PART TASK TRAINERS:

AN EFFECTIVE MEANS TO MEET TRAINING REQUIREMENTS

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ABSTRACT

With the development of increasingly complex weapon systems comes the need to train personnel to operate these systems, which now require an increasing array of aircrew skills. This paper focuses attention on the need for development of Part Task Trainers (PTT) which enable aircrews to acquire these skills in a timely and cost-effective manner. It presents a multidiscipline view of PTTs, as perceived by an Engineering Psychologist, a Fighter Pilot, and a Design Engineer. It briefly reviews the record of PTT development, focusing on the importance of front-end analysis of training requirements as the basis for considering and selecting training approaches that may effectively be met by PTTs. Target areas for PTT applications are discussed and proposals are offered for the development of some unique PTT concepts including the potential for increased use of generic and specialized PTTs. Potential solutions, cost savings benefits, and improved training expectations are discussed.

INTRODUCTION

Aerospace weapons systems (and military equipment in general) are becoming increasingly complex as growing technology provides increased total system capability. Modern military aircraft employ a sophisticated and complex integration of digital avionics, sensor systems, fire control and weapons delivery systems. The degree of complexity is illustrated by aircraft such as the F-15, F-16, and F-18; sensor systems such as PAVE TACK and LANTIRN; and Precision Guided Munitions (PGM) such as the GBU-15 Guided Bomb and AGM-65 Maverick Air-to-Ground Missile.

Operation of these complex systems requires an increasing array of cognitive, manipulative and psycho-motor skills. Methods for training the associated tasks have received considerable attention, but only recently has much notice been given to organizing the tasks so that specific behaviors are treated in specific devices. For a long time, the main thrust of trainer design has been toward designing for maximum training potential...and a much worn out phrase...just like the aircraft. The response to simulator (training) requirements for the newer sophisticated aircraft has also been generally to produce simulators which will fly like the aircraft. Lacking sufficient quantitative data on training effectiveness, simulator users and developers have played it safe and opted for maximum fidelity in simulator engineering. Simulator technology, particularly in the visual area, has made rapid advances and some current simulator programs are pushing the state-of-the-art, sometimes beyond technology limits. Simulators, therefore, have become much more complex and sophisticated...and increasingly expensive. The new B-52/KC-135 Weapon Systems Trainers (WSTs) are examples of highly complex training devices which are representative of current state of the art for full-mission training. The approach to simulating various subsystems for electro-optical(EO)/infrared imaging, fire control and weapons delivery has also been driven by a similar desire to replicate the "real-world." Without definitive analysis to prove otherwise, a fully integrated system has generally been the requirement. This approach is usually based on the general user feeling that only a "fully operational" cockpit will provide effective training.

Recent trends in training systems design have therefore emphasized the large WST systems with intensely accurate visual and sensor simulation subsystems that attempt to emulate the "real-world" environment. This can result in a costly development and production program when (for example) Forward Looking Infrared (FLIR) or Digital Radar Landmass Simulation (DRLMS) is required to be integrated into an existing simulator to produce full-mission simulation over an extensive gaming area. We believe that not enough consideration has been given to identifying related sets of training requirements suitable for smaller, less complex devices to be used as PTTs. This paper focuses attention on the possibilities for part-task training to cost-effectively train many of the unique and complex tasks associated with the operation of modern aircraft and their weapons systems.

Basically, the USAF defines the use of trainers into several categories. Weapon Systems Trainers (WSTs) are the most complex (and expensive) simulators, but they permit each crew member to practice a full-mission task and become proficient in a very realistic environment. Operational Flight Trainers (OFTs) provide training in basic flight maneuvers and aircraft systems operation as well as normal and emergency procedures. Cockpit Procedures Trainers (CPTs) permit pilots to develop proficiency in routine procedures and to react to emergency procedures like engine failures, fire or electrical malfunctions. Cockpit Familiarization Trainers (CFTs) provide basic practice on location of switches and indicators, and are normally used to initiate pilot training for a particular aircraft. Part Task Trainers (PTTs) permit crew members to master and maintain currency in specific tasks like aerial refueling, gun sight dynamics, sensor system interpretation or system tuning. Such mastery can often be achieved in less complex trainers more effectively than using a single WST or OFT. This becomes particularly important when acquisition and maintenance costs limit the quantity of trainers and result in training "bottlenecks."

An operational definition that we have come to use for PTTs is: a device, limited in scope, that is designed to treat a specific set of behavioral events that will...at some time...be integrated with other behaviors to perform a broader task. Part Task Trainers are not new; in fact, they represent possibly the earliest form of "active participation" training aid to be employed (WWI Aerial Gunnery). Groups of PTTs have been known as trainer "families," "building blocks," and more recently "modular" approaches to training. Some recent PTTs have also become large systems, nearly as complex as WSTs...because of the extensive list of cues apparently required by the training task. An example of a complex PTT is the B-52 Aerial Refueling PTT (by Redifon), which has a full cockpit with a Duoview visual display system mounted on a hydraulic motion base (Figure 1).

