OBEWS: SIMULATION AT MACH 1 ON THE DECK DEVELOPING EMBEDDED TRAINING

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ABSTRACT

Embedded training is the mechanism by which training capabilities are combined with actual combat systems capabilities to provide training during routine use of the combat systems. With embedded training, effective training can be realized with a modest investment if the unique requirements for the development of embedded training are properly considered. Many elements of embedded trainers are similar to those usually considered for ground trainers while some elements may be vastly different. In an embedded trainer, the training scenario, operational requirements of the systems with their embedded simulators, the system design and integration, and the *situational awareness* of the student may be quite different from those of a ground trainer. Though many ground trainers have superb fidelity and realism, they cannot replace the experience gained from actual flight training. While gaining the required flight experience, operators using embedded training acquire the extra edge to maintain proficiency as they become acclimated to the multi-stress combat environment. This paper explores some of the unique requirements that have been uncovered on the On-Board Electronic Warfare Simulator (OBEWS), one of the first embedded trainers, now being test flown on an F-16. The subjects that are covered include aspects of the training requirements such as fidelity of simulation and ground requirements; system design,(i.e., can you add onto existing systems or do you need to design it in); the growth of the concurrency problem, now including the system and the aircraft; a look at integration and adaptability for designing into a pod or for internal carriage; and the environmental constraints,(e.g. how to produce the equipment to withstand the environment on the wing of a fighter).

THE SCENARIO

You are flying low over the ground, approaching the speed of sound. Skimming through the valley, you are acutely aware that the enemy and target are just on the other side of the ridge. At the precise planned moment, you pop up over the ridge and make a run for the target. But before you can get close enough to deliver your weapons, a surface-to-air missile system is tracking you and ready to fire; in addition, anti-aircraft guns already have you in their sights. Suddenly, the missile goes to launch, and you employ ECM techniques and maneuver to break his tracking. As the missile misses its target, you are almost in range of the anti-aircraft artillery. You bank to the left to stay just out of its range and continue with your attack. You pop up at the last possible moment and deliver your ordnance. As the bombs are still falling to their mark, you pull up on full afterburner and egress over the ridge to safety, but a MIG has just shown up on your tail. In a matter of seconds, you hear his radar lock on to you. With a couple of hard maneuvers and appropriate ECM procedures you shake the MIG. As you race back over the ridge, you see the search radar blip off your RWR scope for the last time. Now it's an easy ride home after a tough job, well done.

This pilot was wiping the sweat from his brow and counting his blessings for surviving a near impossible mission; however, he was never in any danger of being shot down. The missiles, the guns, and even the airborne interceptor were carried with him from his home base as part of an embedded training package onboard his fighter.

INTRODUCTION

To develop embedded training, the true training objectives and the harsh environmental realities of the operational platform must be considered. With ground trainers, the entire environment is simulated. Some aspects of realism may be compromised in the training environment for a multitude of reasons. For cost efficiency, only those aspects that are critical to the training objectives of the particular system and curriculum are required to be as close to real life as possible. In many cases, items that could significantly enhance the training capabilities of the system are not included in the trainer because they are cost prohibitive for the extra benefit gained; i.e., full motion bases, visual systems, and digital radar landmass systems.

With embedded systems, the benefits of these costly and complex systems come for "free". As a mission is being performed, the operational equipment provides all of these inputs to the airborne platform by its very existence and use. With an embedded trainer, one must determine how to use these aspects to develop the embedded training and provide the capability to meet the training objectives, see figure 1.

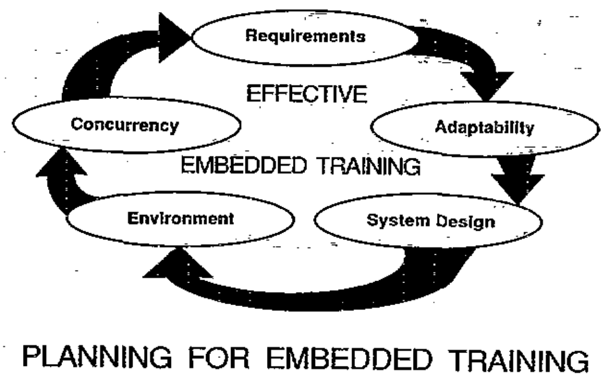


Figure 1

DESIGN-IN TRAINING VERSUS DESIGN-ON TRAINING

A tough question is the issue of whether to utilize design-in training or design-on training; to totally embed all the training functions in existing operational equipment or to design it as a separate loadable entity that can be removed when not in use, such as a pod, carry-on, or ATR chassis. The terms Design-In Training (DIT) and Design-On-Training

(DOT) can take on many definitions and forms. What is detailed here are some of the differences between the various forms of embedded training and what has been learned by developing and flying the On-Board-Electronics Warfare Simulator (OBEWS) through its full scale engineering development program.

