the Job. It has been the custom of the Services of the United States to let Phase II, the on-the-job phase, take care of itself, relegating what may be the most important adult educational experience to first-line supervisors largely ill-trained for teaching, and unaware of their responsibility for same. I suggest to you that we can no longer depend upon such hit-or-miss methods if we are going to modernize the force, to bring in large numbers of very technologically advanced weapon systems. I hold that we must launch now a concerted campaign to intervene systematically in Phase II, the on-the-job training phase of development for the soldier, sailor or airman, both to assure functional mastery, and to provide an ability in the force to handle the influx of newer technologies that will pour out of on-going research and development programs.

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TECHNOLOGY	OPPORTUNITY/RISK	INVESTMENT STATUS
SYSTEMS APPLICATIONS	NATURE OF IMPACT*	
4 M CROPROCESSOR BASED PERSONAL LEARNING AIDS	41/17 2.4	$0M
• TROOP TRAINING	• COMPRESS TRAINING TIME	• AN OPPORTUNITY DESERVING FUNDING $4M
• PROCEDURES		
• MAINTENANCE	• HIGHER SKILL LEVELS	NEEDED
• WEAPON LAYING	• TRAINING COST FLEXIBILITY*	• DEVELOPMENT OF TRAINING SOFTWARE FOR PERSONAL COMPUTERS
	• EXTENDS MANPOWER POOL	
	• AIDS RETENTION	• AN EXPERIMENT PROGRAM OF SUFFICIENT SIZE TO JUDGE EFFECTIVENESS

* ORDER OF MAGNITUDE IMPROVEMENT

Is there a technological intervention appropriate here? Yes, you may recall Number 4 from the list of 17 DSB commended technologies, this one. One last time I quote, if I may, from a Defense Science Board report:

> "It should also be the policy of DOD that support will be provided for these high performance systems at a level which will meet peacetime operating and training requirements and which also will provide the base for surging to wartime utilization and sustainment rates. In wartime intense combat periods, and during peacetime 'surge trials' it will be the objective to move actual field availability A_0 close to A_i, intrinsic availability. Specific support program goals should be established at the beginning of development and managed thereafter with the same priority attention and intensity normally accorded to performance. Training support goals should relate to higher standards based on advanced training technology now becoming available. Advanced job-aids should be designed for simultaneous use in training and on the job. Soon it will be impossible to maintain this kind of technical documentation by conventional generation, distribution, and substitution of paper drawings and text. Digital communication, storage, and display of changes will be required. This whole area should be promoted during

the acquisition cycle not only by R&D community, but by personnel specialists and commanders."

Now ladies and gentlemen, it is not clear at this time whether the strategy advocated in the Defense Guidance will enhance the national security of the United States. Both its technological and sociological feasibility are seriously in doubt. The manpower policy challenges posed by that strategy are enormous in their implications. The branchings in the paths ahead are altogether too numerous for easy mapping or classification. It seems crystal clear, however, that most of them involve choices that could more confidently be made were we to have much better information about our manpower than is presently available to commanders and managers in the Department of Defense. Hence, I appeal to you, individually and collectively, to lend us a hand with your skills. Upon your response, the very security of the nation may rest.