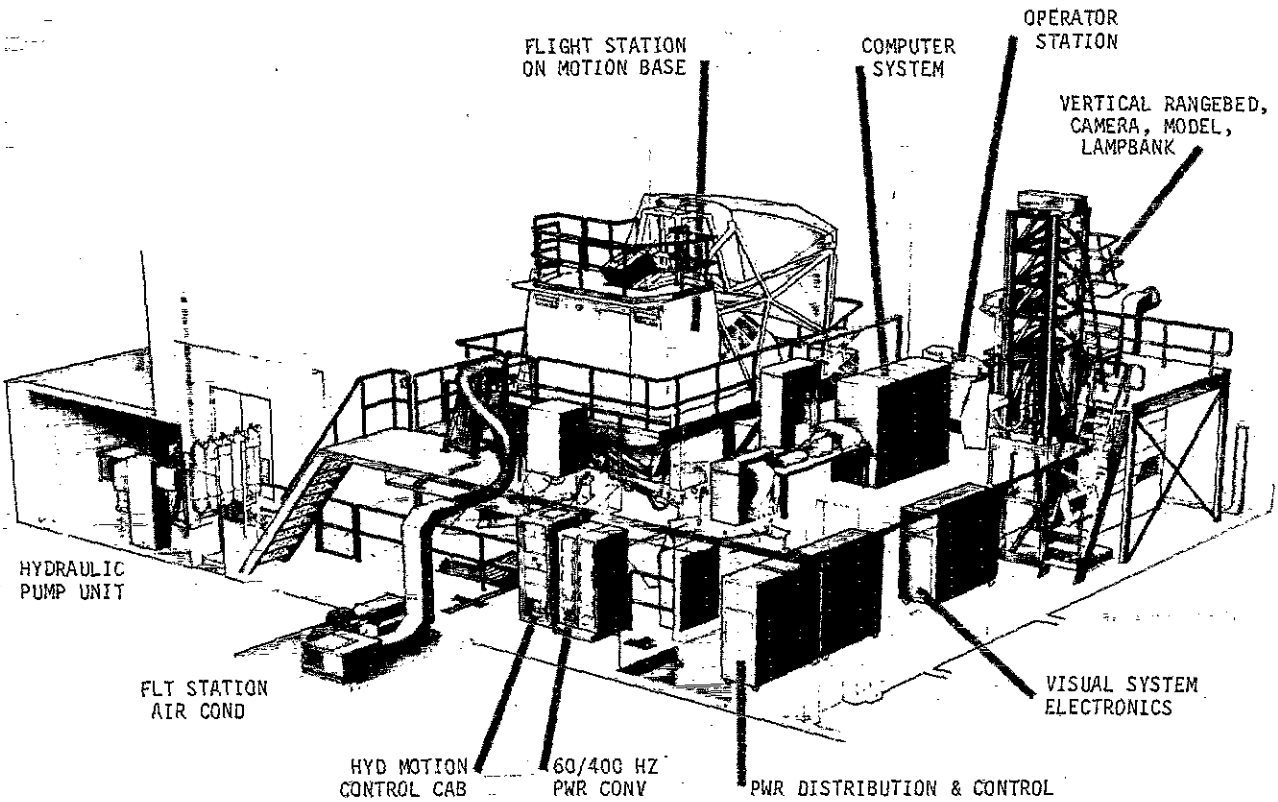


Figure 1. B-52 Aerial Refueling Part-Task Trainer

The KC-135 Boom Operator PTT (by ASD and SRL), with a true-perspective visual display and range bed camera/model image generator, represents an intermediate level of PTT complexity (Figure 2)(4). The Functional Integrated Systems Trainer (FIST) (by SRL) for the AC-130H Gunship is another example of a medium complexity PTT (Figure 3)(2). This PTT is somewhat unique because it provides for simultaneous training of tasks associated with several crew stations, and is the equivalent of multiple interconnected part task trainers. The recently delivered F-106 Aerial Gunnery PTT (AGPTT) (by Honeywell) represents a part-task training system of modest complexity (Figure 4). Prior to AGPTT development successful construction and use of the MA-1 Fire Control System PTT for F-106 aircraft demonstrated a high training value in proportion to overall size and facility requirements (Figure 5)(16). The prototype ARN-101 Navigation System PTT for the F-4 aircraft represents a smaller, but fully interactive training device (Figure 6). This PTT is an attachment for existing ARN-101 mission data preparation consoles, utilizing spare computer capacity for training the aircraft system operation. The smallest part task training devices are represented by the desktop EW trainers produced by several different companies. They allow interactive student instruction not possible with video tape or classroom lectures.

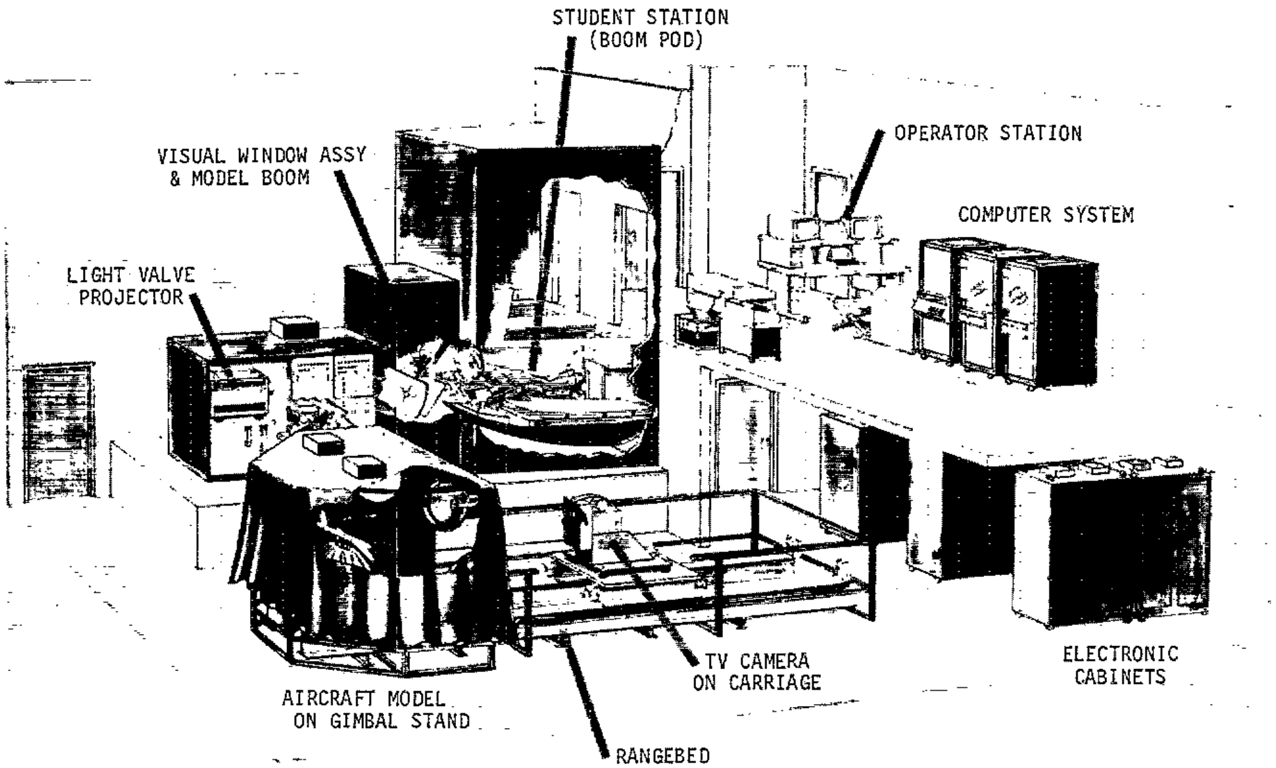


Figure 2. KC-135 Boom Operator Part-Task Trainer (BOPTT)

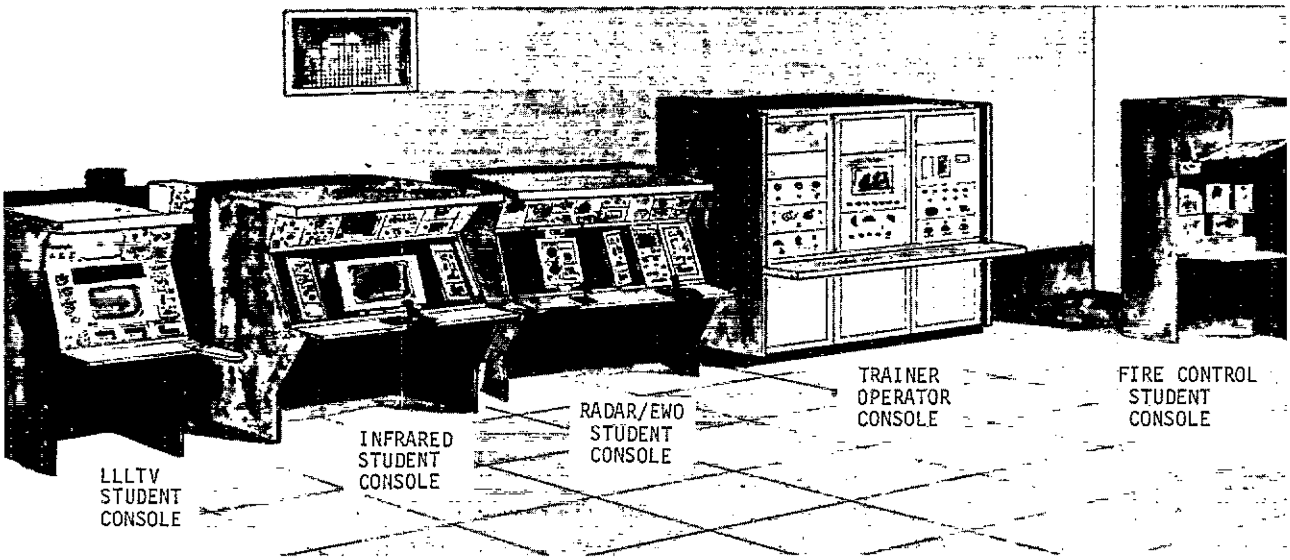


Figure 3. AC-130H Functional Integrated Systems Trainer (FIST)

