OPERATIONAL AND TRAINING ANALYSIS; THE DEVELOPMENT OF TRAINING DEVICES CONCURRENTLY WITH THE DEVELOPMENT OF AN AIRCRAFT SYSTEM

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ABSTRACT

Historically, aircrew training devices were developed after the aircraft were well into production and after the requirements for the training devices were well established. These requirements often reflected aircraft capabilities and failed to take training considerations into account. Currently, aircrew training systems demand the design and manufacture of training devices while the aircraft they replicate are still in development. As a result, training requirements that drive the development of aircrew training devices as well as contribute to aircraft and training systems designs must be determined before the first production aircraft becomes operational. The traditional Instructional Systems Development (ISD) approach, which assigns training objectives to existing training media or to the capabilities of existing training devices, does not readily apply to the concurrent development of training devices with aircraft systems. This paper describes an approach used for the development of aircrew training devices concurrently with the development of an aircraft system. This forward-looking approach defines training requirements, which in turn drive the design of the aircrew training devices. These training requirements establish the training capabilities of the devices as well as the operational threat environments those devices fly into. Included are the process for the integration of training requirements into engineering design specifications, the resolution of technical and cost factors, the established interfaces between the training analysts, engineers and the users, and the traceability and currency of the training device.

BACKGROUND

For developers of training systems and, specifically, Aircrew Training Devices, recent government contracts that call for concurrent development of those devices with their respective aircraft bring a mixed set of emotions. Such programs create challenges and demand technologies and innovations that keep the developer on the leading edge of both the training and aerospace industries. They also, however, create some unique obstacles for engineering and training systems designers.

In the past, training system development was subsequent to aircraft production and firm establishment of design specifications for simulators and other training media. These design specifications were often the product of perceived requirements and lessons learned from other programs. The question was, which existing program does this new system most closely resemble? Specifications were then interpreted by contractor engineers and devices were built. Resulting aircraft, simulators, and training media were turned over to the user, who then built the curriculum. Often the curriculum would need to be designed around capabilities or limitations of the training media and devices rather than to the requirements of the training systems. Certainly there are successful programs that were born of this process, but there are inherent problems that are compounded by concurrent development.

Perhaps one of the greatest blows that can be dealt to any product is that of unfulfilled expectations. The mark of an acceptance-ready device is, and will continue to be, compliance with the specifications. However, when those specifications do not reflect detailed device training requirements, it is entirely possible to comply with the specification yet still fail to provide the required training and instructional capability. Inappropriate requirements also force poor device utilization within the curriculum. Not only may voids exist in required capabilities, but some unnecessary functionality inappropriately written into the specification may later be viewed as contractor "gold plating." Additionally, many training events that are optimally taught using advanced training media are often overlooked.

The classical Instructional System Development (ISD) process covers much of the preliminary identification of device training requirements. ISD can analyze the mission, build task lists and objectives, analyze the student population and entry level skills, develop a syllabus, and even generate high-level device functional descriptions. However, traditional ISD media allocation models have been used to allocate training objectives among existing training media. In a concurrently developed training system, it is likely that training devices will be delivered before operational delivery of the aircraft. Aircrews will initially judge the performance of the aircraft by how closely it resembles the simulator. Obviously, there is a lack of historical training data for the new system and qualified crew members to provide their specific expertise.

This severely limits the extent to which ISD can determine training device design in a concurrent system. Additionally, frequent and often major changes are not uncommon in the development of a new weapon system. Along with potential cost and schedule impacts, continuous training capability assessments must be made available to the customer for use in their decision-making process. A system that relies upon front-end analysis as the total and final training input is incapable of such continuous training response.

The Operational and Training Analysis Group of Link Flight Simulation Division was established to fill the void between training requirements and device design that has historically existed throughout the training industry. In the past, primary emphasis has been placed on the high-fidelity replication of the cockpit or other system to be simulated, with lesser regard given to its training capability. Simulators that looked, felt, sounded, and performed just like the aircraft were considered to be successes. The simulator, though, is not just another line aircraft, and because operational aircraft are not designed with the training of students in mind, training devices must be designed with this approach. There are many tasks that the crew will practice only in the training device, and certainly others for which the device is the preferred training medium. The training device, therefore, must be designed with instructional features and capabilities not available in the aircraft.