Designed-in training, in a broad sense, is when all aspects of the training that are to be provided are designed into and built into the operational equipment. Designed-in training does not require any external hardware, software, or interfaces outside of the operational equipment. This can be designed-in coincident with the equipment development or added in at a later time as a retrofit software package.

Designed-on training is when some, not necessarily all, aspects of the training that are to be supplied are designed into a separate system and built onto the operational equipment. Designed-on training could be separate hardware and its associated software and interfaces that must be tied into the operational equipment to be used for training. Design-On Training does not preclude embedding training software in existing operational equipment to complete the training functions.

Designed-on training can take the form of *internally or externally mounted physical components* on the training platform. They can be built into the platform in the form of a line replaceable unit (LRU), or an equipment chassis, or they may be built onto the platform in the form of a pod, carry-on case or conformal tank. The built-in units are referred to as Built-In Trainers (BIT) and the Built-On Trainers are referred to as BOT within this article.

The decision matrix of which trainer type to pursue has too many factors within it to cover them all here. Presented here are some of the issues between DIT versus DOT, and BIT versus BOT, and some of the lessons learned from the OBEWS development and testing.

The OBEWS system is an On-Board Electronic Warfare Simulator capable of producing a realistic electronic combat scenario which is used to stimulate the ALR-69 radar warning receiver (RWR) on board the F-16 aircraft. The OBEWS is a Design-On Training (DOT) device carried as a Built-On Trainer (BOT) in an AMRAAM shaped pod that interfaces to the aircraft avionics, electronic countermeasures system, and Chaff/Flare dispensables, as well as the RWR (reference Figure 2). Many diagrams and references to OBEWS are made throughout this article to illustrate some of the topics on embedded training as experienced by OBEWS.

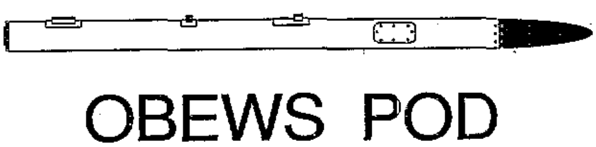


Figure 2

Design-In Training (DIT)

The first and probably most important issue is can the platform with its suite of operational equipment support a fully embedded training system capability? The answer for any older platform and the vast majority of the current platforms is no.

To design and develop a completely embedded system in the strictest interpretation, no additional hardware should be added; only software would be used. This might be possible in an ideal system, but practically speaking, it would not be possible. First of all, one must start with a fully integrated platform, in that all systems required for training can communicate with each other on a common set of buses. They must be able to do so to a level that allows for the meaningful interchange of data between the systems to the level and at the rate required for training. In the simplest terms, this requires communication with the navigation system, usually over the 1553 avionics buses and with the target system or systems for training. With a fully integrated system, it should be possible to implement embedded training with only software because all of the required systems communicate on one or more of the aircraft data busses An embedded training software package would potentially have to be added to each system, on the bus, required for training, reference figure 3.

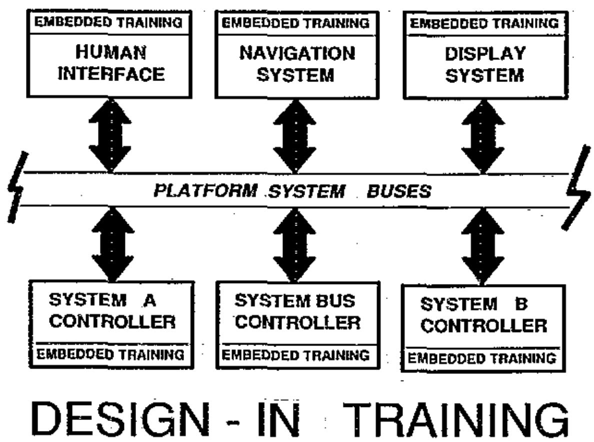


Figure 3

Use of spare time and memory will not be as easy. An adequate amount of spare computing power and program memory must be available in the appropriate systems to perform all of the functions for training in addition to their normal functions. In some cases, the spare capacity will exist; in others it may not, causing the training software and processing to be split and shared across all available systems.