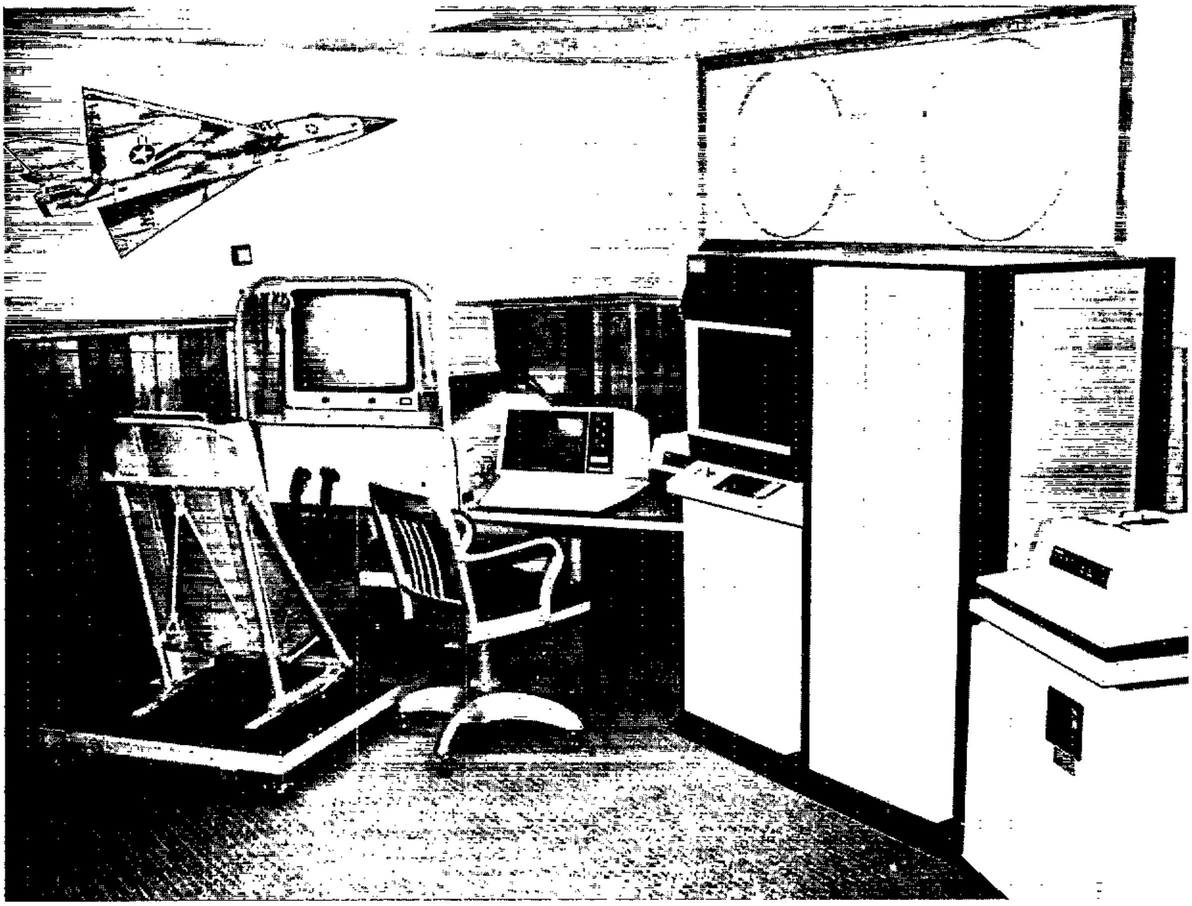


Figure 4. F-106 Aerial Gunnery Part-Task Trainer (AGPTT)

