EMBEDDED TRAINING: PROPER REQUIREMENTS ANALYSIS ENSURES QUALITY

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Abstract

The next generation of tactical equipment will include embedded trainers. The concept of embedded training is for a part of the tactical hardware, whether aircraft avionics, shipboard electronics, or ground-based electronics, to be used to provide training to an operator. The operator will be trained in a variety of tasks to enhance his proficiency in target recognition, equipment procedures, kill tactics and others. The requirements for the embedded trainer are specified in a contract systems specification. Embedding a trainer within tactical hardware poses new considerations in developing the tactical hardware. The embedded trainer requirements may dictate an interactive photo-based imagery to the digital map generator vendor and impose unique weight considerations for the mechanical design teams just to allow proper procedural or operations training. Since the embedded trainer is provided on tactical hardware, the tactical hardware vendors receive the requirements. Who should develop the embedded trainer, the tactical hardware developer or a training simulator manufacturer? If the tactical hardware developer builds the embedded trainer, he must understand the training requirements provided by the government training organization. If the simulator manufacturer develops the embedded trainer, he is faced with new concerns of limited memory and processor speed, tactical equipment weight restrictions, and ruggidized requirements. This paper will offer candidate criteria (Strap on vs. Embedded, host hardware to Mission Planning hardware commonality) to determine proper embedded training requirements, will address how technology advances like the Ada programming language will enhance the embedded training development and will present, from a lessons-learned viewpoint, the interfacing requirements between the tactical hardware and software and the embedded trainer software.

EMBEDDED TRAINING

Embedded Training (ET) is training that results from using a part of the tactical hardware to provide training of the tactical hardware. (Figure 1) This paper will address ET issues around large tactical devices like the Advanced Tactical Fighter (ATF), Light Helicopter Experimental (LHX) and Non Line of Sight/Fiber Optic Guided Missile NLOS/ FOGM System.

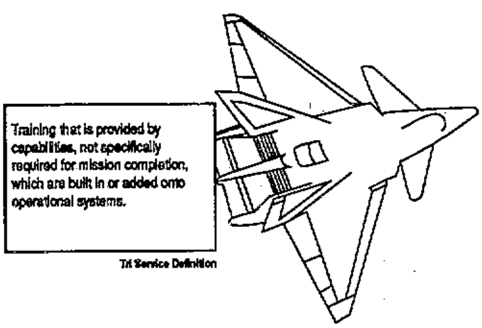

Figure 1
ET Definition

The use of expensive tactical hardware for training raises many long time questions that have yet to be answered. "Is it advisable to utilize mil qualified rad hardened equipment to provide training?" Is the pay off of the training effectiveness worth the cost of the additional increase in mean time between failures? (MTBF). Before the ET requirements appear to the vendor, exhaustive analysis is done to determine if the ET facet for training is feasible for this piece of tactical hardware. The winner of the prime contract for the tactical hardware must now begin the complete requirements analysis needed to allow proper insertion of the ET capability in the system.

The inclusion of ET into the tactical device raise many unique questions of which some are best answered by a prime tactical hardware vendor and some by a training simulator manufacturer. The demands placed on the hardware sometimes cause many problems as the prime tactical hardware vendor cannot phathom the training requirements and even the need for some embedded trainer? Never-the-less, the requirements analysis for the tactical hardware must include requirements allocated to the embedded trainer. It is pertinent that the ET system segment requirements must be clear and concise. If those requirements are vague such as "The embedded trainer shall provide interactive simulation "The prime contractor will always interpret those to the minimum impact as possible. A better way of phasing this requirement may be "The embedded trainer shall provide training representative of an interactive air to air single hostile threat environment i.e., (F14 to MIG23 air-to-air combat) as provided by the training doctrine from XYZ fighter training school." A dilema has just been raised, in which resolution is needed. This paper will address candidate criteria in determining the proper ET implementation.

The proper ET implementation results from a proper requirements analysis by the prime tactical hardware vendor.