For the navigation system, the monitoring of the data is easy, but the translation of the aircraft's position and attitude into the trainer's gaming area coordinate system for exactly locating multiple simulated threats requires a lot of numeric processing. The threat's slant range and location must be determined relative to the aircraft position as well as its relative bearing and received signal strength to perform the proper threat tactics moding based on the training scenario. The geometry becomes far more complicated when you realize that the aircraft may be going through a high rate maneuver such as an inverted spiral dive. Calculating these parameters for all threats in the mission at a sufficient rate to satisfy the equipment being simulated/stimulated requires a large amount of reserve computing power that not too many systems will have.

Now let's add another dimension to the problem. To provide a realistic threat environment throughout the training mission, realtime occulting must be performed on all of the threats at a sufficient rate to support realistic simulation of the environment. This requires accessing a large amount of DMA data at a very fast, continuous rate. In the OBEWS system, the DMA data were accessed at a rate equivalent to one full word as fast as a typical 1553 bus can provide one single bit of data. The onboard occulting system was accessing and processing one megaword per second to provide an accurate realtime threat environment simulation with terrain masking. Not too many integrated systems with their supporting buses onboard an aircraft platform exist either now or in development that can support this amount of extra bus traffic and computing power for embedded training in addition to their normal workload.

To provide the extensive capabilities needed to do both the primary operational functions of the equipment (remember an aircraft must still fly) and the expansive functions required for embedded training, higher processing-power black boxes are needed. When a manufacturer or systems integrator says that he can provide embedded training, providing accurate modeling and simulation of all aspects pertinent to training with only a software package added to the appropriate systems onboard a platform, beware.

He is really saying, "I am providing only those functions that can be accomplished in software under the current system constraints." Or, he may be implying that you will be procuring some of the other assets required for embedded training such as increased computing power and memory under an avionics upgrade program. You may take advantage of some of software-only embedded training only after you procure better processors, VHSIC upgrades, increased memory, and higher data rate buses. The true cost of software only embedded training must include the development and procurement costs of the portion of additional hardware used in addition to the software costs.

A truly embedded training system should have as much embedded into the operational systems as is required to develop the training capability. Instead of loading down and choking the operational equipment, possibly to the point of detrimental operation, a dedicated embedded training system controller should be incorporated into the platform to provide the additional capability required. If it is designed into a new platform as it is being developed or upgraded, the system impact will be negligible compared to the problem of coordinating and squeezing all of the training functions into the various avionics boxes.

Design-On Training (DOT)

A very high level of systems integration is required through some network of communication buses to develop a truly embedded trainer and still provide the fidelity commensurate with effective training, based upon AAI's experience. Most systems that are needed for integrated training are not linked together except through that mystical interface, the human operator. In the case of OBEWS the individual systems are the ALR-69 radar warning receiver (RWR), ALE-40 chaff/flare dispensing system, and the ALQ 119 and ALQ 131 ECM jammer pods.

All systems that are utilized for training must be linked though not necessarily controlled. As a minimum, they must be monitored by a central system that can process all inputs and make the appropriate coordinated decisions for the scenario progression according to the tactical situation.

On most current platforms, no central system exists, so that system must be added to the platform and interfaced to the required onboard operational systems, see Figure 4. The only question for this configuration is whether to mount it inboard where the environment is less severe (space permitting) or to mount it outboard and sacrifice the use of a store station. Depending on the pod size and shape, some carriage configurations may not be allowed over the full range of aircraft performance, limiting some flight characteristics, especially if the aircraft is asymmetrically loaded.