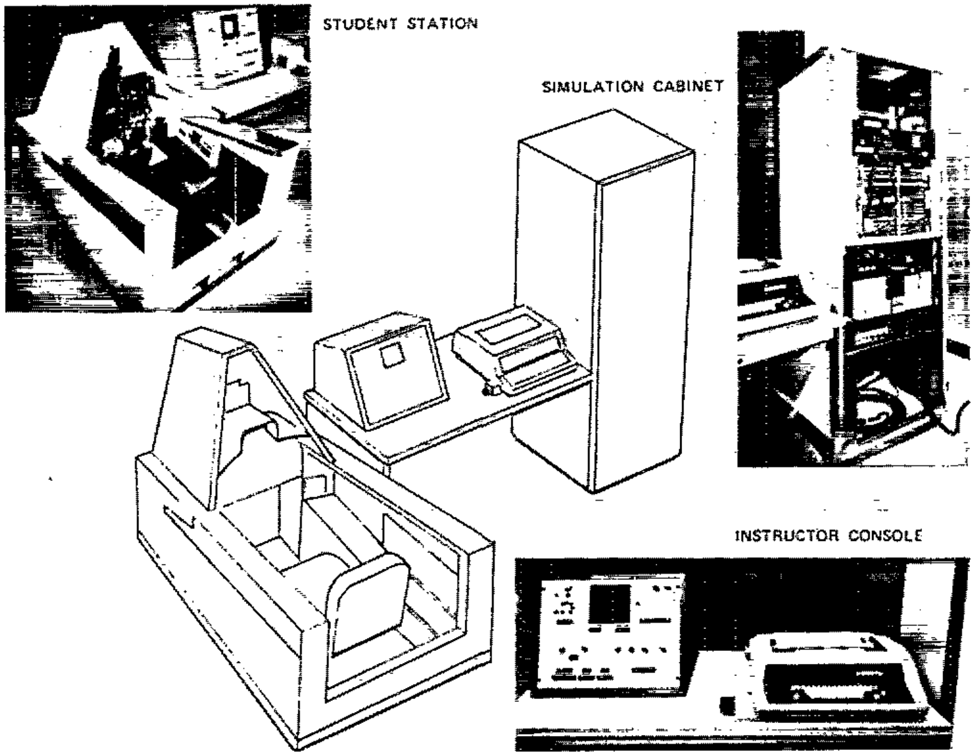


Figure 5A. F-106A MA-1 Radar/IR Part-Task Trainer

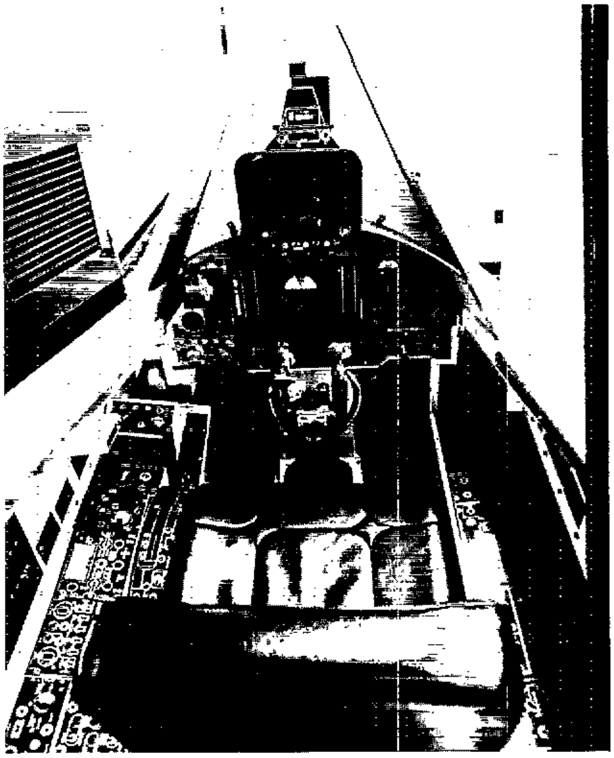


Figure 5B. Cockpit Interior

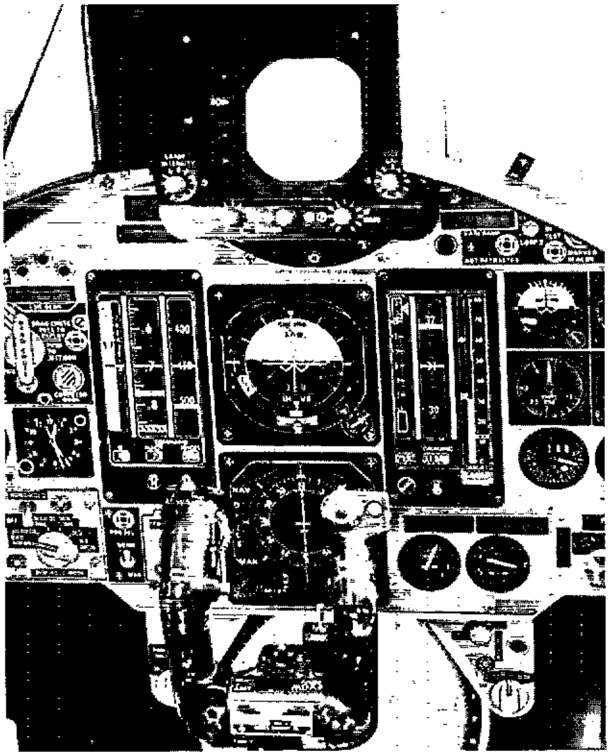
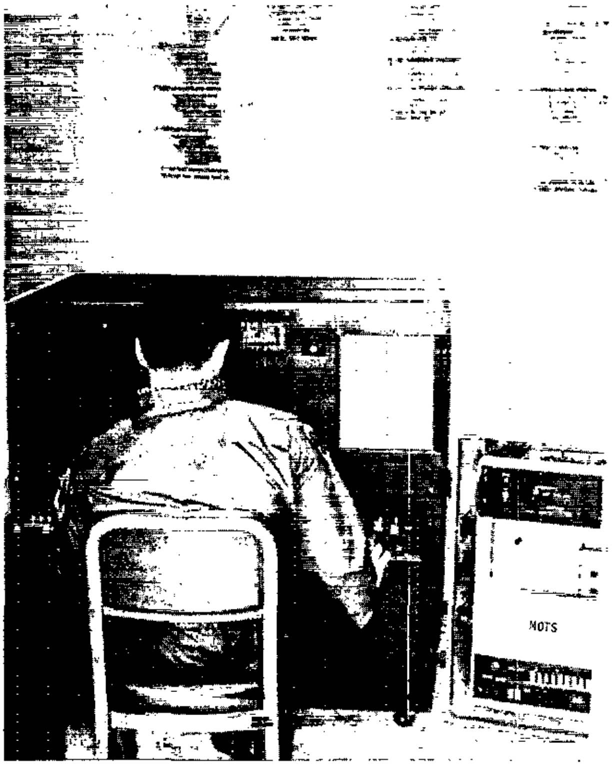
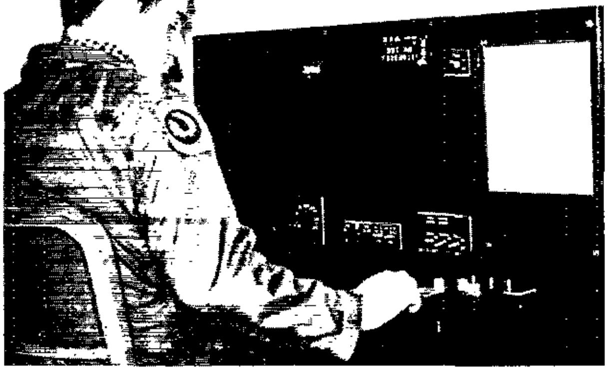


Figure 5C. Control Stick and Radar/IR Display





Note: Trainer prototype is attached as an optional peripheral to the ARN-101 Mission Data Transfer System (MDTS) housed in the portable travel case. The trainer can be disconnected to allow immediate MDTS deployment with associated aircraft.

Figure 6A,B. ARN-101 Navigation System Trainer Prototype

In a time when worldwide commitments for short notice deployment are typical of operational requirements, the status of crew daily mission readiness could be determined by the regular use of a capable, effective training system. The capability of the training system is frequently driven by cost considerations and the time required to manufacture and deliver a system. The future looks like a move is appropriate toward more low cost devices available to more students simultaneously. This approach would enable better use of fewer high cost, full-mission trainers. By using a family of modular training devices, the training and operating commands could have a better potential for keeping the air crews mission ready, while reducing the training backlog created by the part task use of scarce WSTs (where available) and eliminating the reluctant necessity to do "training" in powered-up aircraft parked on the ground.

THE FRONT END PROCESS

From the early start of the Systems Approach to Training (SAT) (19) in the Air Force through growth of the Instructional Systems Development Process (ISD) (24), emphasis has been given to development of the academic process. Analysis of training requirements concerned teaching steps, course content, supporting equipment and media mix. From some of the comments by Montemerlo (13), the Navy took similar approaches. Acquisition managers picked up on the process and wrote training requirements into need documents as though the ISD process was designed to describe training in terms of specific equipment and technical approaches to trainer design. The ISD task analysis was not designed to define performance specifications for training devices. As a result, much interaction has occurred in each of the services about how to accurately and completely provide training requirements to trainer acquisition managers in terms useable by design engineers and program managers. Additionally, we in the USAF simulator acquisition business have sometimes found it difficult to get the simulator user to choose a set of training tasks (or cues) realizable with near-term technology...and within available fiscal constraints. Although the acquisition management process has been amply "procedureized," the needed work to tie training analysis and acquisition management processes for training devices together is still in a growing stage.

Growing interests in clarifying initial descriptions of training requirements and updating on-going training has come from in-depth studies of the analysis process. The current term for this evolving process is being called front-end analysis (FEA) (8, 14, 15, 18, 23). In fact, what is happening is a closure of awareness between training managers, design engineers and acquisition managers of the varying approaches each takes toward doing their part of delivering a useable training device. By somewhat getting into each other's business, we are, in fact, beginning to understand the larger process.

Since training analyses were not designed to specifically describe training devices, a holistic view has existed that designing a trainer to meet most training event requirements was the best approach. This generally led to the evolution of designs for OFTs and WSTs.

For several existing weapons systems, PTTs were designed to deal with specialized training needs that either could not be satisfied in the WST or that saturated the WST schedule while doing skill level training. As overall skill levels increased, training managers found the PTTs to be useful assets and relatively easy to maintain. Successful use of these PTTs (such as the F-106 Aerial Gunnery PTT) has spurred many discussions and proposals for use of PTTs, and has caused the Aeronautical System Division's Deputy for Simulators (ASD/YW) to place more emphasis on the use of PTTs as alternative solutions to training requirements. Additionally, the current economic situation is driving consideration of low cost training devices as interim solutions to training requirements.