Conversely, it is certainly possible to provide too much capability in the design of a device. Functionality that is provided simply because it exists in the aircraft, regardless of training requirements or instructional utilization, merely serves to increase complexity and drive up costs. The goal, then, is to develop device specifications entirely based upon and traceable to training and instructional requirements. The Operational and Training Analysis Group (OTAG) was essentially chartered with ensuring that the training and instructional capabilities required by the user were evident in the final design. This task, in most cases, includes detailed definition of training requirements and individual simulation components based upon training objectives, operator tasks, instructional requirements, and system capability.

REQUIREMENTS DEVELOPMENT PROCESS

In the development of a training system responsible for training tasks, a critical, and previously missing, link exists between functional requirements and training device design specifications. Bridging this gap between functional requirements and engineering design is accomplished through a series of detailed analyses that define training requirements and translate those requirements into engineering specifications that define device design and training capability (see Figure 1). This process ensures that the specific and derived training requirements are embedded in the engineering designs and that the final product meets the desired training goals.

SIMULATION COMPONENTS ANALYSIS

The Simulation Components Analysis is composed of two critical inputs, the operational task list and the device functional description. The foundation of the Aircrew Training Device (ATD) development process lies in the utilization of an accurate, detailed operational task list or set of task lists. The operational task list identifies the specific duties to be performed by each crewmember in the execution of his mission. If not already considered in the front-end analysis, a refinement to this task list must be made. This refinement must examine the entry level of the student to determine which tasks are appropriate for training in each device. Tasks must then be allocated to the individual devices for which specifications are to be developed. This helps to prevent building in capability that will never be used while ensuring that training capability is provided for all operational tasks.

The other critical input to the simulation components analysis is device functional descriptions. These descriptions, a product of front-end analysis, identify high-level requirements of each hands-on device and its functional capability. This helps to determine which components require further analysis. The functional requirements tell us, for example, that based upon the combination of training analysis and media concept development, certain tasks to be trained in the WST require a visual system. The simulation components analysis identifies procedural level tasks that drive visual system design characteristics. The detailed requirements analysis then defines these characteristics in terms of component functional specifications. Figure 1 illustrates the process for the development of engineering specifications from the functional requirements derived from operational task list data.

SYSTEM COMPONENTS ANALYSIS

Once the refined operational task lists and functional requirements are established, a System Components Analysis is conducted to determine component critical tasks. This is accomplished through the use of a task/component correlation matrix in which each task is analyzed to determine dependency on the aural, motion, visual, environmental, operational, and instructional simulation components. This task analysis asks: Which simulation components are required in

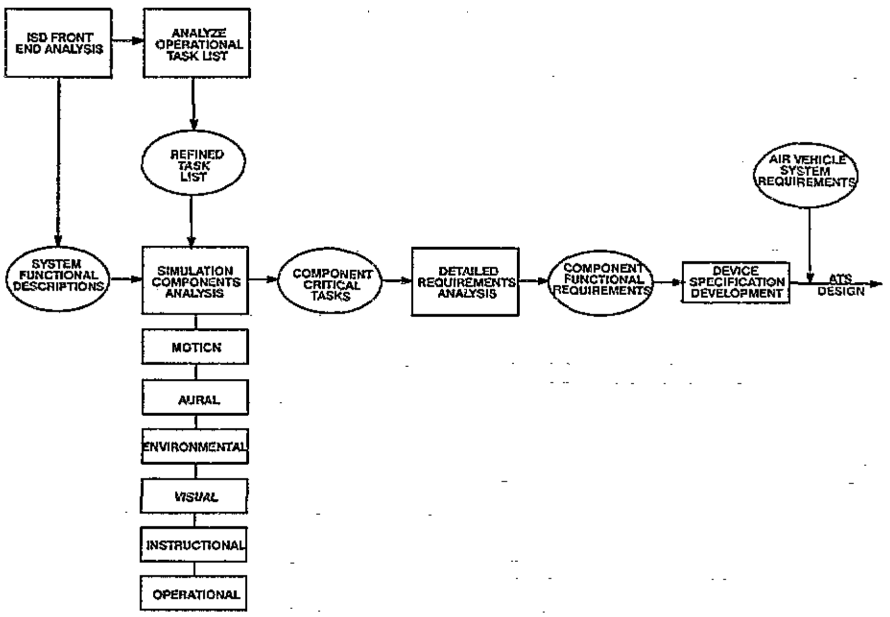

Figure 1 Specification Development Process

order to effectively train each task? Some tasks require the utilization of all simulation components, while others require none. This analysis results in lists of tasks which are environmental, visual, aural, and motion cue-critical. These tasks lists, in turn, become the bases for component matrices upon which the Detailed Training Requirements Analysis is conducted.

