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Research Report 1637

Development of a Concept Formulation Process Aid for Analyzing Training Requirements and Developing Training Devices

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Human Resources Research Organization

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U.S. Army Research Institute

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EDGAR M. JOHNSON
Acting Director

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Training Simulation

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FOREWORD

One problem faced by the military is determining how much simulation is necessary and sufficient for training objectives. One issue in this complex problem is that the capabilities for simulating reality are increasing on an annual basis. Another factor is that the effectiveness of the training program is directly related to the instructional quality of the simulator. A third issue is that techniques for behavioral analysis that identify required features for training devices exist but are infrequently used. In addition, information on the cost-effective use of training devices within courses of instruction is sparse. The development of models, databases, and techniques addressing these issues will support the design, fielding, and use of advanced training technology. The potential effect on the U.S. Army will be to reduce the cost of fielding training devices while increasing their instructional effectiveness.

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) and the Simulation, Training, and Instrumentation Command (STRICOM) joined efforts (Memorandum of Agreement on Advanced Technology for the Design of Training Devices, 1991) to investigate and develop models, databases, and analytical techniques that could support the design of advanced training technology.

STRICOM has maintained partnership in the development and evaluation of this concept formulation process aid prototype. The concept formulation process aid (CFP-Aid) provides a basis for supporting the integration of behavioral and engineering data, knowledge, and expertise in training device design. Final product and user evaluation results briefings were held in December 1991 and July 1992, respectively. Managers from STRICOM's Research and Engineering Management Division participated in both briefings. STRICOM management is currently considering directions for application and further development.


EDGAR M. JOHNSON
Acting Director

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DEVELOPMENT OF A CONCEPT FORMULATION PROCESS AID FOR ANALYZING TRAINING REQUIREMENTS AND DEVELOPING TRAINING DEVICES

EXECUTIVE SUMMARY

Research Requirement:

The perennial problem in training device and simulator design is meeting requirements with adequate effectiveness while limiting cost. The Optimization of Simulation-Based Training Systems (OSBATS) provided a theoretically based generic design-aid approach to this problem. The next step requires user-oriented implementation that aids decisions in the doctrinally mandated early phases of training device design. The tradeoff determination (TOD) phase of the concept formulation process (CFP) provides the focus for developing a usable design aid. The primary users are engineers at the Simulation, Training, and Instrumentation Command (STRICOM) who perform TOD.

Procedure:

A concept formulation process aid (CFP-Aid) prototype was developed using the GURU development system (Micro Data Base Systems, Inc., 1991). The GURU system incorporates spreadsheets, databases, graphics, expert systems, text processing, and communications, along with a fourth-generation programming language. The core material was adapted from the OSBATS program. The OSBATS models selected for incorporation into the aid were based on the results of interviews with potential users of the aid. The CFP-Aid adopted a database organization that incorporates data entry and editing capabilities. The aid supports the development of important user-defined relational links between tasks, cues, instructional features, fidelity features, components, and systems.

Findings:

The formative evaluation of the CFP-Aid shows that the system can help a user select training requirements; examine important characteristics of training requirements; identify effective instructional features and fidelity levels; perform cost, risk, and schedule analysis; and document both the requirements and analysis results.

Utilization of Findings:

The CFP-Aid prototype can be used by engineers to assist in the TOD process. In addition, the system can accumulate and maintain training, evaluation, and training requirements information. Initial use of the system will require additional effort and guidance, as the database and rule base structures are filled and address new application areas. Later use should become much more efficient, as usable task, component, and relational information is accumulated.

DEVELOPMENT OF A CONCEPT FORMULATION PROCESS AID FOR ANALYZING TRAINING REQUIREMENTS AND DEVELOPING TRAINING DEVICES

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DEVELOPMENT OF A CONCEPT FORMULATION PROCESS AID FOR ANALYZING TRAINING REQUIREMENTS AND DEVELOPING TRAINING DEVICES

Introduction

Training devices are designed and developed in an iterative process in which general design concepts are successively refined to produce detailed device descriptions. At each stage in this process, concerns for cost, effectiveness, technological risk, and development schedule are paramount. To satisfy these concerns, the evaluation of device concepts must determine whether the design is affordable, whether it can satisfy the training requirements, and whether it can be produced on schedule using existing or easily developed technology.

