LOW COST TRAINERS:
LESSONS FOR THE FUTURE

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ABSTRACT

A new generation of part-task trainers is required if the simulator industry is to support squadron level training, team training, large networks of manned combat engagement simulators, and deployable simulators to support Global Reach--Global Power. This paper will describe the genesis, development and results of an effort attempting to provide that capability.

The goal of Aircrew Training Research Division is to develop a family of training devices for training research at the operational squadrons. This goal required that training devices had to: (1) be low-cost, so they could be widely deployed at the squadron level, for example, low-cost microcomputers, graphic devices, and selective fidelity to provide user acceptance while cutting development cost; (2) be networked with minimum two-ship network, since in an operational squadron the basic element is a two-ship; (3) be "pilot friendly" without operators, maintenance crews or even instructor pilots; and (4) be able to provide training in mission critical skills. The engineering plan included the additional descriptors: (5) a flexible system or an extensible system to allow for growth, (6) a distributed system to allow for real time high fidelity simulations, (7) a modular system in both hardware and software so the device could keep pace with technology and changing training needs while capitalizing on existing software, and (8) a deployable, self contained system requiring only normal classroom environment.

The result: a family of low, medium and high fidelity trainers utilizing the same software core, networked in local and long haul networks. The low fidelity Air Intercept Trainer (AIT) has been fielded since Oct. 1986, transitioned to user with a total of thirty devices between the AF Reserve, ANG, TAC and AL, and has included several research studies including a transfer of training study. The medium fidelity combat engagement (CET) is an innovative glass cockpit design. Two were fielded in July 1990 and are used as manned flight stations for network and team training research. The high fidelity Multitask Trainer (MTT) is a simulator in a deployable shell. Phase I of the MTT was demonstrated at the 1991 I/ITSC and there are now four units, one of which will have been fielded in August 1992 at the 926 TFG for evaluation.

This paper will portray the evolution of this effort, the engineering solutions, its direct technology transition, lessons learned, field observations and future directions.

ABOUT THE AUTHOR

Garry H Boyle is an electrical engineer at the Air Force's Armstrong Laboratory, Aircrew Training Research Division and has worked there since January of 1981. He is the project engineer for the Part-Task Trainer (PTT) Laboratory. His work includes: the Electronic Combat PTT, the low-level video disc trainer, the MAC electronic warfare tactics trainer, the Air Intercept Trainer (AIT), the Combat Engagement Trainer (CET), and the Multitask Trainer (MTT). During the past six years Garry Boyle has been the project manager for the AIT. He has taken the AIT from project conception through the design, development and transition to Air Force users. He has evolved the AIT concept into a prototype for a deployable mission tactics trainer via the CET and MTT projects. He received his B.S. in electrical engineering from Arizona State University in 1975.

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INTRODUCTION

Today's aircrews must be highly proficient in many operational skills. Modern aircraft systems are intended to optimize the effectiveness and survivability of aircrews during combat, but aircraft complexity also places increasing demands upon the training process. In this age of Global Reach--Global Power, the training manager wants a trainer that can be deployed with the troops. The shrinking defense budget, along with the need to have trainers at the squadron level, requires a new generation of low-cost part-task trainers. The Aircrew Training Research Division of the Armstrong Laboratory (AL/HRA) at Williams Air Force Base, AZ, is developing and validating technology solutions and advanced training methods that will provide affordable squadron level trainers.

Taking R&D into the Field

AL/HRA's goal is to develop technology that enhances and/or lowers the cost of training. The user's goal is to have mission-ready pilots with an experience level equivalent to ten combat missions. The problem has been to develop a trainer that is affordable, reliable, deployable, and focuses training on mission-critical tasks. It also meant development of team training and other concepts that could be best researched and developed in a laboratory and studied in a squadron environment. The solution for both the Lab and the pilot community has been to provide low-cost, stand-alone devices available to pilots at the squadron level.