DETAILED REQUIREMENTS ANALYSIS

The detailed requirements analysis is a criticality-based analysis used to determine the training value of specific component attributes. The training values are derived in terms of frequency of use and criticality.

Criticality is determined, by a team of subject matter experts, on a scale of 1 (low criticality) to 5 (high criticality). Both average criticality values and frequency of each attribute are analyzed to determine the training value and extent of their role in the component specification. The detailed requirements analysis is conducted by a team of training analysts, engineers, and subject matter experts with backgrounds and experience pertinent to the program.

SPECIFICATION DEVELOPMENT

Once all components have been analyzed, component functional requirements are developed. This step involves the compilation of conclusions from the detailed requirements analysis. These functional requirements serve as training input to device design specifications and concurrency aspects of the system development.

An additional analysis, constituting another major input to specification development, is required at this point. Figure 1 depicts this input as the element "Air Vehicle System Requirements". This set of requirements is the product of two distinct analysis efforts: malfunctions and air vehicle equipment. These analyses are focused on a study of air vehicle systems rather than a list of training requirements. The malfunctions analysis is conducted to determine realistic, relevant and meaningful malfunctions that complement systems training and provide thorough resources for system degrade and emergency procedure training. The air vehicle equipment analysis is a study of relevant systems and their functional requirements in each of the potential training devices. The analysis includes a study of air vehicle panels, controls, displays and switches; and identifies the functional vs. non-functional requirements of each for the individual training devices The results of *this analysis exist primarily in* the form of matrices and diagrams, which are then used in the development of device design documents, device specifications, and purchase descriptions.

INSTRUCTIONAL ANALYSIS

Another important aspect of training device design is the development of instructional requirements, including In*structor/Operator Station (IOS) design, instructional fea*tures, and brief/debrief capability. While the other components studied analyze what capability is required in order for the student to learn, the instructional analysis approaches the issue from a different perspective, addressing the question: What capability is required in order for the instructor to instruct or evaluate? Among other differences, the instructional analysis requires the creation of a series of instructional matrices. These matrices are developed in much the same manner already described; however, they are designed to identify specifications that satisfy instructional requirements. These requirements are derived from student tasks,with the understanding that for each task required of the student, the instructor may have a responsibility to monitor, control, record, role-play, setup, and evaluate the student's performance and procedures. This analysis results in a profile of instructor tasking and activity levels that indicate required and desired instructional features as well as automated features designed to alleviate potential instructor overload. This analysis also serves as the basis for Instructor Station CRT page design and Brief/Debrief Station design.

RESULTS

The results of the analyses described in this section form the baseline of device design specification. The methodology used is intended to imbed training requirements and ISD into that design. The goal of the process is to ensure that the capabilities and characteristics of the training devices are the direct result of the training objectives which they are designed to fulfill.

As mentioned earlier, frequent changes to the aircraft mission, systems, procedures, controls, displays, etc., are a fact of life in a concurrently developed training system. The Training Requirements Analysis is continuous and interactive. The process just described lends itself to easy impact analysis of these inevitable changes. Mission and system changes are analyzed across the existing set of matrices based on their impact on crew tasking. Major changes to the way a system operates may require no change to device design if it is imperceptible to the crew in the cockpit. Conversely, seemingly small changes that have little effect on system operations or overall mission accomplishment could be the source of negative training. Effective integration of new requirements and a constant focus on the training "big picture" is only possible through effective communication among all facets of the program. *Additionally, it is essential to have a vehicle by which train*ing issues are discussed and understood and, when necessary, prompt decisions made.