In previous work, the Human Resources Research Organization (HumRRO) developed the Optimization of Simulation-Based Training Systems (OSBATS) model as prototype software (Singer & Sticha, 1987; Sticha, 1989, 1990). The OSBATS program has several interactive models that evaluate training requirements, specify training device design options, and prescribe cost-effective designs in the form of major component descriptions. However, OSBATS was designed from a theoretical viewpoint, without any specific user in mind (Singer & Sticha, 1992). Consequently, it addressed the needs of specific participants in the training device design process only in general ways.

This report provides a summary of a project that revised portions of the OSBATS model. The goal was to provide a useful tool for engineers during the Trade-off Determination (TOD) phase of the training device Concept Formulation process (CFP). The project used concepts and models from OSBATS combined with new concepts in developing a system that produces results that can be directly incorporated into the TOD report.

Background

The OSBATS prototype contains five modules that address general training device design issues:

1. **Simulation Configuration Module.** Task information is used to assign tasks to one of three training device approaches: part mission training devices, full-scale simulators, or actual equipment. The assignment is based on a partial fidelity analysis and rudimentary estimates of time and cost savings.
2. **Instructional Feature Selection Module.** Analyzes task information to identify applicable instructional features, identifies the features, and specifies the order (based on a cost/benefit analysis, see discussion that follows) for selection of the instructional features.
3. **Fidelity Optimization Module.** This analyzes task information in order to identify the appropriate fidelity

dimensions and levels required for efficient learning. The routines then specify the order (based on a cost/benefit analysis, see discussion that follows) for selection of advanced levels of these dimensions.

4. Training Device Selection Module. This aids the user in determining the most efficient family of training devices (eliminating redundancies and less efficient devices).
5. Resource Allocation Module. This aids in determining the optimal allocation of training time to devices and calculates the number of different training devices required to support the training requirements.

The concept for operation of OSBATS is based on the iterative use of the five modules to make recommendations. Both the modules that are used and the order in which they are used will vary depending on the requirements of the problem and the preferences of the user.

The OSBATS model integrates several normative and descriptive modeling constructs (Sticha, 1989). The normative models provide the structure for the training system design problem, specify a decision process, and specify the requirements for data content and format. The descriptive models predict trainee performance and provide the input to the normative models. They also define methods for aggregating available data in order to obtain values for the parameters of the normative model. The descriptive models provide a simple description of the complex processes that occur during training.

Normative modeling. The overall modeling framework is based on methods that attempt to define the training strategy that meets the training requirements at minimum cost. This framework was originally described by Roscoe (1971), and has been extended by Povenmire and Roscoe (1973), Carter and Trollip (1980), Bickley (1980), and Cronholm (1985). It was extended further to provide the normative basis for the OSBATS model (Sticha, Blacksten, Buede, Singer, Gilligan, Mumaw, & Morrison, 1990). In its simplest form, the method compares the ratios of effectiveness and cost for the two training alternatives. The approach thus incorporates the trade-off between differences in training benefit derived from the use of simulator alternatives and differences in the costs of using those simulators.

This simple formulation of training cost effectiveness is used by the OSBATS model to generate an "optimal" mix of simulator and actual equipment training. In this formulation, effectiveness means the benefit or gain made through using the simulator or even a different feature (e.g., an instructional feature or a greater level of fidelity in some component dimension). This gain can be in decreased time to train to some

standard or in being able to improve the performance standard during the same training time or number of training trials. The costs used in the formulation are as all-encompassing as possible, including development, fielding, life-cycle, and operational cost differentials (the difference between devices is used in the formulation). Another included factor is that the marginal change in calculated cost effectiveness (improvement over actual equipment or another simulator) of new simulator training is a generally a decreasing function of the amount of training on that simulator. That is, the first hours of training using the new simulator replace more training time on actual equipment than subsequent hours do. This means that at some point it becomes more cost effective to revert to the actual equipment or another simulator. The optimal mix of simulator and actual equipment training prescribes that new simulator training be conducted until the marginal cost savings from reduced use of actual equipment training equals the marginal cost of using the new simulator for training, adjusted for effectiveness. Therefore the amount of simulator training in the optimal mix is a function of the characteristics of the tasks, the capabilities of the simulator or training device and the actual equipment, and the costs of using each in training.

A second normative modeling aspect, which is based on resource allocation methods, is used to determine which device capabilities can best meet the task training requirements within budgetary constraints. Two applications of this method consider instructional features and fidelity features, respectively. Each of these analyses considers independent features that may be either present or absent in a training device. The benefit of a feature is a mathematical function of the number of tasks for which the presence of the feature can enhance training. The ability of a feature to enhance training for a particular task is derived from task characteristics using an expert system rule base. The analysis proceeds by comparing the benefit of using the feature to the cost of incorporating the feature into a training device. The analysis then orders the features by the ratio of benefit to cost. This ordering specifies the optimal order for selection of features based on budget limits.