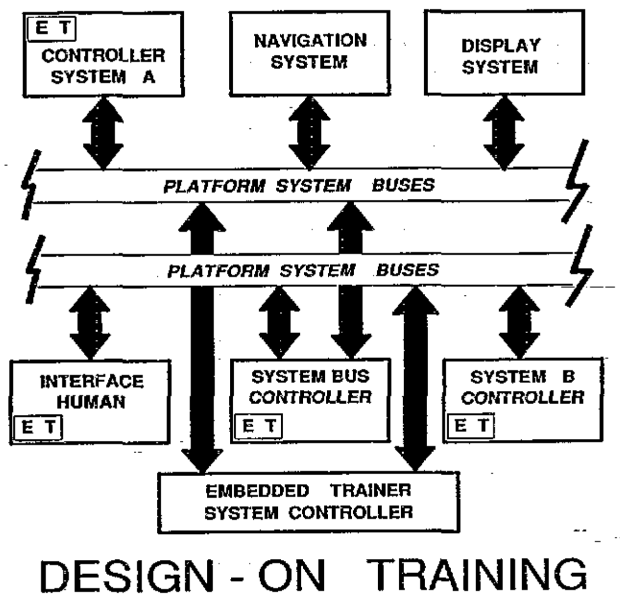
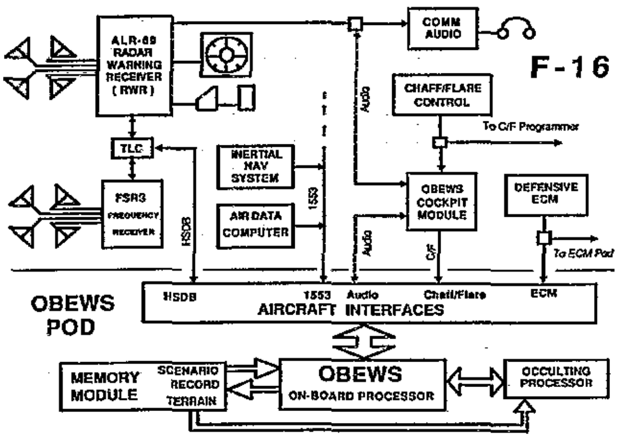


Figure 4

A Built-In Trainer is attractive for many reasons, but first of all, space must be found and allocated within the platform. Useable space is at a premium especially in many fighter aircraft. There is always a long list of what might go into that space and training equipment is often at the bottom of the list. With a built-in system, the upload/download process is gone and the training equipment is generally there ready for use. The built-in system will have a negligible effect on the flight characteristics of the platform, since there will be no associated store to be carried on the aircraft affecting the weight, drag, or flight characteristics. This also leaves the store station free for carriage of other stores for mission support; i.e. more bombs for a practice run or a jammer loaded for training. Depending on the type of system and location on the platform, non-trivial wiring mods may be required to implement and test a built-in system. Essentially, all interfaces to and from the system would have to be wired in for proper integration.

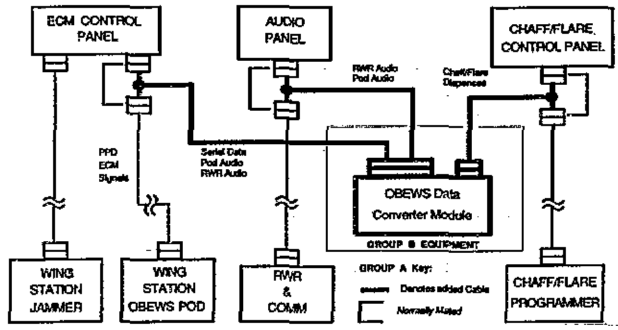
The built-on trainer has several distinct advantages. First, it can be removed during hostile activities, allowing maximum use of the aircraft's systems and capabilities with no need to take along *non-essential equipment. Another advantage is it is* transportable across many platforms allowing fewer assets to service more training needs. If there are any problems with the embedded system, a simple store download and another system upload has the aircraft ready for its training sortie. The external store concept is utilized in the OBEWS system as an AMRAAM pod and shown in Figure 5, OBEWS Interface Diagram. In a transport aircraft, the pod concept could be replaced by a carry-on suitcase with essentially no impact on allocated space or flight characteristics.



OBEWS INTERFACE DIAGRAM

Figure 5

AAI has observed that by going to an outboard system, the onboard Group A and Group B modifications, those being wiring and equipment changes, are minimal, reference Figure 6. Because many weapons stations have several of the required bus interfaces already present, many aircraft can be modified for training with a small cost per aircraft. In the case of OBEWS, all necessary wing wiring was in place for the associated aircraft buses. Only the OBEWS data converter module and seven wires were added to extract the discrete signals in the cockpit for conversion and transmission to the pod to complete the set of required interfaces.



GROUP A & B MODIFICATIONS

Figure 6

Operational Transparency

One aspect that ties in closely with the fidelity of simulation for training is to what level the operational equipment is to maintain transparency during training; that is when actual signals and events are allowed to pass through the equipment along with the simulated environment. With transparency, fidelity must be very good so there is *no obvious distinction between simulated and real* signals. When both real and simulated signals exist side by side, a comparison of the two can reveal embarrassing differences if you have not done your homework.