TRAINING SYSTEMS WORKING GROUP (TSWG)

Throughout the implementation of the integration and high-level design process, the need for a governing body is answered in the form of the Training Systems Working Group. The TSWG serves several purposes:

1) Serves as the decision-making body for requirements disposition.
2) Primary vehicle for the approval of:
   a) Training requirements
   b) Resulting design specifications
   c) High-level engineering design
   d) Instructional utilization
   e) User acceptance
   f) Syllabus integration

A multidisciplined group, the TSWG is composed of members representing Training, Engineering, Program Office, Customer, User, Test, and any other individuals deemed necessary. Meetings must be held on a regular basis throughout the development phase. The TSWG serves as a means to solidify communications between participating member groups and promote face-to-face discussions on issues relevant to the decision-making process.

TRAINING ANALYSIS AND SYSTEMS ENGINEERING INTERFACE

It is relatively easy to understand that a thorough training analysis is a critical input to the production of ATD's that are responsive to training requirements. However, it is important to recognize that a thorough training analysis, in and by itself, does not guarantee that the resulting simulators and ATD's will provide responsive training. In order to guarantee training responsiveness, training analysis must be not only properly conducted, but also properly applied.

In other words, an effective training system is the result of a properly conducted training analysis coupled with the proper application of that training analysis by the systems engineer. To ensure that the training analysis is properly applied, an interface between the training analysis and systems engineering process must be established. The specific interface consist of two components:

1) Establishment of a continuous interaction between the training analysts and the systems engineers.
2) Establishment of a clear path for training analysis inputs into systems engineering documentation.

These two components are described in more detail below.

Continuous Interaction —

The training analysis process has been designed to facilitate continuous interaction between the training analysts and the systems engineers. In order to facilitate this interaction, the members of the training analysis team are engineers with training backgrounds and systems engineers who are included throughout the training analysis process. Training analysis support from system engineering includes inputs into the development of analyses matrices, integration of training requirements into Configuration Item Design Specification (CIDS) documentation, and application of training requirements into the design and construction of the ATD's.

Training Analysis Inputs Into Systems Engineering Documentation —

The most important result of the interface process is the appropriate documentation of those interfaces. The primary documents for establishing the training requirements within the systems engineering process are the CIDS. Consequently, the training analysis has been designed such that the resulting training requirements are in a form that can be readily entered into the CIDS through the engineering Requirements Allocation Sheets (RAS).

In addition to the interface documentation, the outputs of the training analyses become inputs throughout other areas of the engineering process and the logistics support process. These inputs are listed below.

Training Analysis provides inputs for:

a. Conceptual Designs
b. Requirements Allocations (Visual, Motion, Radar, etc.)
c. Human Engineering (IOS Design)
d. Software Database Content
e. Hardware Design Criteria
f. Facilities Design Criteria
g. SEMP
h. Configuration Plan
i. Trainer/Training Equipment Plan
j. Safety Plan
k. Test Procedures Plan
l. Trade Studies
m. Technical Publications (Logistics Support)
n. Entry Level Analyses (Logistics Support)
o. General Inputs to Systems Engineering and Logistics Support:
    1) Definitions
    2) Trade Studies
    3) Test Plan
    4) Evaluations
    5) Functional Analysis
p. IOS Instructor Training/Mission Generation Operator Training
q. Integration and Test Training

TRAINING ANALYSIS AND CUSTOMER/USER INTERFACES

The training analysis has been designed to provide a systematically established basis for making decisions. In this role,the training analysis does not make the decisions that lead to determining the device design requirements; instead, it produces inputs that can direct that decision-making process. As a result, the inputs from the customer/user in the decision process are perhaps the most important aspect of the training analysis.

Customer/user interfaces are ensured by including customer/user representatives and SME's throughout the training analysis process. These interfaces will happen by participating in validation meetings, Training Planning Team (TPT) meetings, Technical Interchange Meetings (TIM's) TSWG's, and scheduled reviews. Results of these meetings are subsequently documented by meeting notes and/or through the completion of validated analyses matrices.

