INCREASED READINESS THROUGH MODULARITY

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ABSTRACT

A current DOD thrust to develop and apply modularity approaches, tools and standards to training simulator development and acquisition is expected to yield benefits in reduced cost and acquisition time, as well as improved supportability. Top-down functional design of stand alone modules and well-defined interfaces will enhance simulator system designs. This paper examines the effects and benefits of modularity which are expected to increase readiness through earlier trainer availability dates and increased supportability. The derivative effect of modularity appears to provide new options that can operate to support increased defense readiness.

INTRODUCTION

The U.S. Government has recently launched a modular simulator design development program. The present effort focuses on aircrew training simulators. Several factors and considerations appear to have influenced this initiative.

Emphasis on ground-based training for the full military aircrew complement has led to the development of complex training systems. In turn, technical and management challenges for procurement agencies, and the simulation industry have resulted, such as:

- Trainers cost more than expected
- Trainers take longer to develop than expected
- Trainer supportability does not meet expectations

Seeking ways to meet these challenges and in light of the success of the Air Force's Modular Automatic Test Equipment (MATE) program, a government decision was made to investigate the advantages of modularizing simulators starting with aircrew trainers. DOD procures, operates and supports a large number and a wide variety of training equipment and could conceivably benefit from the establishment of modularity standards. Envisioned is a program conceptually similar to the current MATE program. Potential benefits include:

- Reduced cost
- Reduced development time
- Improved supportability
- Improved modification capability

If these benefits are realized with the eventual development and application of modular simulator design standards across industry, then it appears likely that another important benefit will result—defense readiness will be increased.

As an example, in a related program the readiness benefit envisioned by the contractor responsible for the MATE program was that the defense mission is better fulfilled through:

- Simpler skills and training because of computer-simplified test procedures, common hardware, procedures, and documentation
- Reduction of false rejects
- Eliminating unneccessary troubleshooting

These benefits are for MATE but do indicate general readiness improvement potential for application of modular principles to simulator development.

DEFINITION OF TERMS

Modular simulator design, or modularization, is defined as the organization of subsystem/hardware/software components into standard units. This involves breaking the flight simulator package down into cohesive blocks (modules) of equipment or software with standards for control of design and acquisition of the modules. Using this approach, any number of modules can be readily integrated to form a new simulator, thereby using known hardware and software with performance results predictable in advance.

Readiness is a complex term and implies different things under different conditions. For our present purpose, readiness is defined as the state of being prepared and able to do the assigned mission without serious limitations. That is, whatever the organizational level or military service, the equipment is ready, the crews are trained and the logistics support is available. There are states of readiness such as "day-to-day" readiness and "crews sitting on the runway." There are levels of readiness such as employed by SAC. But what we basically mean by readiness is "ready and able."

ANALYSIS OF MODULARIZATION BENEFITS

What usually motivates investment of time, energy, or money is the potential payoff. We can better visualize this payoff for the eventual application of the modular simulator design approach as shown in Figure 1. That such benefits can be realized from using the modularization approach is supported by the relative benefits achieved from modularization in an Automatic Test Equipment (ATE) product line, as shown in Figure 2.

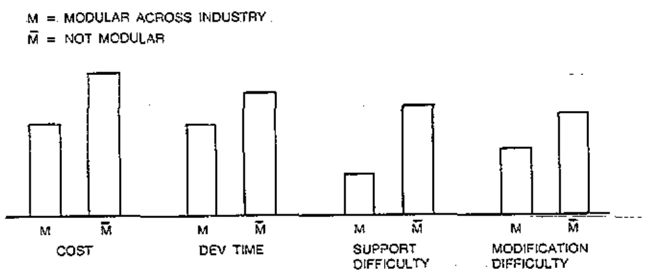

Figure 1 Relative Benefits of Modular Simulator Design Approach Application (Conceptual)

The favorable influence that modularization of training simulators could have on readiness is shown in Figure 3. However, modular simulator design does not automatically buy improved readiness. To realize such improvements will require some consideration for factors that link potential modularity benefits with readiness improvements. This consideration will involve both the government and industry. To illustrate: The involvements and benefits expected from the MATE