Descriptive Modeling. The descriptive models in the OSBATS model provide a simple description of complex processes involved in skill acquisition and transfer. The output of these models provides the critical information that is used by the normative models. These models, in turn, provide logical methods for aggregating more basic analytic and empirical data, and thus affect the data requirements.

The OSBATS system contains models that describe human performance variables and provide training cost estimates. The human performance models characterize the acquisition and transfer processes, predict transfer of training as a function of

device and task characteristics, and predict training efficiency as a function of device instructional features. The predictions are made based on an acquisition and transfer function that describes performance on actual equipment as a function of training time on a training device, which may also be actual equipment. The acquisition and transfer processes are represented or described by a power function. The power function is characterized by an initially high learning rate that decreases with increased training, consistent with a long line of research that has been summarized by Newell and Rosenbloom (1981).

Problems With OSBATS

The OSBATS model was innovative and revolutionary. The goal of the OSBATS project was to develop model training device specification procedures that were not constrained by current operating procedures, organizational responsibilities, or data availability. As a result of this goal, the procedures incorporated into the OSBATS software were not consistent with existing methods and there were considerable barriers to the direct adoption of OSBATS in the training device design process.

A few examples will highlight some of the differences between the procedures specified by OSBATS and existing CFP standard operating procedures. First, the OSBATS model combines activities (such as parts of simulation configuration) that are currently performed by the schools before a training device requirement has been specified, activities (such as fidelity optimization) currently performed by STRICOM as a part of the Trade-Off Determination or Best Technical Approach phase, and activities (such as resource allocation) currently performed by the schools after the training device design has been completed. Similarly, the data required by the model incorporate knowledge of both training specialists and engineers, who will generally work for different organizations. Thus, there is no single user or user organization for whom the OSBATS model is uniquely suited.

Second, although OSBATS can provide useful guidance for various stages of the training device design process, it does not provide a complete product for any specific process or phase. The incompleteness of the OSBATS model is evident when the model capabilities are compared to the requirements of the TOD. The OSBATS model is concerned solely with the ability of a training device to meet training requirements (effectiveness) and the lifecycle cost of the device. However, two additional concerns that are critical to the TOD are the technological risk involved in the device design and the schedule required for development and production of the device. OSBATS is silent on these issues, even though there are significant interactions between risk, schedule, effectiveness, and development costs.

The barriers to the adoption of the OSBATS methodology can be summarized simply by stating that the model was not designed to meet the needs of any specific user. Nevertheless, many of the modeling components of OSBATS are directly applicable to problems of training device design, and to the TOD process in particular. The goal of this project is to take appropriate elements of the OSBATS model, and combine them with additional analyses to produce a decision aid that is tailored to the requirements, procedures, and products of the TOD process.

Organization of This Report

The remainder of this report describes the design, development, and formative evaluation of a Concept Formulation Process Aid (CFP-Aid) for the TOD process. The next section of the report describes the identification of processes that could be aided, and the plan for developing the aid. The design of the aid was based on interviews with STRICOM engineers, review of TOD documentation, and knowledge of OSBATS trade-offs. CFP-Aid incorporates rewritten software algorithms and heuristics from OSBATS. It also adds new analyses and provides a flexible basis for data organization. Formative evaluation of the system during development was based primarily on demonstrations and interviews with prospective users. The software is described in the third section of the report. That section covers the goals and major elements of the CFP-Aid. The next section presents the results of detailed, summative evaluations. The final section of the report provides suggestions for further research and final conclusions from the development effort.

Designing the CFP-Aid

Design phase activities focused on identifying the supporting processes to be included in the CFP-Aid and determining how to implement the prototype software. The design phase involved the following activities.

- identifying the specific activities that could be supported by a CFP-Aid for Trade-Off Determination (TOD),
- determining the tools in the OSBATS model that could help the engineer perform identified TOD activities,
- proposing new tools and analyses that could facilitate the TOD process, and
- developing and organizing proposed CFP-AID support processes.

Prototype implementation was carried out using the GURU[®] development system (Micro Data Base Systems, Inc., 1991). GURU is an integrated system that includes integrated database,

spreadsheet, text processing, expert system shell, graphics, and communication systems. The development system also includes an interpreted fourth generation language, which makes it a good environment for prototype development. The government had previously tested the transition of portions of OSBATS to the development system. Those activities provided a basis for familiarizing the development team with the capabilities of the GURU system that could be exploited in the CFP-Aid prototype.