Transparency can affect the requirements for embedded training whether the embedded training is designed in or on. Transparency requires that the operational equipment functions be maintained for the real equipment throughout the training in addition to responding to the simulated environment. This requires that real and simulated algorithms coexist within the operational equipment. By having the simulation coexist with the operational capabilities, transparency allows the embedded trainer to complement the available assets at a training range to provide a more comprehensive training environment. In a high ambient signal environment, it may be desirable to disable the transparency, mask out the real environment and present only the simulated scenario. A more predictable and controllable scenario can then be used for training.

It has been observed through the flight testing that has occurred to date on OBEWS that the facts are confusing the issue!; that is, the real signals from whatever source they may come are clouding the displays and confusing the operators during the training. It has been asked by many persons, "Can't you get rid of the nontraining signals, for a more closely controlled training environment?" If the requirements provide for a dedicated training mode, the operational equipment may be able to mask out the real environment and operate solely on the training scenario. The capability of "selectable transparency" should be investigated on any further embedded system. Currently, "selectable transparency" is being pursued for use in the threat-rich European theater on the OBEWS system.

Fidelity

As the fidelity of the simulation increases, it is generally assumed that the training value also increases. But to increase the fidelity of a trainer typically requires increased resources such as computing power and simulation hardware. With embedded training, the trick is to use as many of the capabilities of the operational equipment as possible to perform the simulation functions without adversely affecting the existing operational functions. In many cases, the software algorithms and "simulation" hardware are already there. Portions of operational equipment used during a training mission can now be part of the simulation hardware if it has spare capability that can be utilized.

The computer within the radar warning receiver can be utilized and even some of the existing software can be used to perform some aspects of the simulation. If simulated threats are injected and merged into the RWR, its own software routines can be used to perform the final stages of the simulation and provide the ultimate in fidelity.

An example of using the equipment's own routines to enhance fidelity is the case of threat displays during high rate maneuvers. During a high rate maneuver such as an evasive maneuver against an airborne interceptor, the threat symbols will track across the display according to the ownship's change in position and attitude.

During an evasive maneuver, the aircraft's inertial navigation unit provides the quickly changing velocity and acceleration vectors that must be used for calculation of the new threat symbol placement at a high update rate. The RWR internal software then displays these threat symbols with any anomalous behavior as in real life. The embedded trainer system must integrate the data from the existing systems such as the INS with an accurate threat DF and simulation and place it into the radar warning receivers active threat files. The RWR's computer then handles the remainder of the tasks of projecting them on the display.

For strictly monitoring onboard systems, fidelity can be achieved by using those systems as they exist and providing the required simulation software where it interfaces to the remainder of the system; for example, the onboard countermeasures equipment. The active jammer and the chaff/flare expendables can be used as they exist on the A/C with just an interface between them and the embedded system controller. The expendables can be pre- programmed according to the particular mission, but not loaded.

As the equipment goes through its paces, the dispense functions are monitored for type and number but no expendables are dispensed. The same is true for a jammer control panel but without the jammer loaded. The selected jamming functions can be monitored and simulated without the jammer being present and radiating. Both of these simulated ECM techniques can be used against a simulated environment, causing those threats to respond accordingly though no real expendables or transmissions occurred.

In an embedded system, those functions that are *performed in a combat scenario or a multi-stressed* environment should be to the highest fidelity practical for proper training. The initial training and primary learning will have already been accomplished by the time that the student gets to the embedded trainer. The embedded trainer must provide a high degree of fidelity to provide instant recognition and accurate reactions for high proficiency *training*. For example, if not simulated, the dancing or wandering of the threat symbols on the display will be an obvious telltale sign of a simulated threat compared to a real threat.

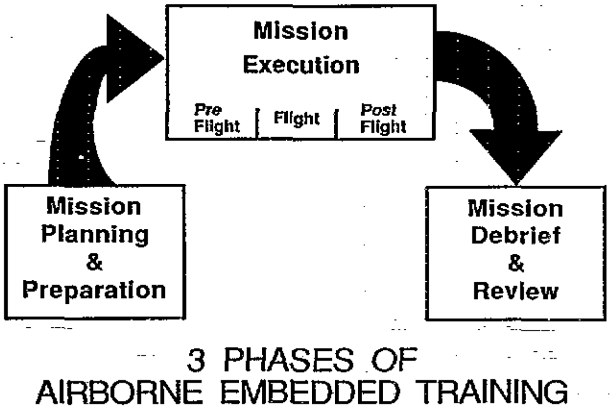


Figure 7

Ground Support

The ground support system (GSS) for an embedded trainer is as important to the trainer as the operational equipment, see Figure 6. The associated mission preparation and debrief system or mission support system (MSS) must be able to be used easily and efficiently for planning, loading and replay of the missions. The workloads of the pilots and operators as experienced in the squadrons do not allow for a lengthy mission preparation, or a complicated system that requires a lot of assistance to operate. Typically missions are not fully planned until just before flight time. When they are ready, last minute changes may need to be made to account for airspace restrictions or lack of assets.