The vendor must flow requirements from the system segment specification to the embedded trainer as if it were a major subsystem function. These types of requirements assist in determining part of the implementation but not the entire implementation. The allocated ET requirements must be further decomposed into two major categories: Hardware affective requirements and training effectiveness requirements. In either case, the requirements must be understood clearly in order to gain an effective ET implementation. The prime tactical hardware vendor must divorce himself from justifying the need for the embedded trainer. The justification has already been made; he must provide the best possible training implementation at the smallest tactical hardware impact.

Tactical hardware affective requirements are those which cause the tactical hardware vendor the most problems. Hardware considerations that must be addressed include:

- weight considerations
- packaging considerations
- additional processor and memory expansion considerations

The weight consideration is often times the most important criteria when trimming ET effectiveness from the system. Often times the prime tactical hardware vendor is faced with, for example, government furnished prime movers on ground hardware, the task of pushing state of the art aerodynamics and implementing complex avionics while minimizing size and cost. The weight consideration in itself could severly threaten a good ET implementation. A requirement received from the government may imply an interactive video disk and the prime tactical hardware vendor in his best and final offer (BAFO) may agree to a video disk player, but that does not ensure that it will be a part of the ET implementation. If the segment specification did not specifically ask for an interactive video disk, and if during weight analysis and allocation a weight problem arises, an alternative method may be employed such as having displays generated from a digital map generator. The quality is sorely affected but the general requirement of an interactive trainer is met.

Packaging considerations are kin to weight considerations. Is there room for this video disk player, or is something needed for the tactical environment more important that the training effectiveness?

Hopefully, 99% of the usage of the tactical hardware will be for ET.

The packaging issue involves determining whether the embedded trainer is strap on or truly embedded. Different types of tactical hardware pose different answers.

As new languages, such as the Ada programming language arises, considerations for processor spare memory and processing become drivers in the ET implementation. Ada offers many advantages such as code portability, understandability and maintainability, but when fielding an embedded trainer, those same luxuries that offer advantages cause disadvantages. Ada is an intense code expansion language, expanding upwards to 25 to 30 bytes per line of code. As ET capabilities cause new lines of code estimates, processing memory and processing requirements increase, thus affecting weight, packaging and cost. Many schemes can be employed to solve this issue. One alternative is code overlays where code is loaded from memory onto tactical processors that may have been idle during training.

Training effectiveness is by far the most important criteria in producing a proper ET implementation. The tactical hardware vendor must incorporate training effectiveness considerations as an equal part of the implementation criteria to hardware affective requirements. One set of criteria as established by Strasel, Dyer, Roth, Alderman and Finkley imply ways to help the tactical hardware vendor determine the proper implementation.

The Task-Stimulus Characteristics Model gives criteria for a better ET implementation, especially if a training effectiveness analysis has not been done. The criteria in the form of a checklist is as follows:

1) What is the need for recognizing and responding to battlefield scenarios?

2) What are the different types of scenarios in which an operator responds and what scenarios happen more frequently?

3) What are the different types of cues provided with these prioritized scenarios?

4) What are the different responses the operator makes and how often are they trained?

5) From the operator response, what are the types of operator tasks which need to be trained?

6) Which responses and tasks require speed in detection of key stimulus?

7) What is the need for tracking of targets and long visual contact with video monitors?

	Rating	Characteristic
1.		Battlefield Stimuli:
	——	Differ from Peacetime
	——	Frequent Experience Necessary
2.		Number of Stimulus Sources:
	——	Frequency of Multiple Stimuli
	——	Criticality of Success
3.	——	Number of Stimulus Patterns
4 or 5.	——	Number of Different Responses or Number of Operator Tasks and Subtasks
6.	——	Need for Response Speed
7.	——	Sensitive Tracking Tasks

* small extent = 1, moderate = 3, high extent = 5

Figure 2
Worksheet for the Task-Stimulus Characteristics Model

Recognizing and responding to battlefield scenarios imply the need to train as if the operator were involved in a real battle. The operator perceives different views during peacetime that may impact his decisions during battlefield operations. The ET implementation must provide sustainment of specific skills which may be lost in the "slothfulness" of peacetime. In some cases, the embedded trainer may be used to provide practice of a scenario the night before that real battle scenario is proposed to happen. As the battlefield changes, the embedded trainer provides quick training not achieved from institutional type trainers.