The USAF approach to developing technical solutions to training requirements has been couched in a multi-discipline team approach to provide functional specialists to analyze the requirements. The team performs an evaluation at an early stage in evolution of the weapon system or changing mission. This team then utilizes their collective experience and the wealth of available information on simulator design to look for innovative solutions to training requirements. In addition, they are guided by documented policy to ensure that Air Force goals in training, supportability, costs, etc. are met. A program is now underway to develop a systematized concept for analyzing training requirements and comparing the analysis to various technical solutions. Using models that may be automated, an iterative cycle of analyze-compare-analyze-compare will occur until functional managers are satisfied that the best alternatives have been described.

It is in participating in the FEA process that the authors have perceived the forthcoming impact of digital avionics and "smart" weapons systems on training requirements, have seen the opportunity for PTTs to meet these requirements and have seen the need for the tri-services and industry to look for some common ground in the development of training devices for these systems. As a start point, we now need to consider some of the tasks and system applications common to modern weapons systems which are particularly applicable to PTT solutions.

SOME TARGET AREAS FOR PTTs

Many of the newer airborne weapons systems possess a high degree of complexity but have similar components. Features such as digital entry keyboards, displays, computers, laser rangefinder/designators, radars, and inertial navigation interfaces, provide some possibilities for cost effective combinations or re-use of engineering effort to model and simulate one particular system. Most new systems are also controlled by a digital computer, which can facilitate the resolution of interface problems. These weapons systems are also intended to be "modular" or "add-on" in nature, a feature that should also lend itself to the concept of a PTT for the weapon. To illustrate possible use of PTT's for these systems, some selected tasks and system applications are described in the following paragraphs.

Task Difficulty/Training Time:

In modern aircraft, despite the technological sophistication, or perhaps because of it, there are an increasing number of tasks which take a disproportionate amount of time to train. In other words, a student will spend extra missions in a simulator to reach the required performance standard in a few tasks, each of which may occupy only a short time in the real-world mission. Additionally, the demands of the more difficult tasks may be such that the student's necessary attention to other tasks is degraded, thereby reducing the total value of the training session. Some of these tasks, such as air-to-air target tracking and air-to-ground weapons deliveries, traditionally require extensive training in the aircraft. With modern simulator technology they can be trained in a simulation device, and because of their criticality and required training time, might well be trained in a PTT. Other unique tasks which require considerable training time, mainly in initial training, include Heads Up Display (HUD) interpretation, Hands on Throttle and Stick (HOTAS) operation, radar and Infrared (IR) image interpretation, PGM operation and control, Inertial Navigation Set (INS) operations, and Electronic Warfare (EW) operations. These are the more obvious tasks; for each aircraft there may be unique tasks which require extensive training time. Provision of PTTs for these types of tasks should reduce total WST training time and therefore reduce required WST numbers. However, analysis of student throughput rates, task training times, training device costs, initial versus continuation training, etc. will be needed to provide the correct mix of training devices.

Visual Discrimination Tasks:

There are many operational tasks which require a high degree of visual discrimination. While some aircrew members may have a greater inherent ability for visual discrimination, the more difficult processes have to be learned through practice and knowledge of the mechanisms by which the visual image is received. These visual discrimination tasks involve out-the-window scenes as well as imagery presented on various cockpit displays such as radar and IR. Although out-the-window discrimination tasks such as low-level flying could merit some discussion, we will consider only the on-board imagery such as radars, EO, and IR. In general, the development of high fidelity simulation of this type of imagery is extremely expensive. However, depending on a complete analysis of the primary task requirements and any associated tasks, it may be possible to train the basic task on a PTT, using such media as slides, videotapes, movies or a combination of media. A complete training program including lecture, written and PTT training will insure that the aircrew member, upon reaching the simulator or aircraft, does not spend a disproportionate amount of time on visual discrimination tasks.

Further complications arise when considering the provision of simulated radar and IR imagery in a WST. The question of fidelity becomes vital, because for some visual discrimination tasks, negative training could result from poor simulation. State-of-the-art radar simulation is generally regarded as providing positive training for the radar discrimination task; FLIR interpretation is a more difficult technical challenge to train by simulation. "Real-world" IR imagery has a high dynamic range, and the variable scene conditions, weather effects, time of day, seasonal effects, and other peculiarities are very difficult to simulate fully. At present, no system can provide full training for IR imagery interpretation while simultaneously allowing random low-level flight over a large gaming area.

It may be more cost effective, or simply provide better training, to use a PTT device for IR imagery which uses videotape or film to provide real-world training in IR interpretation for a limited gaming area. Further analysis will indicate the degree of interaction of other tasks with the discrimination task. Frequently there is a requirement to lock-on to an image so that lock-on parameters can be fed to the aircraft's navigation system. The trainee may learn to lock-on to a representative image in the WST while the target discrimination task is trained separately on a PTT. Alternatively for full-mission training in a WST, it may be possible to reduce the cost of radar and IR simulation by confining the high fidelity simulation to limited gaming areas or corridors, with a lower fidelity generic simulation elsewhere, so that the trainee having learned target discrimination on a PTT, need spend little time actively performing this task in the WST. For simulator mission training and evaluation, the aircrew need only perform the task in defined critical areas such as navigation way points and target discrimination. It may also be cost effective to use the aircraft system for final training and validation. Finally, as will be discussed later, there are a number of PGMs which utilize visual displays, and whether integrated in a WST or as stand alone PTTs, the requirement to train the visual discrimination task will need a critical analysis. Many of the above considerations could well apply.

Mission Critical Tasks:

Part task training is particularly applicable to mission critical tasks. These are tasks where successful task execution at the first attempt is essential to mission accomplishment, for reasons of surprise, hostile environment, or other. The following examples illustrate some mission critical tasks suitable for PTT training: PGM terminal delivery/guidance; electronic warfare terminal threat warning recognition; air-to-air gunnery/missile engagements; and FLIR/radar target identification.

With modern PGMs, strike aircraft will carry fewer of these complex weapons (due to weapon cost and compatible stores position availability), so the accurate delivery of a single weapon is inherently mission critical. Targets that would previously have required multiple passes with conventional bombs to assure destruction, must be "taken out" by a single precision-guided weapon. Another mission critical task involves the rapid recognition of a surface-to-air missile (SAM) radar mode change from search-to-track (or especially from track-to-launch) that may be required to save the mission aircraft from imminent destruction. In some cases, only seconds may be available for the proper sequence of recognition/decision/reaction. The air-to-air engagement of an enemy aircraft will almost certainly be mission critical for a fighter aircraft with an air offensive/defensive mission. However, the same task may not constitute a mission critical task for a ground attack aircraft. These are the sort of considerations which must be examined when determining the required type of training devices. The transition between radar and FLIR sensor systems is another task which may be deemed mission critical. The system operator must correctly correlate target appearance on both sensors in minimum time, acquire and identify the proper target so that a successful attack may be completed. Again, there may only be a matter of seconds to correctly carry out this task.

Precision Guided Munitions:

By its very nature the systems application area of PGM training readily lends itself to the concept of part task training. PGMs are add-on weapon systems that, although utilizing aircraft systems and data, and requiring varying degrees of hardware installation in the parent aircraft, may be regarded as complete systems on their own account. Hence, the development of a PTT to train PGM weapon systems readily (and even intuitively) comes to mind. Other factors combine to strongly suggest the development of a PTT to meet PGM training requirements. Many of them utilize high-resolution imaging sensors for target acquisition and homing, and have associated cockpit displays which require the training of operator visual discrimination skills. Some, such as the GBU-15 and PAVE TACK, require special manual skills for tracking and weapon control...skills which are perishable and which require continual training. Usually the delivery of a PGM is also a mission critical task and requires intensive training so that successful delivery of the PGM is virtually guaranteed.