Preparation

An interesting aspect of the ground support that was utilized by AAI during OBEWS development was the ability to prefly and preview a mission on the ground before the actual flight occurred. This was accomplished using an actual OBEWS pod system with a hot mockup of the RWR system in the Pod Laboratory. The missions were flown along the planned flight routes against the scripted threats using the terrain masking features along that route. It could then be observed how the aircraft would engage the threats during the mission. Threat location and/or aircraft flight path could then be adjusted to achieve the desired test conditions. In some cases, threats would be added, deleted, or relocated (e.g. they were engaged too closely or not close enough). The risk of an untested environment is a threat cluster that makes evasive actions only guesswork, losing training effectivity. A flight preview capability on future embedded systems may help to alleviate this.

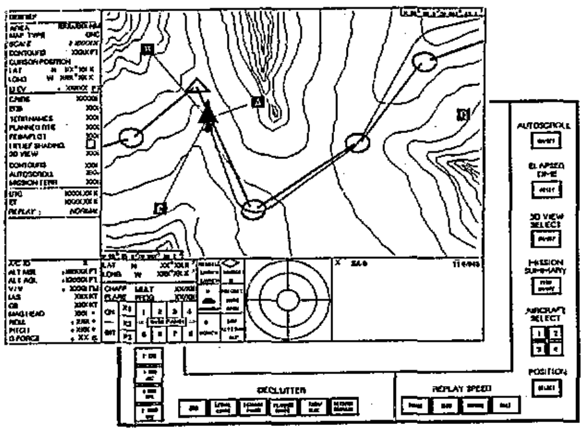
Preflight

Preflight built-in test (BIT) and confidence checks are also an important aspect of an embedded trainer. By design, an embedded trainer must talk to many different aircraft systems through many interfaces. To report only that the training system is down due to some unidentified interface may result in some unusually long preflights and possibly missed scheduled flights. Detailed failure status and individual test status were invaluable tools during testing in keeping the aircraft alive to support the trainer and may be of benefit in future systems.

Debrief

Post-mission debriefing is essential after an embedded training sortie if the maximum gain is to be realized from that training mission. According to the study "Electronic Combat Range Training Effectiveness" by Thomas H. Killion, the training is significantly more effective if coupled with post-mission debriefing for situation review and error analysis. Though the debrief is extremely important, the fidelity of that debrief does not need to be that of the training mission itself.

The operators want to be able to jump ahead to the critical mission points for a quick analysis of critical situations. All pertinent data needs to be presented at that time, such as aircraft position, speed, direction, and attitude, reference figure 8. Other essential data are situational characteristics (e.g., threat type, location, and current mode of operation) the operator must confront and overcome. Pilots reactions such as whether he is jamming, has chaff dispensed or is jinking in behind a ridge must also be presented. All of these facts allow the pilot and lead pilot to assess whether the right actions were taken given the situation and objectives.



DEBRIEF DISPLAY & OPTIONS
Figure 8

The graphics and tabular data should be accurate enough to give a true representation of the mission in real time. Careful time correlation needs to be maintained between the various systems if proper post-flight analysis of jamming, chaff/flare or maneuvering effects on a particular threat mode are to be performed. The visual and aural displays for the RWR and other simulated systems need to be accurate enough to stimulate the memory process and correctly represent the scenario. Items such as symbols dancing slightly on the scope presentation do not add enough to the debrief to warrant their incorporation. A general comment is often made by the designers that the more it looks like what is seen in the cockpit and out the canopy, the better it will be. In other words, the more it is like a football multi-camera instant replay the better it is. But in talking with the pilots and operators, "very good" and "good enough" are much less than an instant replay. They are not there to analyze the fidelity of the replay but to determine how well they performed accomplishing their objectives and avoiding the threats in the mission.