Different types of scenarios and their frequence give good indications of specific tasks and skills which need to be trained. The types of scenarios give insight into patterns in the battlefield. As patterns are trained, the operator becomes proficient enough that the his actions become secondary, as if riding a bicycle.

The different types of cues, such as visual and aural, can play a major role in the ET implementation. A thorough analysis is needed to evaluate their effectiveness as the ET implementation may be a costly one in terms of weight. The proper cue effectiveness analysis must be balanced against cost and weight criterias.

The operator responses and types of tasks are tied closely to the mission analysis and number of stimuli encountered. Proper mission analysis will normally produce a set of operator responses and tasks which should be trained.

Figure 3 is a part of an Operational Sequence Diagram (OSD). From the OSD, operator tasks can be identified. These tasks imply responses and those tasks and responses can be traded against the segment specification requirements. Key tasks which require fast operator responses may also be derived from the OSDs. The fast operator for responses constantly give insight into tasks which need to be trained. The tactical hardware vendor must try to implement the best training possible for these responses.

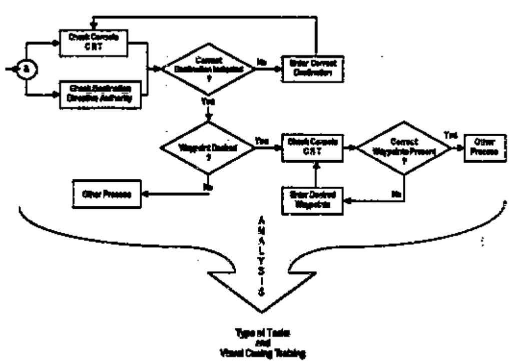

Figure 3A
OSDs Identify Tasks

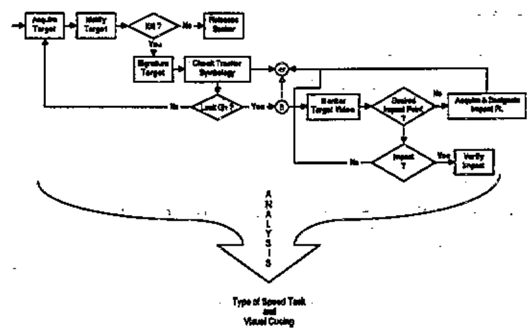

Figure 3B
OSDs Lead to Speed Tasks

Long visual encounters with video monitors training provides training for perception of tracked targets or video monitor actions. These tasks deal with recognition skills. The ET implementation must consider the need for this type of training.

The integration of the hardware affective and training effectiveness is needed for the best ET implementation. The tactical hardware vendor must perform these analyses in parallel. Typically, the physical hardware capabilities will impact the training effectiveness. For example, the training requirement may imply the need for a recording mechanism; whereas the hardware concept may not provide that capability. At that point trying to change the hardware concept is non existent. Figures 4 and 5 illustrate the requirements analysis. Often times the list of training requirements are as diverse as the number of people who are asked to generate the training requirements. The tactical hardware vendor must incorporate a strategy for determining proper requirements similar to those in Figure 4.