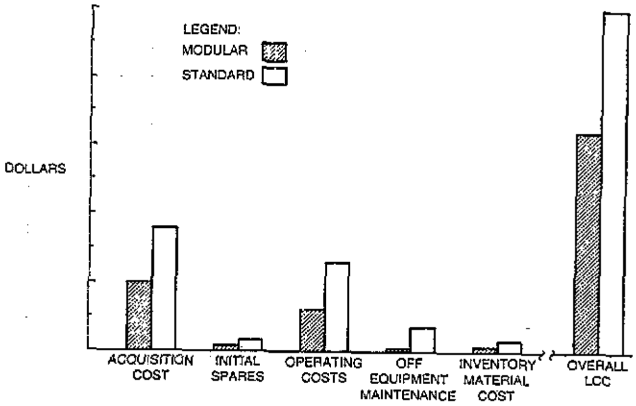

Figure 2 Relative LCC Comparison of Modular vs Standard ATE Design

SOUGHT BENEFIT OF SIM MODULARITY	LEADS TO	POTENTIAL IMPACT ON READINESS
REDUCED COST	AVAILABLE FUNDS OPTION	OPTION FOR REALLOCATION OF FUNDS TO FURTHER IMPROVE OVERALL DEFENSE READINESS
REDUCED DEVELOPMENT TIME	EARLIER DELIVERY OF TRAINING SIMULATOR OPTIONS	SYSTEM PERSONNEL READY TO PERFORM MISSION SOONER, BETTER AND MORE SAFELY
IMPROVED SUPPORTABILITY – COMMON HARDWARE, PROCEDURES AND DOCUMENTATION – REDUCED PARTS INVENTORY – TRANSPORTABILITY – REDUCED SKILLS REQUIRED	OPTIONS TO 1) REDUCE SUPPORT PERSONNEL SKILL LEVELS AND NUMBERS 2) STREAMLINE PARTS SUPPLY SYSTEM 3) INCREASE SUPPORT FLEXIBILITY 4) INCREASE TRAINER AVAILABILITY FOR TRAINING 5) REDUCED SUPPORT COSTS	BETTER SUPPORT = MORE AND BETTER TRAINING + LESS PRIMARY SYSTEM USE REQUIRED FOR CREW TRAINING = PRIMARY SYSTEM IN BETTER CONDITION FOR DEFENSE MISSION ALERT
IMPROVED MODIFICATION CAPABILITY	OPTIONS FOR SIMPLER, EARLIER AND LESS EXPENSIVE SIMULATOR UPDATES FOR *CURRENCY WITH* PRIME SYSTEM CHANGES	CREWS ORIENTED QUICKER TO SYSTEM CHANGES PROVIDING *IMMEDIATE IMPACT OF CHANGE* FOR UNINTERRUPTED READINESS

Figure 3 Modular Simulator Benefits Lead to Options Having Potential Impact on Readiness

program is exemplified in a 1980 AIAA paper by WPAFB logisticians, Lt. Col. Byrne and Capt. Allen, where they, in part, conclude:

> "MATE can make affordable automatic testing a reality for the Air Force and offers numerous collateral benefits. However, standardization, especially during this transition, will not come easily."(1)

These authors enumerate many expected benefits from the point of view of government and commercial developers, the military user, and the logistics supporter. In order to see the origin and sequence of the development of benefit options better, we will next look at one approach to the modular simulator design concept development *program.*

MODULAR SIMULATOR DESIGN APPROACH

This approach employs a disciplined systems engineering structure to take full advantage of the value of this process as a means of providing an unbiased, logical framework for conducting the modular *simulator design* concept definition (Figure 4). The approach is divided into five broad functional areas (Figure 5):

- Design concept definition
- Design concept application
- Impact definition
- Implementation planning
- Concept documentation

Design Concept Definition

The concept definition begins with a top-down functional analysis that considers existing functional groupings, identifies operational *performance requirements and determines the specific capabilities* needed to satisfy the functional requirements. The output, *representing an aircrew simulator functional* analysis, is utilized to formulate the preliminary modularity concept in concert with the initial module selection criteria. Special emphasis is placed on the resolution of hardware/software module levels that meet the *functional* performance requirements yet minimize any effects of modularity on technological innovation and development.

Design Concept Application

The preliminary module selection criteria, developed during design concept definition, is applied to selected Weapon System Trainer (WST) programs to provide additional design insights and validation opportunities. The physical and functional interface definition is explored in terms of establishing a concept that will standardize and *simplify both the physical and functional aspects* of a modular design. The preliminary output is tested by further application of these concepts to the selected WST. In addition, an existing set of physical functional interface criteria, developed in support of ongoing company modularity research and development programs, serves to further refine the candidate approaches for an industry-wide application.