TRAINING ANALYSIS AND AIRCRAFT MANUFACTURER INTERFACES

The training analysis performed for the ATD is a subset of a total training system development system process. The development process encompasses the construction of the entire training system, including the curriculum, training devices, and all training system support functions. As a subset of the total construction of the training system, compatibility is only insured by maintaining an intimate working knowledge of the work being done by the aircraft manufacturer. This knowledge is maintained by:

1) Continuous interface with the aircraft manufacturer through meetings, reviews, and validations of training analysis outputs.
2) In-depth reviews of all aircraft documentation through exchanges of data for task lists, mission analysis, training plans, facilities plans, and all other documents that impact development of the total training system.

The process for ensuring that these interfaces and data exchanges are complete includes an on-site training analysis representative at the aircraft manufacturer, published updates of available training documentation, inclusion of ATD training personnel at the Training Planning Team (TPT) meetings, and scheduled reviews and scheduled validations of training analysis outputs. It is also important to note that this process allows for a "two-way street" for information flow, inasmuch as the device manufacturer must also have the opportunity to influence the work of the aircraft manufacturer.

CURRENCY AND REQUIREMENTS TRACEABILITY

The dynamic combat environment of the future places extraordinary requirements upon today's new weapon systems and their associated aircrew training programs. Training device currency is one of the most challenging elements of any concurrent weapon system acquisition. A significant reduction in program cost can be achieved when the aircrew training device (ATD) accurately reflects the configuration of the air vehicle and its associated training requirements. Programs which rely upon new, emerging technologies pose unique hurdles to the goal of current training devices. This is particularly true if the air vehicle has extensive use of operational flight programs (OFP) whose software designs optimize rapid upgrade capability. These rapidly changing software features make the device's ability to keep current very difficult. While many programs use the critical design review (CDR) as a design freeze point, complete adherence to that principle often forces the device to lag behind the air vehicle's capability. Post-CDR air vehicle changes frequently occur in order to increase the deliverable operational capability. As these capabilities increase, training requirements also expand, thus leaving the ATD behind the aircraft upon its delivery to the user (a phenomenon all too familiar).

The realities of concurrent programming show us that complete weapons systems operational capability is rarely achieved until well into the production cycle. Numerous air vehicle configurations evolve throughout this cycle, each attaining greater capability. Constraints such as developmental designs, test schedules, and changing requirements are program realities. A phased ATD deployment approach overcomes the problems associated with rapidly changing air vehicle configurations. It allows the ATD to match air vehicle performance and characteristics for a specific phase of development. This optimizes the training effectiveness of the device and minimizes the need for block updates. Reducing excessive block update requirements and their associated funding challenges decreases program risk. In order for the ATD to actively maintain its currency for each phase, the development of a requirements traceability tool is essential. This tool highlights those training device elements requiring modification or redesign as a result of changes in the air vehicle's configuration, but on new or evolving training requirements as well.

Air vehicle configuration changes are generally due to either a change in requirements identified by the user or a change in design identified by the manufacturer. Regardless of the reasons behind a configuration change, it is essential for the ATD to react effectively to them. Figure 2 depicts a high-level view of the ATD portion of a traceability tool.

An effective traceability tool, of course, also encompasses all other aspects of the training system, including courseware, CAI, etc. Two data sources are available for interpretation of the impact of these changes upon the ATD. The first source is the aircraft component parts listing provided by the aircraft manufacturer. This set of data is a complete description of each air vehicle in terms of its individual components (including OFP configurations). Each production air vehicle has its own unique component parts listing. A second data source is the weapon system's operational task list. For new aircraft, the task listing is derived from human factors workload studies, then further refined by training developers using traditional ISD guidelines. When the aircraft component list is "married" to the weapon system's operational task list, a requirements traceability listing is established which provides information essential to the ATD's training currency goal.