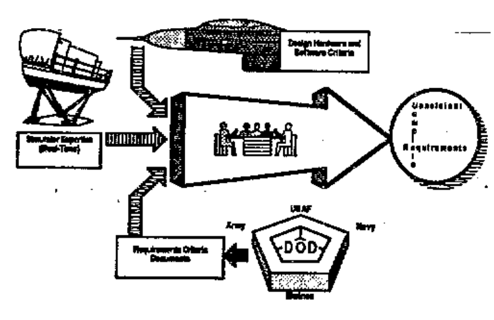

Figure 4
Requirements Analysis

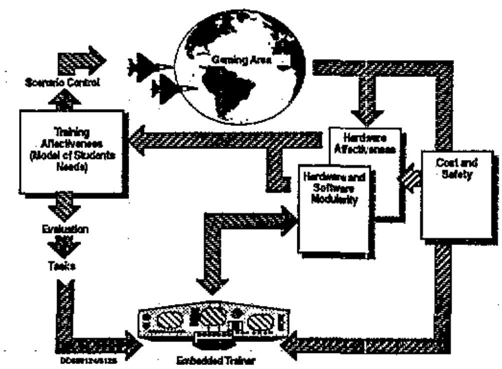

Figure 5
Embedded Training Requirements Analysis: Iterative Process

Other requirements are derived from implementation concepts that affect the ET implementation. Those concepts include requirements derived from strap on vs. embedded approaches, modular hardware and software approaches, Artifical Intelligence/Expert System AI/ES criticality, safety and cost criteria.

STRAP ON VS. EMBEDDED

The argument of strap on vs. embedded trainers depends largely on the tactical hardware. Several specifications have allowed the trade offs to be conducted by the tactical hardware vendor. A strap on system offers advantages such as:

- The major portion of the trainer should not have to meet mil hardening requirements thus decreasing cost.
- Flexibility of the number of strap on ET devices, i.e., devices can be used when needed.
- Total cost of the trainers
- Minimization of memory and processor needs and and disadvantages such as:
- The software partitioning problems are enhanced
- Weight changes during tactical hardware operation
- Increased scheduling of training devices

One implementation concept for a strap on system may be to modularize the tasks or functions which are to be trained. If the requirements support this concept, multiple low cost embedded strap on trainers can be used to "specialize" train before critical missions. The strap on trainer concept may fit better with tactical aircraft than with ground systems. The added risk induced by embedded trainers may force a thorough evaluation of the strap on devices. The embedded system offers advantages such as:

- The trainer is always available with the tactical hardware
- Modular software engineering approaches can be used in development
- Ease in interfacing to the tactical hardware

and disadvantages such as:

- Maximization of memory and processor needs
- Additional "full time" weight considerations
- Utilization of mil qualified hardware and electronics The embedded concept allows a complete implementa tion of the system as a whole thus decreasing if commu nication problems between a separate organization whose responsibility may be to develop the strap on device.

MODULAR HARDWARE AND SOFTWARE APPROACHES

Modular hardware and software approaches offer criteria in determining a good ET implementation. Modular software approaches to the ET are enhanced by improved software engineering techniques whereas modular hardware approaches are enhanced by faster small super linked micro computers.

There are two principal methods of mapping the solution space to the problem space: functional decomposition and object decomposition. The former treats the system as a whole as a black box, or in its stronger form treats the functions performed by the system as black boxes. It is clear that many significant features of the problem space may be overlooked or incorrectly mapped in this method.

Object decomposition attempts to discover the significant objects in the problem space, to classify these objects by common behavior, and to partition the software accordingly. Each of the significant objects will be overlooked, or (b) that objects will be incorrectly classified. For example, the segment specification may require a threat implementation.

An object-oriented approach would yield a database for guns, Anti Aircraft Artillery (AAA), and Surface to Air Missiles (SAMS). An object-oriented implementation is enhanced by hierchical control of the objects. In this case, executives and module sequencers are on a higher level than the object-oriented software, and serve to keep the latter ignorant of the former. For example, lower level modules should not care when or whether another module has executed, but this is precisely the concern of the module sequencer. Because of this hierarchy, and modularity it is possible to change the behavior of a type of Threat within the class by simply recompiling a modular unit.

Partitioning into classes force considerations of what behavior is common to threats, and what is knowable about threats. Further, the number of threat types and the behavior of each threat type are relatively transparent to the overall design. Threats can be added or deleted without side effects.

Another software engineering concept which assists in the ET requirements analysis is transparency. Transparency requires that a module never be permitted to execute on invalid data. Otherwise, the module would be dependent on the process which should have produced that data. Transparency to modules running on other processors means that the interface to a module should be the same whether the module is actually performing the computation or whether the module is sending it out to be processed by another processor.