Concurrency

Concurrency can be viewed as either a bigger challenge for embedded trainers than for ground trainers or almost as a natural fallout depending on implementation and perception. In a designed-on trainer where the embedded system is added to the platform, the training equipment upgrades will not necessarily flow down from any operational equipment upgrades. The equipment is not tied to the trainer, except possibly through an interface and a small amount of resident software. It is highly likely that an upgrade to the system will cause an incompatibility with the embedded trainer.

A ground trainer it can wait until its turn comes around for funding of the concurrent upgrade. Meanwhile, it can still be used as an effective trainer, while just slightly behind the times. An embedded trainer is very different in that respect. When the upgrade to the system that may affect compatibility or functionality has been fielded, the embedded trainer can no longer be used. The embedded trainer is now an idle piece of equipment providing no training unless it has had a concurrent upgrade or the users are willing and able to backfit the operational system to its older version. This immediately defeats the purpose of fielding an upgrade for operational use Ultimately when embedded training becomes accepted and is utilized, it's requirements must be integrated with any system upgrades to which it must interface and operate; otherwise, it will quickly become obsolete and useless.

It is easier to conceive and rationalize that a designed-in software only training system will be easier to maintain concurrent than a designed-on system. It should be a natural fallout of any system upgrade. Embedded training is not a singular function; it uses data from many sources to generate its scenario. An upgrade to one system and its embedded training software could have an impact on another related system's ability to perform its portion of the embedded training if its training interfaces have been changed.

Another difficulty with maintaining concurrency during system upgrades and facing OBEWS at present is the slow or sometimes not so slow disappearance of on-board processor spare time and memory vitally necessary to hold the embedded training interface software. OBEWS was originally designed for the version 5 ALR-69 RWR, using only a small amount of memory in the RWR for the embedded training interface. As the RWR undergoes version updates, the amount of available spare also changes. What this demonstrates is that if embedded training is to become an integral part of a system, the proper amount of space must be allocated and the requirements set forth to ensure that it will exist throughout various upgrades.

Environmental Realities

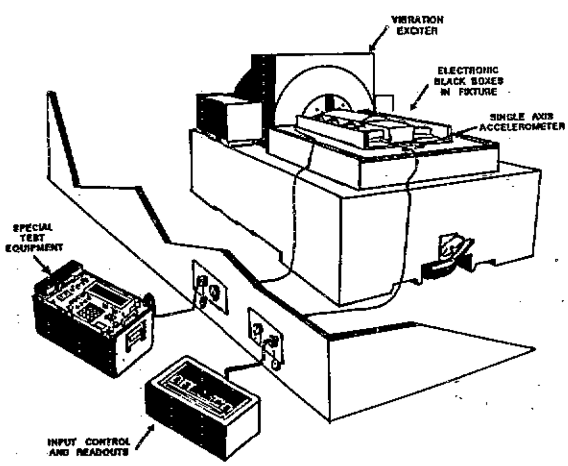
Most ground trainers and simulators reside in a climate controlled lab with filtered clean air, controlled humidity, constant temperature, regulated power, raised floors, and overhead lights; that is, climate suitable to both electronics and humans alike. If there is a bug in the system, you even have the opportunity to wheelup a logic analyzer, hook it up, and monitor the system while its running.

Now, imagine your favorite trainer reduced in size, distorted in shape, and shoe-horned into a missile shell that can experience ambient conditions such as -40 degress Celsius up to +80 degrees Celsius, the pouring rain or the sandy desert air, power that is trashy as a lightning storm, and then shake the system violently while it is operating in any combination of these conditions. It is as gruesome as it sounds. In the trainer and simulator world, these are not typical operating conditions, however for operational equipment, this is the norm.

The environment that an embedded system will experience, can be directly correlated to the platform that will carry it. The extremes of the environment and levels of the conditions will vary based upon whether the embedded training components are inside or outside of an aircraft. It is important to determine the environment within which the equipment will operate as accurately as possible. Underestimating the environment will result in repeated system failures during environmental testing and operational use. Overestimating the environment will result in excessive design requirements, needlessly driving up system costs and increasing schedule times.

INPUT CONTROLLED STIMULUS TEST

In addition to accurately determining the operational environment, understanding of the environmental qualification test criteria is just as important. Given a situation where the vibration 'G' loading is the same level for an internal black box versus a wing-mounted pod, the test criteria and techniques are completely different. For an internal black box, the vibration test would most likely be an input controlled stimulus. That is, if it is specified to be tested at a certain G level for random mechanical vibration, the specified G level would be used to excite the test fixture holding the black box (reference Figure 9). How the box performed mechanically would be a function of its design and construction, monitored only to document the test results.