The Air Intercept Trainer (AIT) and its two successors were the result of the Laboratory's efforts to meet both the training and the behavioral research need. An important spin-off has been the development process itself which demonstrates a successful technology transition within the Air Force (AF). The AIT was first demonstrated at the Interservice/Industry Training Systems Conference (I/ITSC) in 1986. At the 1989 I/ITSC, AL/HRA demonstrated a two-ship AIT with ground control intercept (GCI). The three simulations were on a local network and tied long haul to an AIT at the Aggressor squadron at Nellis AFB, NV. 1990 found the lab demonstrating a glass cockpit system called the Combat Engagement Trainer (CET) tied into the I/ITSC SimNet. 1991 I/ITSC was our year of the Multitask Trainer (MTT), a deployable simulator with helmet-mounted display. This paper discusses development of these devices along with the lessons learned.

Why Focus on Technology?

The technological thrust represented by the AIT program was in part an outgrowth of a leadership obligation of AL/HRA. The original plan was to build a prototype part-task trainer (PTT) to demonstrate how state-of-the-art technology could help meet aircrew training needs. It appeared that the AF was not willing to commit to large quantities of low-cost devices until utility had been demonstrated, and industry could not develop low-cost trainers until there was a quantity demand from the AF. The Lab also wanted to promote the stand-alone trainer concept. This would require developing such techniques as performance feedback and expert systems for providing IP feedback.

The Lab was also interested in the potential training utility and cost savings that micro-computers and graphic systems could provide. This required implementing microcomputer technology to support simulator systems that

need: a) massive computing power; b) real-time distributed processing; c) a hardware design that can grow with need and keep current with technology; and d) a software design that utilized the best of software modularity, transportability, and new programming structures such as object oriented and artificial intelligence (AI) technology.

An earlier Laboratory thrust, the Combat Mission Trainer (CMT), influenced the push toward a deployable squadron-based technology. The object of the CMT ideology was to provide a mission rehearsal capability in a squadron-deployable package. The cockpit, with associated computer and visual system, had to fit into a semi-trailer. This required compact simulators, helmet-mounted displays, and the development of databases and image generators displaying photo texturing.

Waving a Flag

AL/HRA Lessons learned from our work on a unit level trainer focus on four concepts. They are: a) software portability (including between aircraft and simulator), reusability, and concurrence; b) open standards; c) trainer modularity or a growth path; and d) user involvement. Future training dollars must build on today's investment; additional money must provide additional capability. The Lab used the AIT development to demonstrate these points.

1) Software portability and reusability: During the first nine months of AIT development, we took existing radar code from a full-mission simulator (F-16C Block 30 that was being delivered to the AF from the Singer-Link) and re-hosted it on a micro for the AIT. We were able to move the code from a Weapons System Trainer (WST) to a PTT and then, to prove the point, back to another WST. The real intent of this effort was to encourage the ModSim concept. If government agencies would request that industry provide the simulator software in a modular fashion, then PTTs could be developed for each subsystem from existing code. Updates could feed between the PTT and the Operational Flight Trainer (OFT) or WST. This would aid the concurrence problem, the nemesis of simulation-based training, dividing it into manageable chunks where updates could be identified, developed, tested, and controlled. The two succeeding programs were similarly structured.

The CET used AIT and other existing lab software. The MTT used existing AF owned F-16C OFT code along with aircraft systems line replaceable unit (LRU) software that was converted to run on a real-time multiprocessor unit internal to the cockpit. Additionally, this high fidelity software core could then be the software baseline for the entire family of trainers, AIT, CET and MTT. Resources are well utilized; overall configuration control is easier with fewer software packages to maintain, and overall program concurrence can focus on one product.

The issue of resource management is critical to every industry. For a company to remain competitive it must build on its successes. It cannot ignore its gains and start from scratch for each development. Likewise, for the Air Force to maintain its strength in this competitive world it must be able to build on its successful investments. The competitive commercial software marketplace has had to be very efficient at this to survive. Everyone that has used a word processor has benefited because the developer has improved on its successful product. The common word processors used to write this paper is easier to use and more capable than yesterdays most powerful desktop publisher. The government, on the other hand, constrains its procurement such that it must reinvent the wheel each time. Does anybody even know how many F-16 aero packages the government has paid for? Every F-16 aero package we've seen has been deficient. If the government had used its funds to improve a single program, everyone needing a high-fidelity F-16 package would have it available to them and the government could focus on other issues, such as weapons or threat simulations.