Other factors resulting from the increasing proliferation and complexity of PGMs and related systems need to be considered. Newer aircraft with digital avionics are being developed with provision for a range of add-on systems and PGMs. For example, some tactical aircraft will be capable of carrying the PAVE TACK IR sensor/laser designator, with some combination of GBU-15, AGM-65 Maverick, and laser-guided ordnance. Each of these complex weapon systems requires extensive system knowledge by the aircrew and also requires considerable continuation training in the associated cognitive and manual skills. For example, the HUD and Multi Function Display (MFD) may display different symbology and different alphanumerics for each weapon system. The tracking handle may perform different functions for different systems. Different radar functions will be required to support different PGM operations. Apart from the task of individually learning to operate each system, a requirement to remain current in more than one system also adds weight to a PTT approach. Ideally, crews should be designated for one particular PGM system; however, this may not always be possible. If crews are required to be proficient in more than one PGM system, careful thought will have to be given to the training program so that all the tasks required for one particular PGM system are trained as one training unit. This is to ensure that the operation and interaction of switches, function displays and controls are learned to be associated with that specific PGM system and are not confused with other functions. This training of PGM systems as a separate unit again suggests a PTT approach.

Also, given that the delivery of the PGM is normally a mission critical task, a PTT may well be appropriate so that extensive pre-mission training can be provided on the PGM tasks. Thus, the system operator will be trained and "hot" on PGM delivery tasks prior to each mission. In this context, the possibility of crew room PTTs suggests itself as means of encouraging aircrews to attain pre-mission peaks in their PGM skills. A light-hearted extension of this training system envisions a scene where PTTs, dressed up as arcade machines with flashing lights and sound effects, line the walls of a crew ready room. Utilization would not be a problem!

A major concern for PGMs, of course, lies in the individual weapon cost. With some weapons costing hundreds of thousands of dollars, it becomes a very costly exercise to train regularly using live weapons. Dependent on relative cost, it is likely that a realistic PTT may be more cost effective. However, there may also be a requirement for a PGM training capability to be integrated into selected WSTs for full-mission training. Depending on requirements, a range of training devices including WSTs and PTTs may be required. Some suggestion in regard to mixing WSTs and PTTs will be discussed later.

Digital Avionics:

A major area for PTT application is digital avionics familiarization in both pre-flight and flight areas. Many new systems now require significant data entry (way points, targets, delivery modes, etc.) in the pre-takeoff period, and in-flight data alteration due to mission changes. Modern aircraft, particularly tactical aircraft, can have several of these sophisticated systems arrayed at each crew station (pilot, WSO). The training problems inherent in these systems, which eventually are control centers for all missions, are extensive. A complete understanding of the operating modes, interactions, and anomalies of each system will allow the crew member, with regular practice, to perform the assigned mission task using alternate or backup modes as necessary.

Single copies of unique PTTs for some of these avionics systems have been produced through a variety of means (organizational, inter-unit projects, contractual, research, etc.). Often the driver was a desperate need from the field for an effective means to allow operators to master the skills associated with new, unfamiliar, complex systems. The effectiveness of these part-task devices has usually been high, possibly because the crews perceived a real need for a trainer, and were willing to live with minor inconveniences and non-relevent inaccuracies where correction would have increased trainer complexity and cost. A recent example of such a device is the ARN-101 Navigation System Trainer prototype assembled by Ogden ALC for the Tactical Air Command (TAC). The ALC personnel, with depot ARN-101 hardware and software experience, assembled an add-on crew training device as a peripheral for the existing Mission Data Transfer System (MDTS) already used by TAC aircrews to prepare and load ARN-101 way-point data during pre-mission ready-room preparation. Since one MDTS will be colocated with each ARN-101 equipped unit, and the MDTS computer system has spare computational capacity available, the construction of an interface assembly to drive a subset of the aircraft mission avionics "black boxes" and indicators has produced a very profitable training device in minimum time with little additional new hardware. The prototype device has received excellent reviews from users, who look forward to the completion of several more of the MDTS add-on trainers. We must be alert to these opportunities to provide current, effective training devices, and attempt to utilize skilled resources (often from existing programs) to assist the timely development of training equipment. This opportunity is often neglected or ignored during aircraft hardware development and integration. By such neglect, the operational user is often denied an effective means of training assigned mission tasks for the life of the weapons system, and may even resort to sending aircrews TDY to the weapons system contractor's plant to train on any available device. Such an arrangement is not attractive to the using command, which experiences loss of aircrew availability and uncertain training effectiveness, nor to the weapons system contractor who is "coerced" into maintaining a training facility... often by conversion of a portion of internal R&D facilities and resources.

Electronic Warfare:

A third applications area where PTTs have already been applied with resounding success is in EW training. Practical EW PTTs have ranged in size from a desktop device (the size of a hi-fi receiver) used principally for equipment familiarization by individual students, to a multi-station, multi-computer driven electronic "classroom," with multiple, individual student positions (Simulator for EW Training (SEWT) (by AAI) at Mather AFB CA). The two basic simulation techniques of software modeling and equipment "stimulation" have been used alone and in many hybrid proportions to produce a variety of EW training equipment. Some of these PTTs can be (or are presently) attached to a WST or OFT to produce a realistic, correlated cockpit EW display as a segment of an overall integrated training mission, or used in a "stand-alone" mode as true PTTs if the scheduled WST training mission does not involve EW in the scenario. An example of such a *device is the EW section of the A-10 OFT (Figure 7).* Included with the basic A-10 OFT configuration is a dual section console desk/equipment rack, with a sliding partition between the two console sections. Although the computer which operates the EW section is one of several that also operate the OFT, and is not readily separable from the balance of the OFT, the concept of a "modular," multi-use, attachable PTT is worthy of further exploitation. In the example above, the sliding partition allows student and instructor, seated side-by-side, to work closely together without interphones or other distractions for an initial period. When student evaluation is desired, the partition is extended between the student and instructor positions so that the student is not aware of instructor actions except those visible on the student EW displays. Thus, the A-10 OFT (by Reflectone, with EW by AAI) can provide a separate EW part-task training mission to another student when the primary student in the OFT cockpit does not require EW displays.

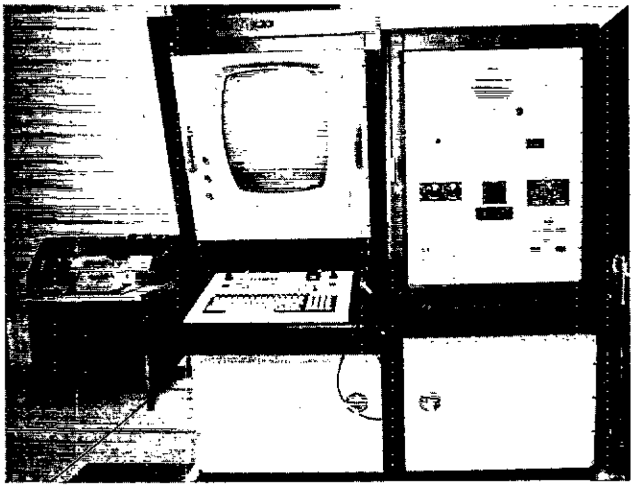


Figure 7. A-10 Operational Flight Trainer EW Auxiliary Station

Recently, a generic EW PTT has been announced (Figure 8) (20). This device is reprogrammable, through its own keyboard (an option with associated optional software), and thus can be self-supporting at individual sites for many aspects of operation. If a careful choice is made for the PTT system components (Computer, displays, interface equipment, etc.), commercial supportability can be facilitated for many years. At the user site, if operational hardware is available, the utility of the device would then be a function of the effort raised by Air Force instructor personnel, many of whom have proven to be skilled innovators in using less capable systems to a greater degree than the designers had expected.