Impact Definition

During impact definition, the impact on module testing/qualification. Higher Order Language (HOL), logistics, aircraft equipment and *existing simulator modularity* elements are assessed. Knowledge of military systems and proven logistics models are applied toward an objective evaluation of the modularity impacts. This approach to module testing and qualification is refined through development of a list of requirements based on the final selection criteria and the selected interface approach. Development of implementation tools parallels this activity. The output is a plan that clearly defines the path *to module qualification.* An assessment of the interrelationships between the modularity concept and related support elements is conducted with impacts being defined and quantified in terms of cost, availability and manpower. Additional impact *assessments are* conducted relative to the use of HOL and Ada languages on military simulators. Cost data generated in the preceding areas is used to assess the impact of the modularity concept on aircraft equipment and the results quantified in terms of capabilities which may be built into aircraft systems to support simulator modularity as well as any impact on acquisition and life cycle costs.

Implementation Planning

Recognizing that the success of the simulator modularity concept is *dependent on an effective and appropriate* management system, planning is developed that establishes a viable schedule for phase-in/out of simulator modules/standards, the required management structure and modularity tools. Close coordination with the government is imperative in this process. Implementation costs are developed using proven cost estimating methods for development, production, and operations and support elements. A *follow-on* phase plan is to be developed to provide for the redesign of an existing simulator, testing/qualifications of the resulting modules, integration of modules into a training system and validation of the modularization tool system *performance.*

Concept Documentation

As the final action, a technical report is prepared which will present a complete and comprehensive documentation of the modularity approach. This report includes statement of work and associated specifications as well as the procedures, processes and rationale *used in conducting* a follow-on study.

ANALYSIS OF AIRCREW TRAINING SIMULATOR FUNCTIONS

System engineering techniques and procedures are used to conduct a top-down functional analysis of aircrew training simulators. Existing functional grouping concepts used in all levels of training devices are considered during this analysis. *However, these grouping* and module concepts are not considered as constraints on the functional analysis. For example, Figure 6 illustrates two potential modularity approaches to a given aircraft multifunction training application.