2) Open standards: The Department of Defense has been adamant that all future training systems have the capability to interact. Yet this is probably the most difficult of all the before mentioned concepts to achieve. There are many standards that must be worked out; network protocols, data base formats, threat simulations and modular software (such as, Distributed Interactive Simulation (DIS) or SimNet, Project 2851, Universal Threat Systems for Simulation (UTSS), and HAVE MODULE (ModSim).

3) Trainer modularity: System design must accommodate growth and evolution to the

widest extent possible or be a throwaway design. Provision for technology injection is essential because of the speed of technology change and the need to keep pace with user requirements. If the design does not allow for implanting new technology during the process, the system is out of date and unmaintainable upon delivery. The process must accommodate infusion of new technology such that the project is not consumed "chasing" technology and is never fielded. In our effort to deliver current technology, we first tried to design with future technology. In the process we found ourselves on the "ragged edge" rather than the "cutting edge" of technology. What finally worked for AL/HRA was to use two prototypes. One prototype was used for experimenting with new technology; the other for product development. The engineers could bounce between the two. This made the freezing of the product design palatable to the engineers who still had a device to experiment with. Knowledge gained from the test prototype helped the engineers know when a technology was ready to be inserted into the product prototype.

4) User involvement: User involvement receives a lot of lip service but actual working examples are rare. The definition of user is a person who will use the fielded device. Although it can't be treated adequately here, suffice it to say, the user must be involved throughout the process (system specification, contracting, design reviews, development, and test). The success of the AIT/MTT was in large part due to the efforts of users that needed such devices. Government contracting and industry must find ways for the developer to have a meaningful dialog with the person climbing into the cockpit.

PUTTING IT ALL TOGETHER

Three factors were critical to the success of a unit level trainer: a) identifying a suitable mission-critical task; b) building the right team; and c) involving each member of the team such that the training of that task becomes the focus and object of the entire team.

Let the Need Arise

Discussions were held with each of the major commands (MAJCOMs) about suitable training tasks. Long-standing discussions at the operational training echelon of Tactical Air Command (TAC) now Air Combat Command (ACC) had identified a need for an F-16 head-up display (HUD) training device. Meanwhile, the Air National Guard (ANG), faced with the necessity of developing a new training program to accommodate a new aircraft (F-16A) and a new air role (air-to-air), were most interested in the potential of the low-cost technology under exploration at the Laboratory. A team of subject matter experts lead by Major Milt Miller from the ANG (now with the Air Force Reserve (AFRES)), identified the beyond visual range (BVR) aspects of the air intercept as their highest priority training need. The ANG requirements specified a real-time simulation with radar electro-optical (REO) and HUD displays along with associated cockpit controls. A device with such capabilities could be used in the schoolhouse to train a) "hands-on throttle and stick" (HOTAS) skills, b) HUD/REO interpretation skills, c) basic situational awareness of target tactics (that could be seen on the instructor operator station (IOS)) from symbology movement on the radar, and d) basic intercept geometry. The expectation was that such a device could also be used in an operational squadron for a) honing basic skills to automaticity, b) developing two-ship communication, c) teaching target sorting skills, and d) teaching basic two-ship intercept tactics.

There have been two configurations of the AIT. The first AIT had a hi-fidelity radar, a crude aerodynamic package, a black-and-white monitor displaying only HUD symbology, a throttle grip that we bought from the original manufacturer, a stick put together in-house, a 68000/VME-based microcomputer with a Singer Link- developed, real-time multi-processor operating system, and a Z-248 (PC AT)-based IOS we called the Student Information/Control Station (SICS, or in the pilot vernacular, "check your six"). The HUD and REO were driven from the same graphics board utilizing two of its RGB (red-green-blue) signals. Four of these devices were fielded but later updated to maintain configuration control. This next configuration added a graphic workstation as a one-channel visual with HUD overlaid, a newer central processor unit (CPU), a Block 5 aerodynamics downloaded from an existing laboratory simulator, and the capability for local area networking (LAN) via Ethernet.