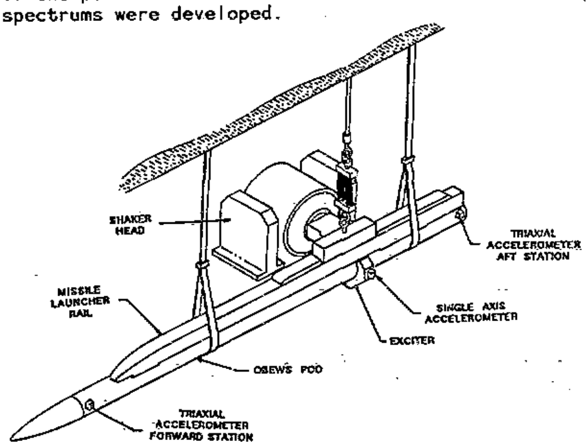


INPUT CONTROLLED VIBRATION TEST

Figure 9

RESPONSE CONTROLLED STIMULUS TEST

An external store, such as a pod, must be tested in accordance with MIL-STD-810, which specifies a response controlled stimulus type test, matching the fore and aft spectrums. This entails exciting the test fixture and pod with a random vibration spectrum of sufficient level to drive the system to the point of measuring the desired G level of vibration as an output from the pod, reference figure 10. For example, if the pod is specified as a 10 GRMS forward spectrum output and 15 GRMS aft spectrum output the exciter must input enough energy to vibrate the pod until those two levels are measured at their designated locations. If it requires a 12 G input that is what is used; however, it may require an input of 15 G's or even 20 G's. The objective is to input whatever energy level it takes to get the required matched spectrums out. This is a time consuming and complicated process, especially if the pod is not the exact same one for which the spectrums were developed.



RESPONSE CONTROLLED VIBRATION TEST

Figure 10

Other factors also affect test levels. The operational life expectancy is factored into the tests. As time in service increases, either the test times must extend or the test levels must increase. This will carry across all pertinent tests such as captive flight vibration and captive flight buffet as well as gunfire vibration, if appropriate.

TEMPERATURE CONTROL

Heat extraction is also a key factor in designing a system for operational use. An inboard system could have a fan for air circulation and cooling, while an outboard system may be completely sealed to keep out rain and other contaminants. An interesting factor is how altitude affects the fan's utility. At 50,000 feet, there is not much air to push around with a fan. The fans effect is minimal, but the ambient air temperature at those altitudes is well below freezing, providing adequate cooling without air circulation. All these factors must be calculated and weighed for a dependable system design.

Another factor after the design has been optimized for heat extraction, is what can be done about a supersonic dash on the deck? At that point, the air acts as a heater to cook the system instead of a radiator to cool the system so that the great cooling path to the outside now acts as a heating path to the inside. The proper sized thermal capacitors need to be designed in to provide the delicate balance between being too hot and cool enough. For embedded trainers, the tricks of the trade for operational equipment must be learned and utilized.

CONCLUSION

Embedded training bridges the gap between full ground weapon system trainers and hostile wartime experience to provide effective training in a cost effective manner. It is an ideal method to hone skills and maintain proficiency on a regular basis when fully instrumented ranges are not available. Embedded training is still in the infant stages but has a very promising future. If we can share what we have learned from the first embedded systems and apply it to future systems, overcoming the developmental problems and making the right decisions will come more easily.

The questions of design-in training versus design-on training and built-in versus built-on will have to be analyzed and answered on an individual basis. Fidelity will probably always be a subjective topic of discussion. Concurrency and environmental constraints may get better or worse but will most assuredly never go away. The implementation of embedded training systems will require the same level of analysis as ground training devices in addition to the size, weight, power, and environmental issues associated with flight systems, as well as mission analysis, pilot workload analysis, and flight safety.

The OBEWS system has been developed within the frame-work of embedded training. It has successfully demonstrated that embedded training can be effectively added to an existing operational platform with minimal aircraft impact by utilizing Design-On-Training (DOT) in a Built-On Training (BOT) pod. OBEWS has addressed its fidelity and transparency requirements accurately, providing realistic simulation along with useful transparency. The rigid environmental constraints have been met and overcome successfully, leading to a reliable test phase. OBEWS current flight test and evaluation can provide a great deal of insight into the future of embedded training, the next frontier of training.

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