EW PTTs will soon become airborne in an innovative experimental program to provide in-flight training for B-52 Electronic Warfare Operators (EWO) while reducing flight hours in their rated aircraft. The Strategic Air Command (SAC) has proposed the Companion Trainer Aircraft (CTA) program to retain flying hours for B-52 crew training while lowering the operating cost of the training flight vehicle. Initially, two T-39 aircraft will be temporarily fitted with B-52 crew training facilities, including an EWO station with a subset of the EW systems found on the actual B-52. The reduced size of the CTA training station is primarily due to the size limitations in the T-39 passenger compartment. The proof-of-concept EWO station will provide a pre-canned playback of a pre-determined mission scenario, with threat signals appearing at prescripted times. The student EWO actions will be noted by the controlling microcomputer and logged on a miniature paper tape printer for post-mission analysis and debriefing. No outside signals are radiated or required. During initial operational test and evaluation (IOT&E), SAC will test whether this simple PTT concept can provide the required training.

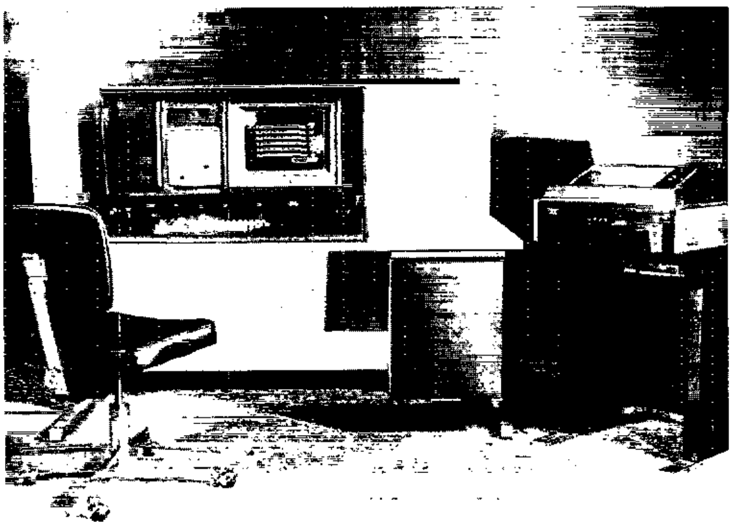


Figure 8. EW Part-Task Trainer for Individual Self-Paced Instruction

AN APPROACH FOR CONSIDERATION

We have illustrated some of the areas of modern digital weapons and avionics systems where PTTs can be effective solutions. The point to be made at this stage is that these types of digital systems are being developed at an increasing rate. The use of digital systems, micro-miniaturized computers and technology advancements, particularly in the optical and sensor field has facilitated the rapid development of on-board and modular weapon systems. The adoption of a simulator interface bus could facilitate integration of modular PTT systems in a similar manner as the MIL-STD-1553 Aircraft Internal Time Division Command/Response Multiplex Data Bus has assisted airframe/subsystem integration. An added spur to the development and use of modular systems is the rapidly increasing cost of modern aircraft. With the high cost of new aircraft, we are looking to higher technology to provide improved avionics, missiles and guided weapons to enhance the basic parent aircraft capability. A classic example of this process is the adaptation of the cruise missile to the B-52. For other examples, consider some of the modifications to our current aircraft, such as the F-111F, F-15, A-10, F-18, and another classic example...the F-16...originally designed as a lightweight, visual fighter. This increasing proliferation of digital weapons affects all our Armed Services, and unless we plan carefully, we may well be swamped by the training impact of these complex systems. Already, we are starting to feel the impact. Within the Deputy for Simulators, we have recently considered training devices for PAVE TACK, GBU-15, AGM-65, LANTIRN and the ARN-101 Navigation System. The Navy and Army and other DOD components have obviously been looking to similar training requirements. Since most of these systems require the type of training tasks described earlier, which are particularly applicable to PTTs, we suggest that development of PTTs to meet the training requirements will be effective solutions for cost, schedule and training value. Development of PTTs for these systems should allow for the integration of these devices into a WST to provide full mission training. Ideally, PTTs should be designed to facilitate this integration when and if required.

As a first step, we believe the Services and Industry should collectively expand their studies of unique training problems presented by these weapon systems. Many of the tasks such as the visual discrimination tasks apply across a range of aircraft and weapon systems. There may be some general solutions where a basic development program may provide a solution which is useable on different systems. As a fundamental approach however, we believe that many of these PTTs for digital avionics and weapons systems could be developed according to a modular concept and therefore interface requirements need to be determined and defined across the total simulation spectrum. "Modular" and "standardize" are almost dirty words in the simulator world, so let us point out that by modular we do not necessarily mean two units connected by cables. In our context, modular means a device which can be stand-alone, but is also relatively easy to integrate into a WST or multi-task trainer if required. This concept for PTTs may require considerable innovative engineering for some task combinations. A modular concept for PTTs should provide a great deal of flexibility in the utilization of such devices. As a basic satisfaction of training requirements, it means that the PTT can be used as a stand-alone device...perhaps even in a crew ready room...or it can be integrated into a WST at some central location. Thus, initial and qualification training can be conducted on the PTT, full mission training can be trained on the integrated WST, and continuation training of perishable and manual skills can be carried out on the PTT.

Another benefit of the modular PTT approach is that the developed PTT can be utilized across the range of aircraft which utilize the weapon system. For example, the AGM-65 Maverick Missile is presently used by at least seven aircraft types. A point to be made here is that it will not always be possible for the PTT to have a common interface definition with a series of WSTs, particularly older aircraft WSTs such as the F-4. However, if future PTTs are developed with common interfaces, one side of the interface problem is determined, and a later upgrade or change of PTTs is facilitated. Another benefit of standard interfaces is that it may be useful to combine certain PTTs into a combined trainer to utilize a common student station, common data bases and common display equipment such as radar or FLIR displays (where practical). This would be particularly useful where the parent aircraft utilizes both systems.

The flexibility of modular PTTs should allow them to be relocated easily if a squadron or wing moves or is equipped with a new weapons system. They can also be rotated through operational units (and maintenance/upgrade) on a regular basis. A further refinement could provide that the PTT be designed so that the various PTT components (controls, displays, etc.) fit into appropriate removable blank panels on a CFT or CPT. This would provide an even more realistic training environment.

One approach to assist the modular/common interface problem is for the WST and PTTs to be designed to accept control and interface signals over a standard simulator interface bus. This could give the simulator and PTTs some commonality with the weapons systems being simulated. The parent simulator or PTT may not need to have any actual aircraft avionics control computers within it, because MIL-STD-1553 interfaces for several types of general purpose computers have already been designed, tested, and introduced as standard products (21, 22). These interfaces allow software simulation of functional portions of an active multiplex bus within a general purpose computer, and thereby facilitate interconnection of varying amounts of aircraft hardware such as HUDs, air data computers, stores management system displays, etc., to a basic simulator or PTT (9).