The first F-16A AIT was delivered to the Tucson ANG in Oct 1986. Several experiments were conducted on this trainer. The second AIT was delivered a year later to TAC at Luke Air Force Base, AZ, and it could be operated as an F-16A or F-16C depending on selection at system boot up. A noteworthy transfer of training study was performed over a two-year period on this device, demonstrating its training effectiveness for entry-level F-16 students.

AL/HRA (then HRL) demonstrated a low-cost network at the 1989 I/ITSC. AL linked two AITs with GCI at the conference in Ft. Worth with an AIT at the 64th Aggressor Squadron at Nellis AFB, NV. This was accomplished over a 56KB line using Ethernet bridges. This test served as a bases for the radar extensions to the SimNet protocol used in the 1990 I/ITSC network demo.

The ANG has six AITs (three at both of their F-16 schoolhouses). The ANG schoolhouse in Tucson, AZ, has had an AIT since October of 1986 and is a model of how to assimilate an AIT into a training syllabus. The ANG has been able to restructure three flight sorties to allow for much more advanced training, and has received a laudatory write-up during their Inspector General (IG) visit, because of the AIT. The ANG Bureau has procured additional CET-type F-15 and F-16 devices for their operations squadrons. They have included specifications for the following additional options: self protection, networking, limited air-to-ground operations, and several of the more important emergency procedures. This gives a view of how the ANG views future use of such a device in their squadrons. The latest Unit Training Device (UTD) Program Management Directive (PMD), and associated Aeronautical Systems Division's (ASD) effort provides a further definition of AF needs in a unit level device.

There are now thirty operating AITs. Every student, either beginning or transitioning in the TAF, receives instruction on an AIT. An experiment was performed in 1991 to evaluate the efficacy of using an AIT for pre-training transitioning pilots unfamiliar with the intercept role prior to receiving the concentrated academics of the schoolhouse. The advantage these students had was so apparent that one of the next F-16-bound squadrons negotiated with a Reserve unit to borrow their AIT. A major loan program has now been instigated with the ANG to lend AITs to their transitioning squadrons prior to the formal schoolhouse training.

Building the Right Team

A balanced team means having the right disciplines with rapport, a sense of ownership, and a feeling that the project will "make a difference." From the beginning there was a close working relationship between the engineers and psychologists and we were determined to involve training design and subject matter experts. Psychologists stressed the need for a stand-alone trainer, emphasizing that with today's computer power the trainer should guide, offer feedback, and track pilot progress. Chief subject matter experts, Maj Milt Miller and Maj Ed Kosiba from the AFRES, educated the team to the mission requirements, kept the design honest, and inspired the team with a sense of mission and importance. The manager for the on-site contractor team had a "can do" attitude. The engineers, software and graphics programmers had a great deal of experience in the simulation field and a desire to be innovative. The training designer was able to keep those innovations focused on the task and to organize and record brainstorming sessions as well as subject matter expert interviews.

PRINCIPLES IN THE EVOLUTION AND TRANSITION OF TECHNOLOGY

Analysis and Selection of Critical Skills

Ask any ten pilots how best to fly a particular mission and you will get a minimum of fifteen responses. Ask them what critical tasks they would like more practice on, and you will find much more agreement. The aircraft is the best place to practice most mission skills. But because of various restrictions, simulation affords a better opportunity for developing and polishing the enabling skills. Training in the simulator can make time in the jet more effective and allow the "JP-4" to put the fighting edge on the pilot.

Designing a training device requires knowing the mission, defining the training problem, and knowing the strengths of media. Communication between training designers and engineering teams from the beginning will pay big dividends

throughout the project. The task selected should focus on skills that can't be practiced frequently in the existing environment. The training community must also be aware of external factors that change training requirements, such as the low-level flight restrictions imposed in Europe, or lessons learned in Desert Storm.

Some tasks we found particularly conducive to part-task training include: a) electronic combat skills, because one can't arrange for enemy radar or openly employ countermeasures; b) emergency procedures, because one doesn't want to break something or put students into life-threatening situations; c) weapons employment, because of the expense of firing expensive weapons; and, of course, d) air intercepts, because they require frequent practice with infinite variations (adequate practice is hard to come by in the aircraft because of logistics). It should be noted that all these examples require the pilot to develop a sense of timing which clearly delineates a real-time simulation system.