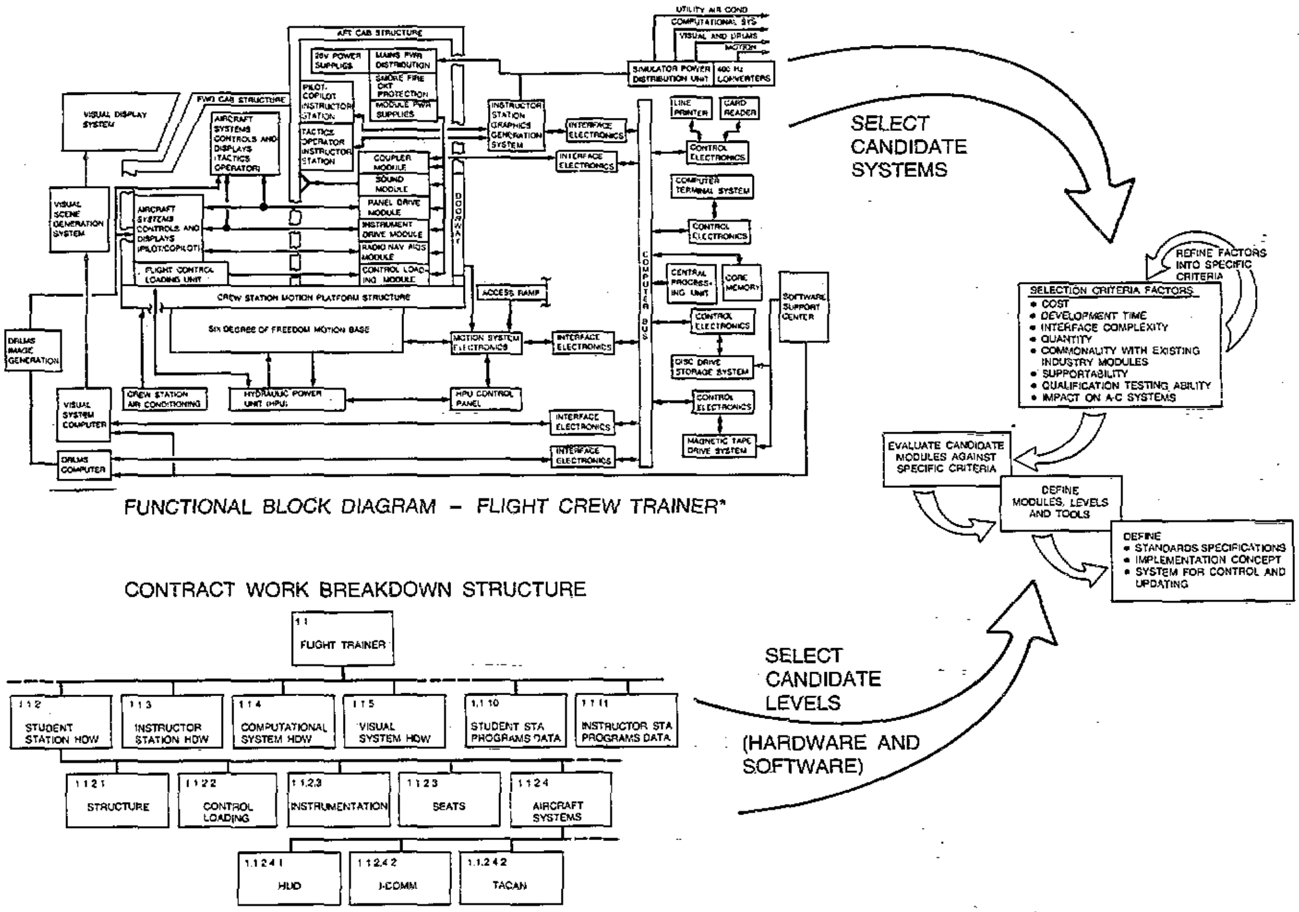

Figure 4 An Approach to the Modular Simulator Design Concept Development Program

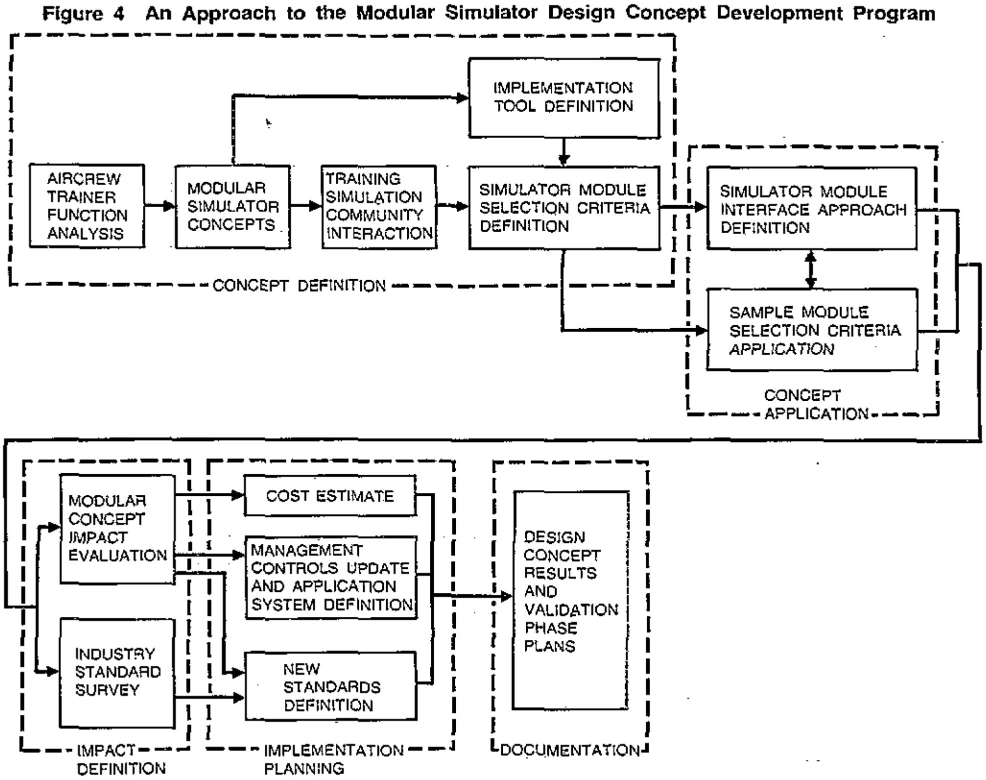

Figure 5 Modular Simulator Design Concept Development Road Map

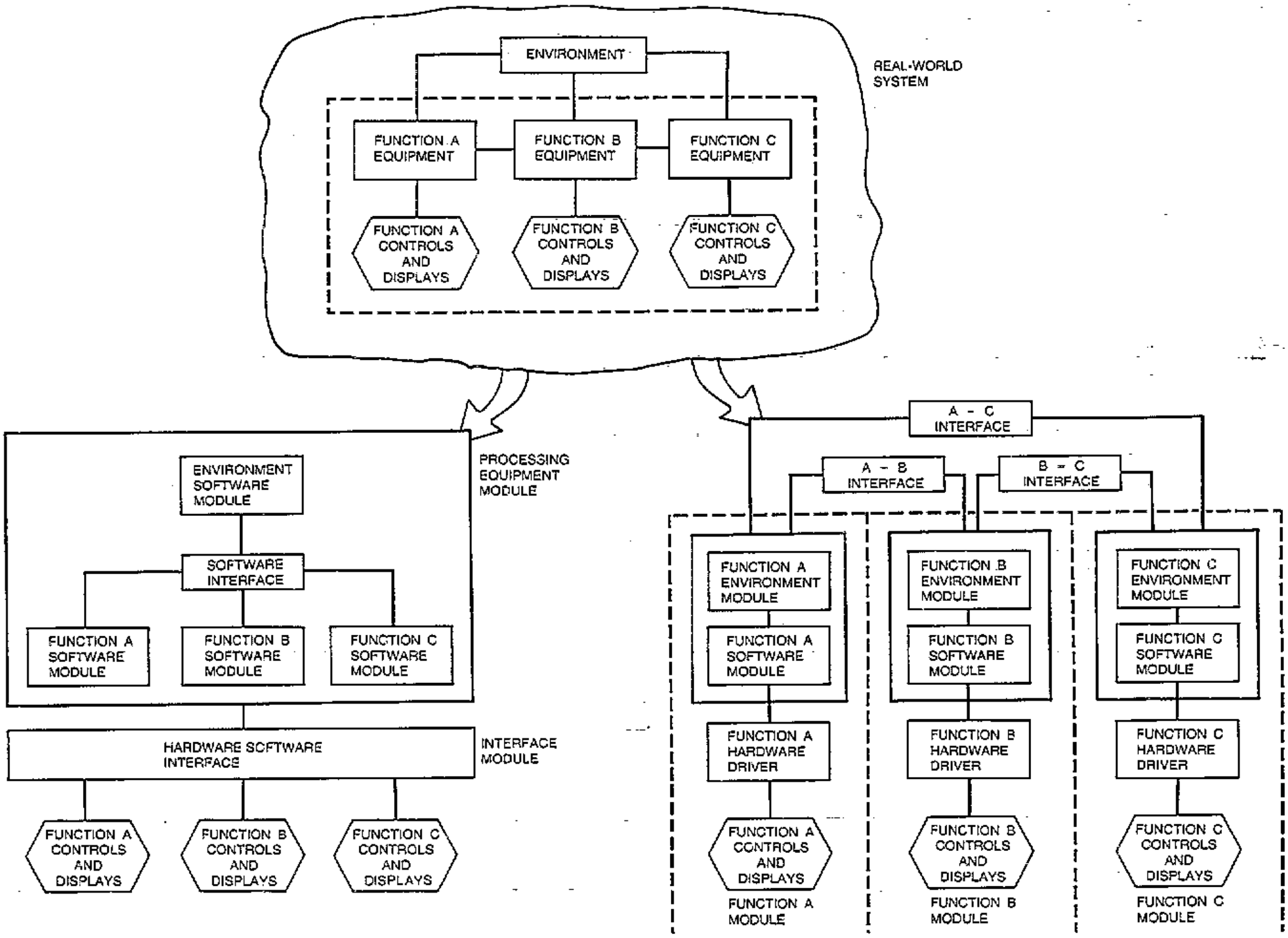

Figure 6 Two Potential Modularity Approaches

The first approach is representative of current training simulation technology. In this approach major system modules perform common simulation tasks across all simulated aircraft functions. Computational processing and hardware/software interface equipment are treated as major system modules. Individual software and hardware modules at a lower level simulate the aircraft/system functions.

An alternative approach might involve modularization by aircraft/system function. In this approach, all necessary processing hardware and software, interface and control/display capability for a particular subsystem would be contained within a given function module. In this case, it would be extremely important to identify and specify a flexible, common interface to communicate between system modules. In current applications, visual, DRLMS and motion systems lend themselves well to modularization at this level. Extension of this type of function/module allocation to other training subsystems such as instructional, environmental and aircraft systems simulation are considered.

Operational performance requirements for military training simulators are identified, including the support requirements necessary to maintain the operational capability of these systems. Operational constraints are also defined. This analysis determines how each function is performed and considers feasible alternate combinations.

Capabilities required to satisfy identified functional requirements are determined by:

- Examining each system function to determine the kinds of capabilities needed to meet training simulator performance requirements.
- Exploring possible combinations of functions which provide the required performance capability, while simplifying the interface complexity.

Potential modules and functional groups of modules are then allocated to the identified functions and required capabilities. A similar process was followed in using MATE guides to simplify interfaces as those shown in Figure 7.

