VISUAL SYSTEM TECHNOLOGY APPLICATIONS FOR IMPROVED TRAINING/SIMULATION

Short Title: **VSTA**

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EXECUTIVE SUMMARY

High-fidelity scene-generation technology will continue to be in demand for training devices for all the Armed Services. Intuitively, those who write training device requirements for the services will stipulate artificial visual stimuli approximating reality. Since DoD expenditures for simulators is likely to increase year by year, any company in a position to provide higher-fidelity scene-generation than others, while remaining competitive in overall price, will be assured a comfortable niche in DoD procurement.

Three reservations must be expressed: (1) user intuition, in this instance, may prove to be unreliable, since there is evidence that, for some applications at least, high fidelity visuals may be disfunctional; (2) the trend is for weapon system designers to place electro-optical sensors and other instruments between operator/crew and the operational environment, so that high-fidelity scene-generation becomes less a matter of depicting that environment as it might look to the human eye, than of replicating the displays of the mechanical contrivances --probably less demanding in terms of density of picture elements, color, depth portrayal, and other aspects of high-fidelity as it is now understood; (3) high-fidelity scene-generation has, up to now, been expensive, and the overall cost of any proposed training device will almost surely be more important in future decisions on configuration and choice of contractor than visual fidelity.

To date, it is **institutional training** (see Appendix 1 for definitions) which has largely underwritten simulators featuring high-fidelity scenes. However, during the last fifteen years, the most significant advances among the training devices adopted by the Armed Forces have been those related to **unit training**. Current interest is on **collective training** in combined arms, or joint tactics and techniques. The Army and the Air Force have funded jointly with DARPA some $150,000,000 to field a prototype of SIMNET, networks of scene-generating simulators for joint, combined arms training; the Army has $750,000,000 in its POM for SIMNET procurement over the next five years. The Navy is intent on breaking away from shore-based and dockside simulators so that it can conduct its full range of training on ships underway.

Seven trends are evident: (1) robust, growing market for computer-generated, scene-based simulation; (2) decreasing computer costs, accompanied by dramatic increases in speed and memory; (3) smaller, lighter, more rugged computers will ease embedding such simulations in weapon systems; (4) new opportunities will present themselves in applications of simulation to materiel prototyping, and to evolutionary development of requirements; (5) computer architecture is turning to commercial standard open hardware and software; (6) market growth is most pronounced in simulation for unit training --for ships underway, operational squadrons, and deployed battalions; (7) institutional training market will remain, and higher per-device costs will continue to be justifiable for such applications.

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Soldiers receive most of their training in their units. There they can best train as individuals and as members of teams under conditions that approximate battle...Unit training should simulate as closely as possible the battlefield's tempo, scope, and uncertainty. Units and headquarters that will fight together in teams, task forces, or larger units should train together routinely...
U.S. Army Field Manual 100-5, Operations, 1986

Department of Defense Directive 1430.13, dated August 22, 1986, subject Training Simulators and Devices, recognizes that such materiel can facilitate: "training which might be impractical and unsafe if done with actual systems or equipment; concentrated practice in selected normal and emergency actions; the training of operators and maintainers to diagnose and address possible equipment faults; enhanced proficiency despite shortages of equipment, space, ranges or time; control of life-cycle training costs; and reducing systems required in maintenance training." (para A.3.; text of the Directive is Appendix 2). As a matter of DoD policy, training devices and simulators must (para D.1.):

a. Proceed from requirements analyses which include "benefits and tradeoffs, and consider Reserve Component needs.

b. When related to a major system, be documented and reviewed with that system, and when otherwise, be justified with respect to a specific training program or course.

c. Be considered for procurement independent of the prime contract for the major system supported.

d. Enjoy the same priority as the major system.

e. Be fielded at the same time as the major system.

f. Be treated thus in acquisition funding from advanced development through procurement.

g. Be considered for joint (multi-service) acquisition.

Each Military Service is further directed to justify its acquisitions with economic analyses of alternatives, including life-cycle use versus costs, trade-off with munitions, and device changeability; to include among alternatives commercially available practices and equipment; and to specify training functions, performance levels, and required proficiency.