Selective Fidelity

A real program killer is unmet pilot expectations. If you are not simulating it, don't try to make it look like you are. Functions modeled must either be of such low fidelity that the pilot does not try to equate them with his aircraft, or be equal to the fidelity of his aircraft environment. For example, an experienced pilot expects a real-time (meaning as in the aircraft) response capability in the trainer, otherwise, it can throw off his timing and rhythm.

To make this point we took selective fidelity in the AIT to the limit by making the "cockpit" very plain. The AIT lacks a certain cosmetic appeal, but it proves the point that the user will look past some starkness if the right systems have high fidelity. On the other hand, pilots see and feel the high-fidelity MTT cockpit and expect it to operate exactly as the aircraft.

Trainer fidelity must consider the experience level of the user. We found a "lieutenant-trainer" phenomena with the AITs. The pilots who trained on the original black-and-white HUD/REO trainer thought it was a fantastic trainer. As they went to new squadrons, they wanted AITs there too. Their experience had been in using the AIT for basic skills acquisition, for which it had

performed extremely well. AITs fielded in the first operational squadron were more sophisticated than the older schoolhouse trainers. Yet the pilots tended to pick at all the subtle differences between trainer and aircraft. They felt restricted by the structured menus and modes of operation used in the schoolhouse. They were more interested in using the AITs in a network but the early network setup was very cumbersome. Considerable system changes had to be made before the AIT could capture the interest of the experience pilots. The MTT has grown out of our effort to meet the needs of the operational squadrons.

Provisions for System Growth/Evolution

The Lab atmosphere was crucial to the evolution of this trainer concept. The simulators in the Lab are being modified constantly, added to, or combined with parts of other projects to accommodate different research goals. One might say that the Lab has come up with its own version of the "Potato Head" game. Laboratory devices must have the capability to capture data for yet-to-be determined research efforts. In this case, the lab became a sort of greenhouse for the growth of fragile yet crucial concepts, which otherwise might not have survived to maturity. The AIT, CET, and MTT designs have benefited from this environment because they inherently provide for flexibility, computational evolution and growth, and software hooks for capturing pilot performance. This design "built for a laboratory" has also proven to be an optimal design for the field. A case in point, is the planned update of the fielded AITs to inherit selected capabilities from the MTT including its software.

The options for a computational platform were many. A workstation, which typically has a great development environment, lacks hardware flexibility, a simple growth path, and usually real-time operation. A bus-based system, which offers flexibility, growth, and an upgrade path for keeping up with state-of-the-art technology, puts us once again on the ragged edge of technology. But the ability to innovate and evolve with technology won out, and this philosophy led us to choosing a VME-based system. This decision has been invaluable in the development and upgrading of the AIT, as well as its blossoming into a CET and MTT.

Simulation visual systems have always been expensive. Analysis of the BVR intercept indicated that a visual was not required, and the first AIT, called the HUD/REO PTT, did not have one. It used one VME graphics board to drive both the HUD and the REO displays. We gained some interesting insights from this configuration. At first there were comments that it would be hard to use, since there were no instruments or a horizon line to allow the pilot to fly the plane. The comments came back that although it was difficult to fly (maintain level flight), it was doing wonders at increasing proficiency with the HUD. Because of this, we now include a HUD-only option with current versions so that the AIT can provide these added training benefits. A one-channel visual was finally added. The reasons could be summarized as follows. First, we were trying to teach air intercept skills, not how to fly our particular aerodynamic package. Second, the visual capability increased pilot acceptance of the device. Third, the introduction of 3-D perspective graphics workstations that cost less than $30K made it cost effective.

We decided to keep the visual a separate module, which allows us to easily take advantage of new low-cost image generators as they became available. The visual has been connected via an Ethernet. This has created some inefficiency when using workstations, since they typically have a very powerful CPU that may not be fully used. The inefficiency has been more than offset by the advantage that modularity and flexibility have added.