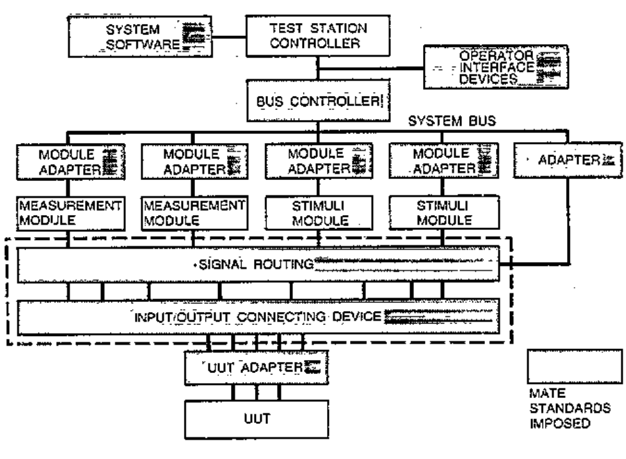

Figure 7 MATE Standard Interfaces

CANDIDATE MODULE GROUPING

Candidate groupings of potential modules are prepared from the aircrew simulator functional analysis previously discussed. These candidate groupings, taken from a cross section of simulation and aircraft industries are documented in terms of functional capability and interface descriptions. Examples of the results of such groupings are shown in Figure 8 for a flight crew trainer. Development of the candidate groupings goes hand-in-hand with development of the candidate levels discussed in the subsequent section.

Sensor simulation systems, such as visual Computer Image Generation (CIG) and Digital Radar Land Mass Simulation (DRLMS) systems, provide good examples of potential candidate modules.

Sensor simulations incorporate Digital Data Bases (DDBs) which provide a processor-compatible earth topography model to be used in generation of simulated visual/sensor imagery. Historically these DDBs have been quite different between suppliers and even between the individual sensor simulation types of a particular contract. This has been due primarily to the fact that DDBs were a result and not a requirement of the sensor simulation design process.

Improvements to digital processing state-of-the-art have removed many of the constraints on sensor simulation processing, raising the possibility that the DDB could become the standard component or module around which new CIG, DRLMS and other sensors are designed. Figure 9 shows a potential approach whereby an integrated data base generation/support system could be employed to support a number of sensor simulations.

A modularity approach whereby the DDB is considered a standard "module" may provide both training fidelity and supportability benefits. Since the DDBs for these simulations provide real-world terrain references and since multiple sensor simulations may be active simulataneously, this approach would provide a high degree of correlation between the individual simulations. Additionally, the necessity to create, maintain and support a number of separate DDBs would be reduced or eliminated.

In this example, it is important to note that any standardization of the DDB would have to be carefully applied to data base content and format and not to specific media. Advancements in laser-optical, bubble memory, and other high density bulk memories would quickly cause the obsolescence of any media standardization. Sensor simulation systems present other possibilities for modularity beyond the DDB since processing subsystems such as line-of-sight, coordinate transformation, data retrieval and memory management subsystems perform largely the same function regardless of application.

MODULAR LEVEL DEFINITION

Development of the candidate levels is an iterative process which is initially derived from the top-down CWBS examination of the typical trainers in conjunction with the functional analysis of the natural interface groupings. However, the ultimate definition of the modularity levels comes concurrently with the definition of the modules themselves through repeated refinement and application of the module selection criteria. Two considerations in level selection discussed here are: (1) future industry innovation impact and (2) module complexity.

Innovation Impact

The interplay between a specific modularization concept and future technological innovation is a subject requiring special emphasis and insight. In most areas of technology the simulator industry uses the latest "state-of-the-art" techniques and will probably continue to do so; however, the industry is not generally in itself a significant technology driver. The only major exception is that of sensor system (visual/digital radar landmass simulation) in which new techniques such as laser scanners are under development. If modularity is standardized incorrectly, the ability of industry to use state-of-the-art innovations will be inhibited. Ideally, from an innovation viewpoint, the modular simulator design concept should standardize interfaces but allow total freedom of design within the module. If the standardization dictates the internal design of the ERU, innovation flexibility is lost. It appears that the most important level(s) at which to apply the innovation freedom is a combination of the system level and the ERU level.