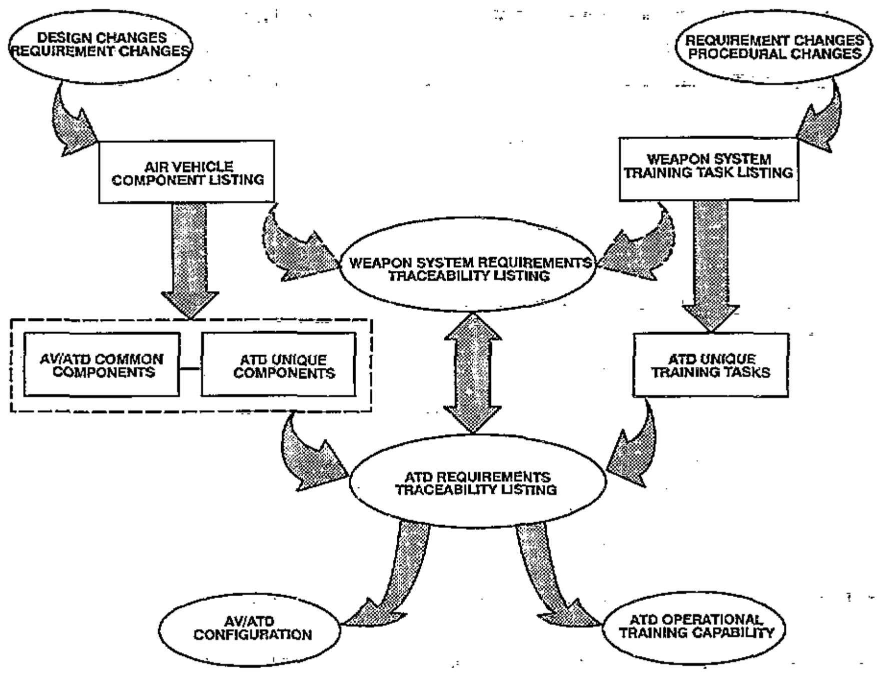

Figure 2 Training Device Requirements Traceability Tool

This portion of the process requires substantial effort in order to keep the amount of data manageable. For example, suppose the training task is "retract landing gear." We do not need to concern ourselves with a particular lug nut on the number-two tire which is identified by a part number. Instead, emphasis should be placed upon the higher-level landing gear assembly component whose redesign could impact retraction time and affect the training task. The key here is to ensure that components are identified to such a level that technical performance changes are not overlooked. It is much better to assign components to all training tasks rather than assign training tasks to all components. Some components may not be appropriate for tracking, but all training tasks must be monitored.

Taking this approach one step further, we define those ATD components which are common to the air vehicle and those which are unique to the ATD. After media analysis of the weapon system's operational task list is complete, an ATD unique task list is available. Aligning ATD training tasks with appropriate ATD components provides a highly effective tool for assessing the degree of currency which the ATD has attained. This tool is the ATD requirements traceability listing. The task/component correlation matrix, previously developed during system component analysis, is very helpful during the development of this tool. Essentially, one major database is required which identifies all significant components in the ATD, their relationship to the air vehicle (whether it's actual, stimulated, or emulated), and their relationship to each of the ATD's required training tasks. It is then capable of highlighting impacts due to changes in either the air vehicle technical configuration or the weapon system training requirements.

Under this approach, it is critical that ATD training capability milestones be set that are compatible with the availability of existing air vehicle information. The training capability milestones should be when the production device is delivered. Any devices placed on site prior to this final capability milestone are considered interim devices and are eligible for upgrade under the production contract. These milestones can be used as convenient points in the schedule where appropriate technical data changes can be incorporated into the ATD design to support specific increases in the air vehicle's operational capability. The milestones provide an excellent framework for using the traceability tool to determine which changes should be incorporated into the ATD design and which ones should be deferred until the next training capability milestone. This also ensures that training requirements are validating the amount of engineering design change in the ATD. In many cases, the ATD may be able to exceed the initial capabilities of the air vehicle and provide effective training for upcoming air vehicle enhancements. This tool covers a diverse spectrum of activity, from hardware component improvements in the ATD cockpit to CRT page display modifications at the instructor's station. It now becomes possible to confirm that ATD "X" is technically configured to air vehicle tail number "YYY". It also provides a means to confirm that the ATD can train specific tasks for a particular air vehicle's operational capability. Use of this tool minimizes ATD/air vehicle inconsistencies and optimizes the training developer's ability to effectively integrate the ATD into the complete aircrew training system.

CONCLUSION

As the designs for weapons systems become increasingly more complex, the training systems that support those systems must also advance. The traditional scenario where system designs and training device specifications precede the development of the supporting training systems is no longer acceptable. Prudent foresight, and appropriate processes, in establishing training systems is critical if the overall training system is to be responsive to the operational mission. The result of this process is a training system that is more responsive, more cost-efficient, and more training-effective.

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