There can be little doubt that the Armed Services will pay more attention in the future to training devices and simulators, and that, seeking higher readiness at lower costs, they will enlarge their procurement of such equipment. Training devices or simulators provide

vicarious experience through stimulating human responses comparable to those which actual equipment or situations would evoke. Usually, the principal such stimulus is visual, and the more faithful the portrayal of what is seen, as a general rule, the more effective the simulator or device. Hence, any firm which can competitively furnish high-fidelity scene-generation should be in an excellent position to market its capabilities.

It is assuredly true that most military officers intuitively value high-fidelity scenes, and given a choice among two similar simulations, will invariably be attracted to the one with higher scenic fidelity. In the past, service requirements writers have tended to stress fidelity, and contracts have tended to be awarded to firms who promised high-fidelity. But more recently, training developers within the services have cast some doubt on the proposition that high-fidelity scenic-presentation is always desireable for effective learning. For example, trials of audio-visual teaching materials supported in part with color photography, and in part with cartoon drawings, have shown that the latter taught more efficiently, evidently because of better learning focus and fewer distractions from scenic detail. In terms of cost, of course, the color photography was significantly more expensive, especially because of propensities to require retakes of scenes with detected minor infidelities of costume, equipment or procedure. Similarly, there is evidence that color itself can be disfunctional for learning, and that in some applications, monochrome visuals are preferable.

Electro-optics, as they proliferate, are changing the need for scenic-fidelity, which is becoming less a matter of optical "realism", in the sense of relating closely to what the naked eye sees, aided or unaided, than a question of being a reasonable simulation of the output of some electro-optical sensor, such as a thermal-imaging weapon sight, or a Forward Looking InfraRed device (FLIR). Day or night, the thermal sights now broadcast on tanks and anti-tank weapons provide any soldier used to their nuances a better view of the battlefield than might be obtained through binoculars or other optical aids. And thermal sights work well precisely because they display mainly what the soldier is looking for, objects warm in comparison with background --men and vehicles-- suppressing or filtering out other scenic detail. Generating scenes of thermal imagery deserves high-fidelity, but is probably much less demanding in terms of density of picture elements, colors, perspective, and other aspects of high-fidelity scene generation as it is now understood. And monochromatic FLIR imagery may be even less so.

Up until the very recent past, the costs of high-fidelity scene-generation have confined applications to **institutional training** (see Appendix 1). Only in fixed school-like settings, where a small buy could service many trainees, and where these could be reliably scheduled to keep utilization factors sufficiently high, could the high capital investment be justified.

But the major costs of service training are those for gaining and maintaining operational readiness in units (battalions, ships,

squadrons). Beginning in the early 1970's, all the services turned their attention to devices which could enhance **unit training**:

* The Navy has developed instrumented ranges for air-to-air engagement simulation, built vans which on a pier beside a ship can create simulated "attacks" and other emergencies to train an entire crew prior to going to sea, and placed fire-control simulators aboard ship for underway training in weapon system employment.

* The Air Force has also had broad recourse to instrumented ranges and engagement simulation, has adopted computer-based battle simulation to train commanders and staffs, and relies on simulation for almost all its squadron training in electronic warfare.

* The Army has distributed the Multiple Integrated Laser Engagement System (MILES) throughout the force for engagement simulation, has emphasized instrumented ranges, and has made broad use of both manual and computer-based battle simulation for training of commanders and staffs.

But it was a case of too little, too late. The Gramm-Rudman-Hollings strictures have mandated severe cuts in outlays, chiefly Operations and Maintenance funds. Training, especially OPTEMPO --ship days of steaming, flying hours, battalion days of field-training-- has been the major bill-payer. And technological aids, which might have helped, have not materialized. Service acquisition processes are so lengthy (12 years, plus or minus), and so complicated, that any product is almost surely overpriced and outmoded when ready for fielding.