System Design Economics

The challenge was to build a device for a quarter of a million dollars. The results of some existing code, $1.55 million in non-recurring costs (for both F-16A and C versions, networking, and basic debrief), and three years of evolution produced a design that provides two networked AITs along with a GCI station or twice the capability for less than that goal. The AFRES has fielded a networked pair in each of its F-16 squadrons for about $100K each ($162K if nonrecurring costs were included) or $200K a pair. The cost was kept low by using microcomputers and other commercial, off-the-shelf hardware, and closely monitoring the fidelity that we put into the device. We have to add a "don't try this at home" because our

nonrecurring costs were kept low due to it being an in-house government project where we had access to documentation and existing simulator code. Also, we were not required to "make a profit."

Early in our design phase we discussed developing "smart" targets. If we were going to train tactics, the pilot needed a bogey that could be maneuvered against. Our feeling at the time was that there are many inherent problems associated with developing intelligent, reactive bogeys including the cost of developing realistic characteristics, and if the pilots can game the system, it could sour them on its usage or even result in negative training. Our decision was to devote major effort to developing a low-cost device that could be tied together in a low-cost network, thereby providing man-in-the-loop tactics, as well as team training. However we also provided targets that flew to way points. This capability allowed scenarios to be built where the targets (up to five) accomplished elements of typical tactical maneuvers. This allowed students to develop their radar interpretation skills and mental model of the real world (situational awareness) by correlating maneuvers that they could identify on the SICS with the radar display.

A SQUADRON LEVEL TRAINER

"Train-As-We-Fight"

One would not expect to have a championship basketball team if its players a) had restricted practice time, b) could dribble, but only occasionally shoot, c) played only on the home court, d) practiced only with their own team, and e) very seldom played with the whole team. Development of expertise requires instruction, practice, and critique with the whole team.

The goal was to provide a "train-as-we-fight" environment. The basic fighting element in the tactical air forces is the two-ship. If we could provide the trainers in a two-ship networked package, we could train basics in two-ship communications, radar usage, and tactics. The idea of working on communications skills led us to adding a GCI station. Intercept controllers are an integral part of an intercept, and yet have little chance to train and debrief with the pilots.

In a two-ship, the radars should be utilized as complementing rather than redundant systems. Pilots need to practice sorting, "sanitizing," and targeting as a team. We hoped the networked configuration also could help in providing refinement and coordination of tactics, and situational awareness. The deficiency in our system was that it did not include any emergency or weapons training. The concept was to replace one of the networked AITs with an MTT. The AIT would eventually run the same software as the MTT and become an AIT+ or CET. A pilot could then practice intercepts or some weapons on the AIT+ and EPs, instruments, or weapons on the MTT and team training with the two networked. This also kept the number of simulators in the squadron to a minimum and limited software maintenance to one software package.

Although we anticipated and designed for the operational squadrons, we became caught up in the regimentation of the schoolhouse and some of it transferred into the AIT trainer. The operations pilots wanted control over their program--(human nature, especially among pilots). The squadron weapons officer wanted to design scenarios that complement what they were working on in the air. Operational pilots wanted a mission orientation rather than the formation orientation of the schoolhouse. Operational pilots were also very interested in the weapons training possibilities inherent in the AIT. The project emphasis had to be directed once again to recurrence training and team practice in a mission atmosphere, hence the development of the CET and MTT.

Batteries Not Included vs. Stand-alone

When you buy a simulator, you must buy the operations and maintenance support with it. This normally includes an operator, one or more maintenance technicians, special facilities with unusual power requirements and heavy air-conditioning loads, and expensive software maintenance agreements. This is not so with the AIT, CET, or MTT. No maintenance technicians, operators, special facilities, air-conditioning, special power, or proprietary software rights are required for reliable operation.

How do you make a computer system "pilot-friendly" as well as "pilot-proof?" The

existing AIT is made up of a VME system core that operates under a real-time operating system. It has two separate software loads (one for F-16A and one for an F-16C), an IOS that is a PC operating with an MS-DOS system connected via shared memory, a visual system operating under Unix and connected via Ethernet, and all of this connected via Ethernet to another AIT. It took some effort, but the AIT has a one-switch turn-on that comes up in a couple of minutes to a pilot-oriented menu.