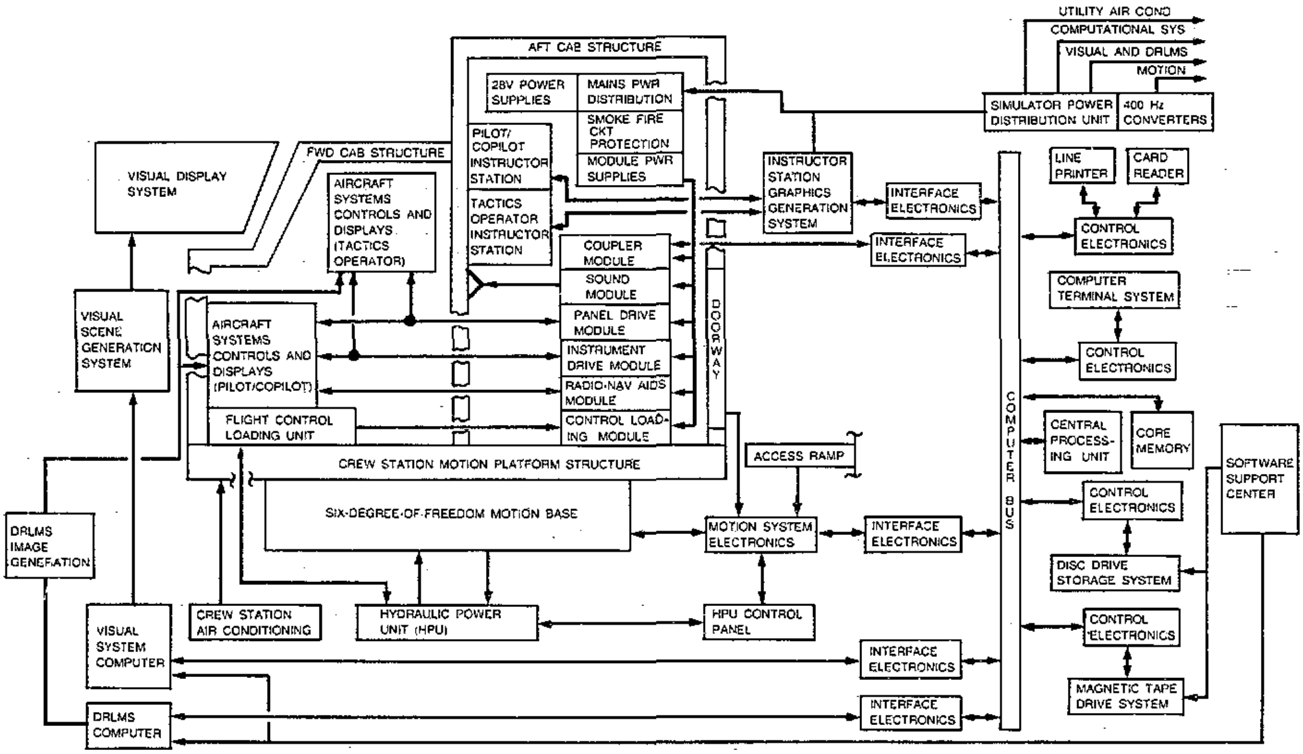

Figure 8 Flight Crew Trainer Module Grouping Example

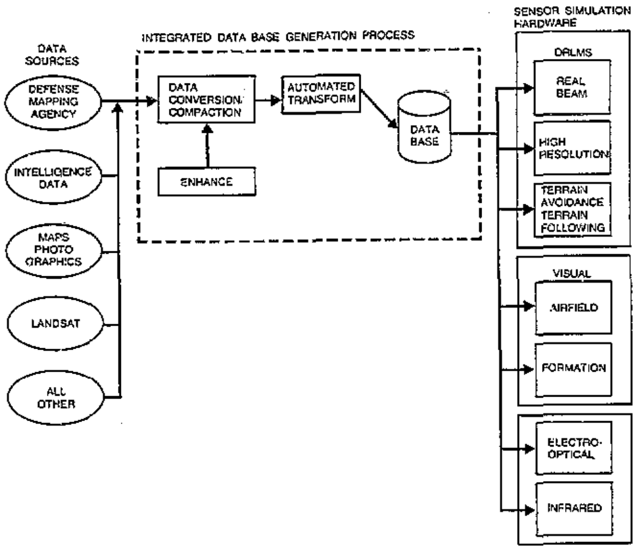

Figure 9 Data Base Driven Sensor Simulation Example

Module Complexity

Module levels are also resolved in light of both hardware and software complexity needed to meet the functional performance requirements. For example, if trainer A requires only 50 percent of the performance capability of trainer B in a particular module or module grouping, does trainer A pay the overhead of carrying the additional capability for the sake of standardization or go to the next lower level and still select standard modules to provide the required level of capability? An example of software levels is provided in Figure 10.