Cost considerations have begun to dominate decisions on the procurement of training materiel. Recently, for example, the Army curtailed planned procurement of both ARTBASS --a battalion battle simulation system using advanced computer-generated graphics which it had been developing for over twelve years-- and its tank Conduct of Fire Trainer --a tank-gunnery simulator built around high-fidelity computer-generated scenic presentations, in development for a decade. These decisions are particularly instructive because the Secretary of the Army and the Chief of Staff of the Army, in their Annual Statement to the Congress on the Posture of the Army for Fiscal Year 1987, cited both ARTBASS and the Conduct of Fire Trainer as examples of technologies required to offset decreased OPTEMPO, or rate of use of equipment for training, so that readiness could be sustained in a time of fiscal austerity:

> **OPTEMPO was decremented from a level of 1,000 miles per tank in FY 1984 and earlier years to approximately 850 miles in FY 85 and beyond. This reduction is based on a number of factors --investment in simulations, budget constraints, refinements in modeling techniques, and other changes. Near-term offsets to support investment in simulators have concentrated more on procurement accounts such as ammunition**

than on operating or support costs, However, simulators that offer potential as OPTEMPO surrogates are now beginning to be fielded. These include: Unit Conduct of Fire Trainer (UCOFT), and Army Training Battle Simulation System (ARTBASS).

The UCOFT, a computer driven visual scene simulator for gunnery skill training, provides the best example of this situation. Two years after UCOFT is fielded to each M-1 tank battalion, each tank is decremented 34 main-gun rounds. The cost differential associated with this reduction is shown below:

UCOFT COST AVOIDANCE

TYPE OF ROUND	ROUNDS REQUIRED/ TANK/YEAR	COST ROUND*	# TANKS/ BATTALION	COST AVOIDANCE PER BATTALION PER YEAR
105MM				
TP-T	14	$132	58	$107,184
DS-TP	20	$168	58	$194,880
				$302,064
120MM				
TP-T	14	$1,278	58	$1,037,736
TPCSDS-T	20	$854	58	$990,640
				$2,028,376

*FY 86 PROJECTED COSTS. AS MORE 120MM ROUNDS ARE PRODUCED, PRODUCTION WILL BECOME MORE ECONOMICAL AND UNIT COSTS WILL DECLINE.

Further, annual cost avoidance associated with the UCOFT fuel and maintenance costs is estimated at $320 thousand per battalion. Most important, however, these simulators provide soldiers training opportunities transcending the constraints associated with full service firing...

POSTURE, FY 87, pp.44-45

ARTBASS was set aside in favor of a battle simulation to be hosted not on its expensive, van-size, special-purpose computer, but on commercially purchased, desk-top work-stations. And COFT was cut back to finance (jointly with the Defense Advanced Research Project Agency) fielding prototypes for SIMNET, a family of netted simulators using lower-fidelity computer-generated scenes, but costing much less per tank or other system simulated. In both cases, ARTBASS and UCOFT delivered what Army's requirements called for. In both cases, being so long in development, they were overtaken by the arrival of cheaper technology, which if less elegantly graphic, holds promise for excellent training.

There can be no doubt that all the Armed Services, like the Army, are are under intense pressure to find ways of training despite austere

budgets. Scene-generation producers ought to find a ready market, for just at a time when circumstances limit traditional approaches to training, requirements for proficiency, especially for joint readiness, are growing sharply:

* Aviation training in all four services is constrained by environmental and civil safety considerations, by civil encroachment into approaches, and by reduced funds for fuel and parts. But the reach, firepower, and sentience of aircraft have been increasing by leaps and bounds, and maintenance tasks require new skills and knowledge. The Air Force has invested substantial funds in a project to upgrade the quality of individual training in operational squadrons, expecting structured unit training in skill progression to reach 90% of all airmen, and to accomplish 75% of individual training Air Force-wide.

* Land warfare training, especially in Germany, is affected adversely by urban sprawl and increasingly effective environmentalist objections, at a time when range, effectiveness, and speed of weapon systems are increasing, and the premium on sychronization has created new imperatives for practice in the coordination of the combined arms, and in joint employment techniques.

* Naval training has been complicated by the proliferation of new ship types, the admixture of old and new in the fleets, and the heavy operations tempo that has been mandated by requirements for continuous presence in all the earth's oceans. There is keen interest in moving training for ship's crews, both individual and collective, to sea, aboard ship, away from shore-based schools and dockside simulators.

Concerning computer-generated imagery for simulators, the fundamental issue is <u>not</u> scenic fidelity, but cost. To date, high-fidelity scene-generation has entailed expensive software, which in turn has constrained scenic coverage. But now lower fidelity, relatively low cost scene-generation seems to be at hand.