ARTIFICIAL INTELLIGENCE/EXPERT SYSTEM AI/ES CRITICALITY

Artifical Intelligence and the Expert System also should be considered when doing the ET requirements analysis. AI/ES concepts introduce more unique concepts which affect the tactical hardware vendors implementation concepts. The tactical hardware vendor must understand the need for an expert, i.e., instructor like function is needed. This is a hard concept for him to understand since training is really not his speciality. The correct ET implementation, when an expert is needed, will probably not be achieved unless the tactical hardware vendor is assisted by a training requirements analysis group. Government procurement contracts today offer assistance in this area as they force teaming of tactical hardware vendors with simulator manufacturers.

SAFETY AND COST CRITERIA

Safety and cost are vital criteria when determining the proper ET implementation. The safety of the crew and the tactical hardware surrounding may be jeopardized in a casual ET implementation. A thorough safety evaluation is needed during requirements analysis to assist in the best possible implementation. Cost considerations often times drive many implementations. It is pertinent to build within or around cost, but the ET implementation should not be the area for major cuts when projects begin to overrun. Remember,

HOPEFULLY, 99% OF THE USAGE OF THE TACTICAL HARDWARE WILL BE FOR ET.

It is pertinent to produce the best ET implementation to maintain combat readiness. Figure 6 represents key factors for the production of a consistent and complete ET implementation and Figure 7 most often represents the view of embedded trainers by tactical hardware vendors.

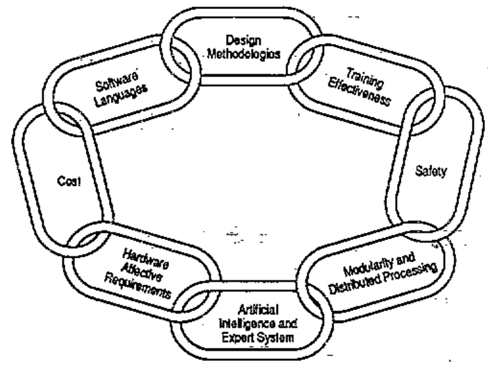

Figure 6
Key Embedded Training Requirement Contributors

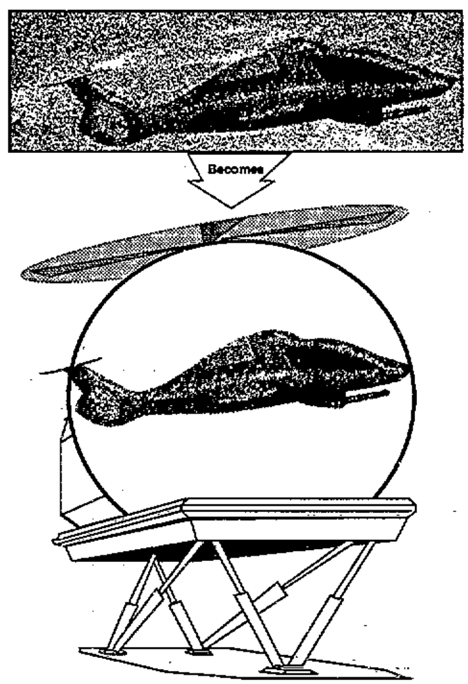

Figure 7
Tactical Hardware Vendors ET Impression

The next generation of tactical equipment will include embedded traners. It is up to contractor and government to act as a team to provide a proper ET implementation. Since the embedded trainer is provided on tactical hardware, the tactical hardware vendors receive the requirements. Who should develop the embedded trainer, the tactical hardware developer or a training simulator manufacturer? If the tactical hardware developer builds the embedded trainer, he must understand the training requirements provided by the government training organizaiton. If the simulator manufacturer develops the embedded trainer, he is faced with new concerns of limited memory and processor speed, tactical equipment weight restricitions, and ruggidized requirements. The proper combination of both vendor mindsets is the mix needed for successful ET implementations.

This paper has presented an approach to proper requirements analysis to lead to the best ET implementation. Hopefully, this paper has exposed some of the knowledge needed to start the transition to successful ET applications. Many ET implementations may be developed before the full set of requirements criteria is obtained. Never-the-less the mindset of determining trade offs between hardware and software modularity issues, strap on vs embedded concerns, AI/ES concerns and safety and cost concerns will yield a better ET implemenation.

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