Identification of TOD Processes

The TOD activities selected for the CFP-Aid were identified through interviews with potential users of the aid, review of CFP documentation, and analyses of existing and possible procedures to support the CFP. The result of this analysis was a list of proposed supporting processes for the CFP-Aid. The proposed supporting processes were then reviewed by users, who prioritized them. The following subsections describe design phase activities in greater detail.

User interviews and document review. Review of STRICOM user interview transcripts provided an important source of information about TOD processes. These interviews addressed how the Concept Formulation Process is currently conducted, what data are available, and what types of assistance users would like to receive. The review indicated that there is tremendous variety in the procedures that are used during the TOD phase. The general opinion among interviewees was that there are few generalities in the TOD process. The process is viewed as depending on the specific nature of the training device need, the relevant school, and the engineer performing the analysis. Our examination of the provided TOD documentation examples confirmed that there was considerable variation in the scope and depth of the analysis, the number of device configuration options and evaluation factors considered, and the formality of the analysis procedures.

However, some common methods and considerations were identified in the review of user interviews and example documentation. The first critical concern in the TOD process is to identify the major component categories required (e.g., visual systems, motion systems, equipment mock-up) and the possible levels of simulation in each of these categories (referred to as families in the CFP-Aid). The second step is to estimate, assign, and develop a trade-off for the cost, technical risk, and development schedule for the individual configuration options (e.g., different visual system field of view options). The engineers use their expertise to identify possible options that would effectively apply to the training requirements. Once these options are identified, the trade-off determination is structured. (The Trade-Off Analysis or TOA is the phase immediately following the TOD, and is performed by the training

device proponent based on the TOD information and structure.) Often, in structuring the TOD, both technical risk and development schedule are simply assessed on rating scales with five or fewer categories (e.g., low, medium-low, medium, medium-high, high) by the engineer. The cost estimates typically address the research and development, procurement, construction, installation, and sustainment costs required for each option. In general, the TOD process at STRICOM does not question the capabilities specified in the training device requirement (from the school or the major weapon systems project officer) unless those capabilities are demonstrably infeasible in terms of cost, schedule, or technical risk. Consequently, many of the fidelity considerations addressed by STRICOM (e.g., resolution in visual systems) only compare fidelity levels greater than those specified in the requirements.

Review of OSBATS capabilities. We reviewed the capabilities of the OSBATS model to identify those portions that would be most useful in supporting the TOD processes. Based on this analysis, and on reviews of the interview transcripts, we developed a list of candidate operations for the CFP-Aid. The major concern of TOD is the identification and evaluation of major design options, as described above. Consequently, the OSBATS Training Device Selection and Resource Allocation modules were not judged as useful for adaptation into a TOD decision aid. Those modules are more concerned with the analysis of a set of training devices in order to determine the best set, order of use, and device use time that supports the efficient acquisition of a group of tasks.

The device design modules from OSBATS (Instructional Features Selection and Fidelity Optimization) were appropriate for adaptation, although they use greater detail than is required for this stage. In addition, these rule bases are specific to a category of task types (i.e., helicopter pilot training), and need to be supplemented with other ways to obtain requirements for training device components (major pieces of the training device).

The equipment checklist in the OSBATS Simulation Configuration module represents activities that are generally conducted before the TOD. However, because it may provide some utility as a memory aid and was judged to be very easy to implement in the current aid, it was included.

Selecting CFP-Aid operations. Candidate operations for the CFP-Aid were listed and organized at a meeting attended by both HumRRO and ARI researchers. The candidates were integrated into a single list, and preliminary assessments of cost (of development or translation from OSBATS) and benefit (to the TOD process) were made. Operations that represented straightforward translations of OSBATS capabilities were judged to have low cost. Any development of new capabilities was judged to have high cost.

The benefits were tentatively assigned at this point, and were subject to STRICOM review.

STRICOM engineers reviewed the integrated list and sorted the proposed CFP-Aid support operations according to priority. Priority was rated as high, medium, or low for each of the candidates. The STRICOM input was used to adjust the benefits and to select the operations for inclusion in the final design.

CFP-Aid Development Plan

During the design phase, we reviewed the capabilities of the GURU development system (Micro Data Base Systems, Inc., 1991) so that we could exploit the strengths of the development system in the CFP-Aid design. As part of this review, we examined demonstration software that ARI developed to illustrate capabilities of the GURU system and possible interface options for the CFP-Aid. The demonstration software focused on system organization and implemented portions of the Instructional Feature and Fidelity Optimization modules. It illustrated the capabilities of the GURU development environment, and showed how OSBATS modules could be translated into the GURU environment.