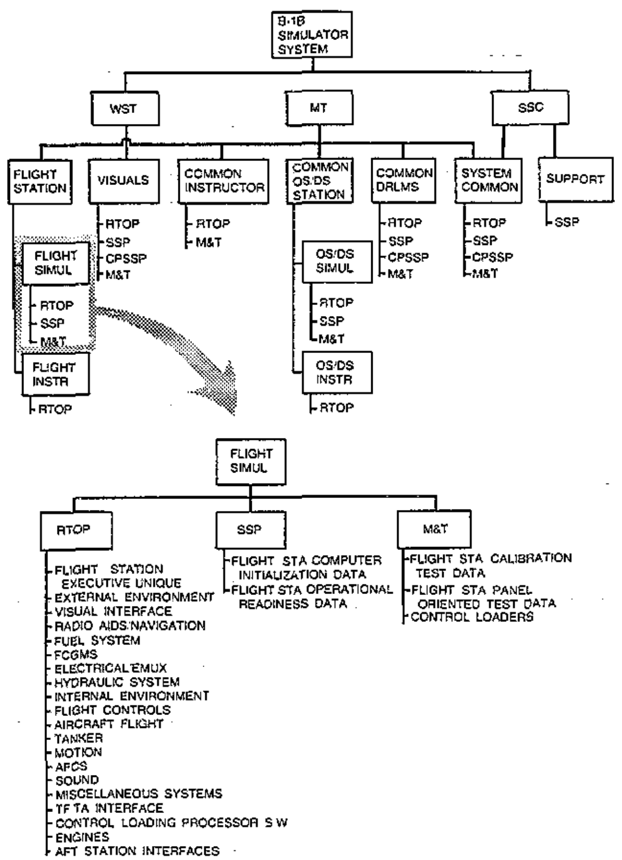

Figure 10 Example of Computer Program Modularity Levels

OTHER MODULE DEVELOPMENT CONSIDERATIONS

The purpose of this paper and space/time limitations do not allow a full description of the process of development of the modular simulator design approach. However, this approach includes:

- An industry survey
- Implementation tools definition
- Module selection criteria development and use
- Modular design concept applications
- Logistics considerations
- Development and validation of modular simulator design "tools"

Now that we have reviewed an approach to the development, and to some extent, the application of modular simulator design concepts, we have a better foundation to visualize how modularization benefits can be linked to readiness.

ANALYSIS OF MODULARITY/READINESS RELATED BENEFITS

Some modular simulator design application benefits may well provide fallout readiness benefits without specific plans, decisions, or actions. We can be satisfied with that, or we can thoroughly analyze all potential links between modularization and readiness benefits and plan to enhance the value of simulator modularization benefits that improve readiness. The key is to recognize the improved (or increased) decision-making options in working alternatives. For example, in Figure 3 if the sought benefit of reduced cost is realized, this leads to an "available funds" option. These would be government funds that could, by decision, be left unused or used for any other purpose within the fiscal constraints. In this case, the only way to enhance readiness is to reallocate saved funds to a readiness cause. A second example from Figure 3 is the earlier delivery of training simulator option which is possible when development time of a simulator is reduced through modularization. If this benefit is expected and the decision is made to start the training simulator development later, by the number of months saved, then of course the modularized simulator trainer would be delivered at the same time as the unmodularized simulator trainer, and there would be no beneficial impact on readiness from that modularization benefit. The point is, that only if the appropriate decision-makers are aware that such options exist and that there is a plan in effect that states a requirement to weigh such factors in their decision-making consideration, will some potential readiness benefits be able to be realized from modularization.

On the whole the derivative effects of modularity appears to provide new options that can (or can be made to) operate to support increased defense readiness.

REFERENCES

1. Byrne, R. O. and M. K. Allen. Affordable Automatic Testing. AIAA-80-1826, AIAA Aircraft Systems Meeting August 4-6, 1980, Anaheim, CA.

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Mr. Frederic W. Snyder is a Training Equipment Engineer in the Military Training Systems organization of the Boeing Military Airplane Company, Wichita, Kansas. He is currently performing system studies in the new business area. He has a Master's degree in Experimental Psychology from Wichita State University. He has served as a Research Specialist and Senior Supervisor in Crew Systems. In these capacities he has participated in and directed Crew Systems Engineering and Simulation programs as part of military airplane development and R&D at Boeing for 25 years. Prior to joining Boeing he was Staff Research Psychologist at the Menninger Foundation and an instructor in Psychology at Wichita State University. Mr. Snyder has published and presented a number of research papers in the field of psychology and crew systems, authored a book chapter on vibration and vision, and co-authored a book on inverted vision research.