For example, SIMNET, using the extensive Defense Mapping Agency digitized terrain data, can make possible vicarious random "travel" over extensive tracts, and enables cooperative tactics (overwatch, fire support) with friends, or even duels or battles against "opponents," all injected by simulator into the same environment. The lower-fidelity scenery is good enough to permit navigating by map, and to cue tactical interactions. Versions of SIMNET simulators are also intended to facilitate experiments with materiel development --new crew arrangements, new man-machine interfaces, new weapons. DARPA, the Army, and the Air Force will spend about $150 million in research, development, and prototyping SIMNET; the Army Program Operating Memorandum (POM) anticipates procurement of some $750 million worth of SIMNET simulators, configured in division sets of eighty or more, with a mix of tanks, infantry fighting vehicles, and helicopters. Obviously, it would be desireable to upgrade the

quality of the "views" through the putative vision blocks, telescopes, cockpit canopies, or sights, so that each were as sharp as reality. But, any Service must now ask, what would it cost to provide that fidelity, and what would be the tradeoff in ability to "travel" long distances at fast speeds? Computer-generated imagery consumes enormous amounts of memory, and updating rapidly very dense data, like high-fidelity scenery, as might be required to simulate an attack helicopter flying nap of the earth, quickly outstrips the capabilities of even the fastest, most versatile, most expensive processors currently available.

There is a possibility that coming generations of computers will eliminate the present cost disadvantage of high-fidelity scene-generation. Craig Fields, Chief Scientist for the Defense Advanced Research Projects Agency (DARPA), considers advances in computers the most assured technological progress in sight. Fields believes that over the next four years there will be increases in speed and power of processors comparable to the changes which took place over the forty years between 1946 and 1986, what he calls a "step-function increase". In 1946, ENIAC, a house-size computer, could perform 5,000 calculations per second. By 1990, ENIAC-like capability could be available in a wristwatch. Today's CRAY-2, a commercial cabinet-size 64 bit parallel processor which weighs 5500 pounds and costs $17 million, has a speed of 1.6 billion calculations per second. DARPA now has an experimental processor of comparable speed very much more compact, what Fields refers to as "a giga-flop in a soupcan." He opines that by 1990 it ought to be possible to "put a Cray in every serviceman's pocket". If so, low cost, high-capacity, super-speed, multiple-path processors ought to be able to generate very high-fidelity scenes for "travel" at any imaginable simulated speed.

It also seems evident that special-purpose computers will be unattractive. The recent decisions by the Army on ARTBASS and UCOFT came at the same time that the Army began to seek solutions to its C^3I problems in commercial computer hardware capable of multiple applications, directing evolutionary development in a divisional test-bed where requirements could be refined by users actually employing prototype systems. At the same time, the Army moved its computer requirements for both command and control and for battle simulation toward open hardware and software architectures in order to tap the growing commercial supply of such systems. The Corporation for Open Systems in McLean, Virginia (headed by Lieutenant General Lincoln Faurer, USAF (Retired), former Director of the National Security Agency) promotes that market, and has established standards for the industry which all the services will find compelling.

These trends are evident:

1. There is a robust and growing market for computer-generated, scene-based simulation.

2. Near-term decreases in computer costs, accompanied by order-of-magnitude increases in speed and memory, promise newly cost-effective, high-fidelity scene generators.

3. Decreases in computer size and weight will ease embedding such simulations in actual weapon systems.

4. New opportunities will present themselves in applications of simulation to materiel "prototyping", and to evolutionary development of requirements.

5. Computer architecture for simulation will increasingly be based on open systems, not only for ease of update and revision, but for commonality with other computer tasks in units.

6. Market growth will be most pronounced in simulation for unit training --designed to be used aboard ships underway, in operational squadrons, and in deployed battalions. Cost-per-device will dominate procurements.

7. A solid market will remain in institutional training. Higher per-device-costs will continue to be tolerable for institutional applications.

ARMY TRAINING: A CONSTRUCT

APPENDIX 1

to

VISUAL SYSTEM TECHNOLOGY APPLICATIONS
FOR IMPROVED TRAINING/SIMULATION

Short Title: **VSTA**

ARMY TRAINING: A CONSTRUCT

All Army training --all military training-- can be described with four terms: **individual** or **collective**, **institutional** or **unit**.