However, we found that some of our ideas did not fit the "user-friendly" mold. The original Unix boot-up time was too long for some pilots. Even with a timer displayed, some would become impatient and cycle power which would corrupt Unix and render the system unbootable. We replaced Unix and the VME hardisk with erasable programmable read only memory (EPROMs). This design shortened boot-up time, reduced parts, lowered costs, increased reliability, and made it easier to make software updates. Today, many repairs can be evaluated over the phone and a computer board sent next-day-air to the unit as a replacement. Student performance and research data is still being collected on the disk drives on the SICS. The networking has been simplified considerably and there are short-cut menus for experienced users. Notebooks holding operating instructions are being augmented with pilot kneeboard checklists.

Another objective that the team worked toward was that we wanted the AIT set up so that it was impossible not to have a learning experience each time a pilot used the device. We wanted to teach the "why" of intercepts rather than procedural rules of thumb. This required that cognitive as well as procedural skills be developed. This meant well thought-out scenarios, that covered all the basic intercepts and tactics elements, and fitted into an instructional design that by their sequence formed a training methodology. Experience suggested that providing only a capability to generate scenarios translated into a lot of scenarios of places pilots had been involved in (Red Flag, Crow Valley, etc.) and not necessarily designed with training in mind. Probably the best solution is a combination of building block training scenarios and the capability for the weapons officer to design "scenarios-of-the-day"

based on Defined Operational Commitment (DOC) and expected threat.

Another requirement for a training device to be stand-alone is to have a debrief capability. Performance measurement systems can be problematic for several reasons: a) experts do not agree on what is the "best" intercept; b) the intercept method is based on the rules of engagement (ROE) as well as the squadron's DOC; c) there are many possible "right" paths or flight envelops; and d) pilots may resist being "scored" by a computer. AL/HRA has investigated this issue extensively. A "score" can provide a number to judge from, but not enough information to learn from. Thus it is hard to gain a consensus on any one set of values or algorithms. Experience suggests that the best approach provides a simple yet clear picture of what took place during the engagement. This includes identifying critical events as well as the switchology. AL/HRA spent a good deal of effort in getting the computer to recognize the elements of an intercept. If the pilot can get a concise mental picture of what was taking place and when, he can usually determine how to correct or improve upon his performance. A user-friendly feature of the AIT is that the student can save the debrief on a floppy disk and replay it for his instructor on any PC that is convenient. AL/HRA is continuing work on debriefing strategies including manipulating the simulation replay in a virtual reality environment.

Enter Stage Right

The AIT and MTT are now being produced by ACC's Training Systems Center (TSC) facility at Luke Air Force Base. This is a good example of how technology can be transferred. That is, a close working relationship between the laboratory or developer and the user will evolve the concept through a prototype that can be evaluated in practice. Continued shadowing by the laboratory throughout the production phase insures continuing user acceptance and training effectiveness. The commercial market should translate this to having an R&D and training design group develop the trainer, with the user and the fabrication group as team members (by another name, it might be called Total Quality Management).

AFRES has now placed AITs in each of their operational squadrons. We are requesting user feedback through a newsletter and a usage study. The Reserves have set up a very effective management scheme. They have provided a means whereby revisions for concurrence and upgrades are built into the management system including a manager that has a flying slot. AFRES has been very interested in making the squadron level trainer a success.

WHAT NEXT? - FUTURE DIRECTIONS FOR LOW-COST TRAINING TECHNOLOGY

Are we growing the PTT into an OFT? Two viable answers apply. First, there should always be a place for a trainer that is built around a specific, mission-critical training task. Second, it's hoped that the OFT of the future will utilize many of the design concepts of the AIT/MTT, in fact, it may be imperative if future trainers are to meet the Global Reach--Global Power challenge. AL/HRA is evolving the AIT in both directions with the CET and MTT.