We do not believe that the full potential for utilization of aircraft multiplex bus equipment to augment simulator performance has been examined. Avionics system design adherence to MIL-STD-1553 and other recently published standards may indirectly facilitate the interface of PTTs with one another and with WSTs because of the common design features. These standards are: MIL-STD-1589B (JOVIAL J-73 Programming Language); MIL-STD-1750A (16-Bit Computer Instruction Set Architecture); MIL-STD-1760 (DRAFT) (Standard Store

Interface; Aircraft/Stores Electrical Interface Definition); and ADA (The new DOD standard programming language for command, control, and avionics systems)(3). The impact of these standards on simulation must be thoroughly examined to determine optimal design policies before the increasing development of new weapons systems and the resulting call for simulator upgrades/modifications becomes an avalanche.

THE PAYOFF

The success of training devices is usually measured in terms of cost, schedule, and training value. Training value has various meanings to different people, but generally will include the elements of training effectiveness, aircrew acceptability, and inherent availability. Historically, PTTs have been successful in these areas, probably because they were generally less complex and because they were directed at training one particular task or set of tasks. PTTs of modest scope and complexity have also been successful in terms of acquisition cost and schedule. For example, a recent device, the F-106 Aerial Gunnery PTT, was delivered 2 months ahead of schedule and has received favorable reports from the users. In looking at the impact of an increasing number of complex weapons systems on current and future training requirements, we have described some typical tasks and systems where we believe PTTs will be particularly useful in the future. Because of the scope of these applications, we have also suggested a coordinated and planned effort in the development of these PTTs...including the standardization of interfaces to facilitate integration (modularity). We believe the pursuit of these approaches will provide opportunities for reducing cost and schedule during development and production, while meeting training objectives.

For any new program, the concept envisages a spectrum of training devices, with lesser numbers of complex, costly WSTs...because of the effective use of PTTs to train certain tasks. Ideally, the PTTs which are developed for any program would be modular so that they could be readily integrated with a WST where required. WSTs will still be required for full-mission training, but they will tend to be more centralized, with an optimum mix of WST/aircraft for full mission training. The thrust here is that the WST and aircraft should be utilized more for full-mission training and evaluation than for individual skill training.

One approach to simulator development which has proven useful is to develop the simulator capability either ahead of, or in parallel to the aircraft development (e.g., F-15 program and the McDonnell Douglas F-15 Engineering Simulator). Although this concurrency requires extra cost and coordination, the simulator may primarily be used as a design tool or prototype, and can also be used as a training device for test pilots and initial aircrew cadre. The same principle is very relevant to the development of PTTs. Initial front-end analysis will identify target areas for PTTs (e.g., HOTAS and HUD operations and displays; EW operations; avionics operations and displays). The prime aircraft contractor could be required to build hot mock-ups or proof-of-concept devices for these systems(15). This type of process would have several advantages. The test devices are useful to both the aircraft prime contractor and the aircraft system program office as proof-of-concept for the new systems before design freeze. From the simulator procurement point of view, early involvement of the simulator design team with aircraft development will produce a better, more timely training simulation product. When the aircraft design is "frozen," experience gained with the proof-of-concept devices can then be used as the basis for competitive acquisition of the final training devices from interested simulation contractors. A further advantage of this approach is that the training effectiveness of particular PTTs can be assessed before commitment to a production program. This assessment should include the intended users of the training devices, and should allow some re-definition of training requirements. One result may be suggestions for alternative concepts for production PTTs or WST integrated systems, thus avoiding training devices of low or minimal utility. Because, under this concept, the initial development work on the experimental PTTs may be carried out by the aircraft prime contractor (whose personnel should have maximum access to development data), and because of the early involvement of engineers and others from the government simulator procurement activity (to ensure proper documentation of parameters used for the PTTs), cost and schedule risk for the delivered production training devices should be reduced. There will be some limitations with lack of problem control (i.e., freeze, malfunctions) on contractor R&D engineering simulators, but any action to move simulator engineers up from the "tail end" of the design data stream could help to shorten the multi-year cycle of simulator procurement.

For systems such as PGMs, the cost and schedule benefits accrue from the development of modular PTTs which can be used in several modes: as stand-alone devices; integrated as combined trainers; or attached to WSTs for different aircraft types. These benefits are realized from common PTT development requirements and thereby a reduction of future integration effort. The modular approach should also provide a degree of flexibility to "swap out" PGM PTTs when required. This is an important consideration, as modern PGMs are essentially modular by design, allowing change of weapons load mix to suit individual aircraft missions while preserving the precision guidance capability. PGM systems may also be rotated among units as the overall planning situation dictates, or they may be replaced by even newer PGM systems. The modular PTT, whether it is stand-alone or integrated with another device, should be capable of being swapped out with a training device for another similar class weapon.

Cost savings will also be realized in the life cycle of PTTs since considerations will include designing the training devices for a specific, realistic life (maintenance and logistics). Also, by using engineering design guidance, common core components can be adapted to other requirements as necessary. Conversely, if a PGM system is being integrated into an existing aircraft, the remaining service life of the parent aircraft will obviously be an early consideration. If the parent aircraft has only a short service lifetime remaining, some of the unique simulation tasks requiring complex/high cost engineering solutions will have to be identified and consideration given to finding more simplified, but effective PTT solutions. In some cases, it might be determined to be more cost-effective to complete full-mission training in the aircraft.

Currency of operational, in-use training devices is another area for examination. Important to the update of PTTs, as well as other training devices, is a continuing analysis of training requirements to determine modification needs. This point is frequently overlooked and becomes the loose thread that brings about loss of confidence in existing trainers. When the device no longer matches the actual equipment, both students and instructors immediately recognize the difference and soon resort to using the actual equipment as a trainer. Since most PTTs can usually be updated at reasonable cost (or in many cases replaced), the problem is less noticeable and causes less loss of confidence in the training system.

While we have noted the rapidly advancing technology which is producing modern weapon systems, we should not forget that the same technology can also assist the solution of our training problems. We must look for new and innovative applications of these technologies to provide cost-effective training systems. For example, the gamesmanship designed into current-day video and computer games has surfaced new concepts in presentation of data for training. Stress is increased by timing and saturation, and anxiety is developed through random presentation of unexpected challenges. Such ideas can meld the uses of PTTs into training syllabii as modules of training events that can be integrated into broader training tasks in the simulators. Computer-based instructional systems currently being acquired by the services will provide potential for management of PTT resources, scheduling them into curriculums and documenting their use. Such potential heightens the applicability of small, microcomputer-directed devices as major components of the overall training program.

The students of the 1985-2000 time-frame will enter military training with a high level of exposure to the microcomputer and game-oriented training from school resource centers. We can expect greater acceptance of PTT concepts as building blocks of instruction that can task the student in highly stressed exercises similar to anxious moments of live combat. These applications can serve the transient needs of changing missions and combat scenarios that now drive the tactical and strategic training costs out of sight.

In summary, the payoff comes when effective front-end analysis provides a dissected definition of training requirements delineating the use of various levels of training equipment. By designing PTTs to build operator skill for practice and integration at the next level of training, instructors can control training resources and maximize the use of moderate-cost devices to bring about a higher overall level of skilled readiness, and thereby reducing the requirement for extended training in the WSTs or the mission equipment. This represents a change in training strategies and demands disciplined instructional designs, but is a viable way to maintain high training standards in the future, and ensure better access to current training equipment.

Standardization in engineering design and the modularity concept should facilitate integration where required. We have suggested that innovative approaches in the design and utilization of PTTs will produce cost and schedule savings for a particular set of training tasks. However, the bottom line is that we must be prepared to meet the training requirements of an increasing number of complex and sophisticated weapons systems.

We perceive the part-task trainer as a viable answer to the dilemma of providing timely, cost-effective training.

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