-- **Individual** training refers to undertakings aimed at developing the cognitive and psychomotor skills of one person, as distinguished from teams. Since civil education and training are preponderantly of this sort, and since related pedagogical literature is similarly focused, the services tackle individual training with confidence, and some evident competence, especially in institutional settings.

-- **Collective** training refers to undertakings directed toward developing teamwork, or constructive interpersonal working relationships among several individuals performing a common task. The varieties among individuals, and the permutations and combinations of experience and skills within casual groupings have led educational researchers --civilian and military-- to experiment with and write about collective training mainly of entry-level personnel, where some commonality of background, experience, and age tends toward more homogenous, definitive results. Training of more disparate, and more realistic collectives is largely unexplored.

-- **Institutional** training refers to methods for training either individuals or collectives in which a faculty is established and facilities provided so that groups or classes of trainees may be processed through a fixed curriculum, or set of educational experiences. The school systems established to meet the societal requirements of the 19th, early 20th Century Industrial Revolution provided the model, and have largely conditioned the administrative procedures and forms of instruction used within all the armed services in their training centers and schools. In general, a relatively stable faculty of subject-matter specialists train repetitively changing populations of trainees.

-- **Unit** training refers to that which takes place within battalions, companies, platoons, and detachments, squadrons, or ship's companies, where the "faculty" and the "trainees" are stable, and the "curriculum" varies from day to day, according to mission-needs, or some training management plan laid down by the unit's leaders. The latter bear the primary instructional burden, and are seldom genuine subject-matter experts comparable to those in institutional training. A significant amount of unit training is actually peer training, on the job, with even less expertise or experience brought to bear. **Unit** training, properly a military preserve, has been poorly explored by scholars and experimenters, yet most soldiers, sailors, and airmen are in units most of the time, and their peacetime activities are principally training, more or less structured. Therefore, **unit** training is patently the most expensive kind of training, and the least effective.

The universe of training may be characterized with the following paradigm, or construct, in which there are four distinct regimes,

relating to "who is being trained?" and "where is the training taking place?"

Who trained?	Where trained? INSTITUTION	Where trained? UNIT
INDIVIDUAL	Individual Tng in Insitutions	Individual Tng in Units
COLLECTIVE	Collective Tng in Institutions	Collective Tng in Units

From the point of view of resource allocation, these distinctions are not trivial, for **Institutional** training managers can assure seemingly efficient utilization of quite expensive facilities and personnel overhead, whereas **Unit** training managers are notorious for failing to take adequate advantage of classrooms, learning centers, ranges and training areas, let alone more elaborate training mechanisms. For this reason, most of what the services have spent over the years for better means of doing the training job has been spent on **Institutional** training. This assuredly is true in the Army, for in addition to TRADOC's Program 8 bite out of the Army budget, and the dent it makes in quality manpower, there is the National Training Center, and its upcoming counterpart at the Seventh Army Training Center, in Germany. There is a discernible interest, however, in all the services, the Army included, in better **Unit** training. The Vice Chief of Staff of the Army, General Thurman, recently indicated that he was willing to forego procuring some of the planned quantitites of new weapon systems if he could be shown that he could resource instead **Unit** training which would assure that what equipment he did procure could be employed to full potential. For example, he has advocated embedding training aids or simulations into the weapon system itself, and in the interest of defining goals for training developers, he has strongly supported establishing standards of performance horizontally across the various units of the Army, and vertically from the lowest private soldier in any unit to the highest ranking general commanding forces afield.

Still, significant resources are earmarked expressly for training of individuals in the Army's Schools and Training Centers. Our history bids policy-makers and resource-allocators remember that it was the Army school system which prepared the Army for the mobilizations of World War I and World War II, and developed the cadre of leaders from which came Marshall, Eisenhower, Bradley, Patton, Gavin and Taylor --men who played central roles on the national stage from 1941 well into the 1960's, each of whom has acknowledged a debt to the individual training he received in the Army's institutions of his time. But there has always been tension between the needs of the Army of today, whose readiness depends in some large measure on the presence of trained leaders capable in turn of training their units,

Department of Defense Directive Number 1430.13

TRAINING SIMULATORS AND DEVICES

August 22, 1986

APPENDIX 2

to

VISUAL SYSTEM TECHNOLOGY APPLICATIONS FOR IMPROVED TRAINING/SIMULATION

Short Title: VSTA