The purpose of the CET is to provide AL/HRA with an additional manned simulation capability for conducting multiship, combat-oriented training research. The Reserves are evaluating the design for AIT+ applications. The CET is built around a "glass cockpit" design using a 27" cathode ray tube covered by a plastic mask to model the front console. The mask houses all the buttons and can be removed easily thus providing the cockpit "feel" that the pilots prefer, yet provides a means to change the console layout quickly. The side panels are separate modules that can be added as requirements dictate. The cockpit shell can be broken in half so that the stick, throttle, and side panels are in the same half. This was done so that, broken apart, the CET can fit through a standard 36" door and, by replacing the mask and back half of the cockpit, a new aircraft can be simulated.

AFRES came to AL/HRA several years ago and said that they needed an emergency procedures (EP) trainer but did not have the facilities for more simulators. The solution was to augment one cockpit of the two-ship AIT with additional capabilities to support additional or multi-tasks such as EP training. Thus the AIT could be used to teach intercept basics and as a finger exerciser before a sortie, and the MTT

could be used for training "inflight" emergencies. The two devices could be networked to provide the two-ship training accomplished by the two AITs as originally configured.

AL/HRA began this cooperative effort with AFRES to investigate several research questions, including the following: a) What technology can be used to lower the cost of safety of flight training? b) Can lower-cost, glass cockpit designs be used for EPs that require high fidelity cockpits? c) Should EPs be taught in a dynamic (vs. static) environment? AFRES feels that some safety of flight problems occur because most emergency training is limited primarily to static or nondynamic training devices. d) Can AI methods be used to update EP cockpit response procedures? e) Can we keep the student motivated during this type of training? f) Can AI programming techniques be used to enhance training capability with adaptive training and reduce instructor pilot workload? The Reserves, ANG and TAC have recognized a need to reduce IP workload and provide training to students whenever they have a few spare moments.

An F-16C aircraft simulation was implemented to test the design. The physical device is a fully functional, three-dimensional cockpit, with all cockpit controls. All the computers necessary to drive the real-time simulations, cockpit instruments, instructor operator station, and a one-channel visual as well as air conditioning are self-contained. The MTT can be split apart to fit through a 36-inch doorway and requires only three 110 volt, 20 amp circuits ensuring access to any squadron classroom. Actual aircraft code was used to insure high fidelity avionics and concurrence. Existing high-fidelity, Air Force-owned operational flight trainer (OFT) software was used to provide the aircraft simulation. Government-owned software was used to keep development costs and risks low while maintaining the highest fidelity simulation in existence. The result is an OFT in a less than five by six foot box with a design capable of training many mission critical tasks at the squadron level. It can be deployed with the unit to continue combat mission training. The technical success of the program, and its impact on the future of aircrew training device design resulted in the MTT program being selected as the USAF "Technology Demonstrator" for the 1992 international air shows.

A simulator using actual aircraft avionics software modules provides not only concurrence with the aircraft but also offers many opportunities for multi-use in programs other than training. The MTT design could also provide in-depth test of proposed line replaceable unit (LRU) updates prior to aircraft tests. A proposed LRU update could be prototyped and even put into specified squadron trainers for user feedback prior to design freeze. The same concept could be carried into new aircraft development in which case the prototype/trainer software becomes the designed, written, and tested aircraft code as well as trainer code. Simulator and aircraft concurrence would no longer be an issue.

A low-cost image generator and display appear to be the last frontier for the unit level trainer. AL has worked with several displays, including: a slewable view, a 360-degree alternate view point (ATOF plot), and a low-cost liquid crystal display (LCD) helmet. We are evaluating the Display for Advanced Training and Research (DART) display, and high resolution black-and-white CRT and color LCD helmet-mounted displays. We are closely monitoring the image generator and computer graphics market, especially for compact low-cost image generators with photo-texturing.

The Last Hurrah

So what do we see as the family of trainers of the future? We think critical features will include: a software design using the same high fidelity, modular, object-oriented, reusable code in each of the trainers; commercial, off-the-shelf, Cray-on-a-chip-based microcomputer boards-- with a bus bandwidth to support it; a modularly designed cockpit that can be fitted to match the training need and deployed with the unit; expert systems helping to provide IP quality debriefing; a network that will work over regular phone lines with similar devices or tied in through a network interface to other network players; a low-cost, high-resolution color helmet-mounted display with texturing; and a combat-ready pilot in every cockpit.