The product of the design phase was a development plan. The plan described both the supporting operations to be included in the initial CFP-Aid prototype and an identification of operations that could be incorporated as later enhancements. In fact, many of these enhancements are included in the prototype CFP-Aid. The plan also described the top level of the user interface. The user interface is designed around a set of pull-down menus that represent the general classes of operations. The complete details of the menu structure are presented in the CFP-Aid User's Guide (Elder, Sticha, Page, and Singer, 1993).

The development plan enumerated both file management and analytical operations that were planned for the CFP-Aid. The file management operations are required to start new analyses, open files, save and delete files, and print information. The planned analytical operations would perform the following analyses to support the TOD process.

1. **Identify Tasks.** This module allows the user to select tasks from a master database or to enter them and their associated data directly. It provides information about the tasks associated with the Military Occupational Specialty (MOS) and associated Additional Skill Indexes (ASI) and Skill Qualification Indexes (SQI) for which training must be provided. From that information, the user may select the tasks and associated information that will be used to identify the required training device components.

2. Determine cue sources. This module allows the user to select or enter the types of cues (visual, auditory, proprioceptive, kinesthetic, etc.) and the sources of information (terrain, instruments, cockpit, system motion, etc.) that are required to perform the activities involved in a task. Baseline information will provide a preliminary set of cue sources, which the user may edit.
3. Simulation checklist. This module allows the user to identify those tasks that are the specific targets of simulated training because of safety concerns, need for special training conditions, or the possibility of improvements in training efficiency. This essentially replicates the OSBATS Simulation Configuration module, which was used to ensure that tasks required simulation.
4. Instructional feature requirements. This module applies a set of rules that identify the instructional support features required for a training device. The rules require information about the characteristics of the tasks being trained. This capability was available as the instructional feature rule base in the OSBATS model.
5. Fidelity features requirements. This module applies a set of rules that identify the fidelity features required for a training device. The rules require information about the characteristics of the tasks to be trained. This capability was available as the fidelity rule base in the OSBATS model.
6. Select device components. This module allows the user to select training system components that will compose candidate system designs to be evaluated in the TOD. The components may be based on the previous rule bases, the user may select the components directly, or may define new components.
7. Component cost, effectiveness, risk, and schedule (CERS) analysis. This module provides an analysis that supports a component by component CERS trade-off. The analysis operations are based on engineer models and recommendations.
8. Define system alternatives. This module assists the user in combining components to develop system alternatives.
9. System CERS analysis. This module supports CERS analysis at the system level. It assists the user in assessing and comparing cost, risk, and schedule between whole system alternatives developed in the Define system alternatives module.

Three of the nine modules included in the development plan were obtained directly from OSBATS capabilities. Those are the

simulation checklist, the instructional feature rule base, and the fidelity rule base. The other supporting operations were identified from user interviews and review of TOD documentation.

Since we employed a prototyping approach to the development of the CFP-Aid, the initial plan could not completely specify the design of the CFP-Aid system. During the development phase, the design was modified several times as new operations were identified or redundant operations eliminated. Many of the changes were minor, and covered such topics as the naming of menu items, project subdirectories, and so forth. Other changes were of greater scope. For example the system was altered so that instructional feature and fidelity rule bases could take input data from either tasks or cues. In addition, fidelity rule bases may take data from instructional features.

Software Description

The CFP-Aid software is used in the TOD phase of the CFP in the training device development process. This software aid assists the designer in proceeding systematically through the stages of trade-off determination.

CFP-Aid Goal

The goal of the CFP-Aid is to assist the engineer perform the activities of the TOD. The following activities are specifically addressed by the CFP-Aid.

- Selection of training requirements.
- Examination of training requirements.
- Identification of effective instructional features and fidelity levels.
- Performance of cost, risk, and schedule analysis.
- Documentation of requirements and analysis results.

Each CFP-Aid capability is designed to support some TOD activity. The basic operation of the CFP-Aid is organized around data elements which are connected by links. The following discussion describes CFP-Aid operations in this context.

Elements of the CFP-Aid

To understand CFP-Aid operations, it is first necessary to become familiar with several terms that describe elements of the analyses performed by the aid. The terms and the relationships among them are shown in Figure 1; each of them is briefly defined below.

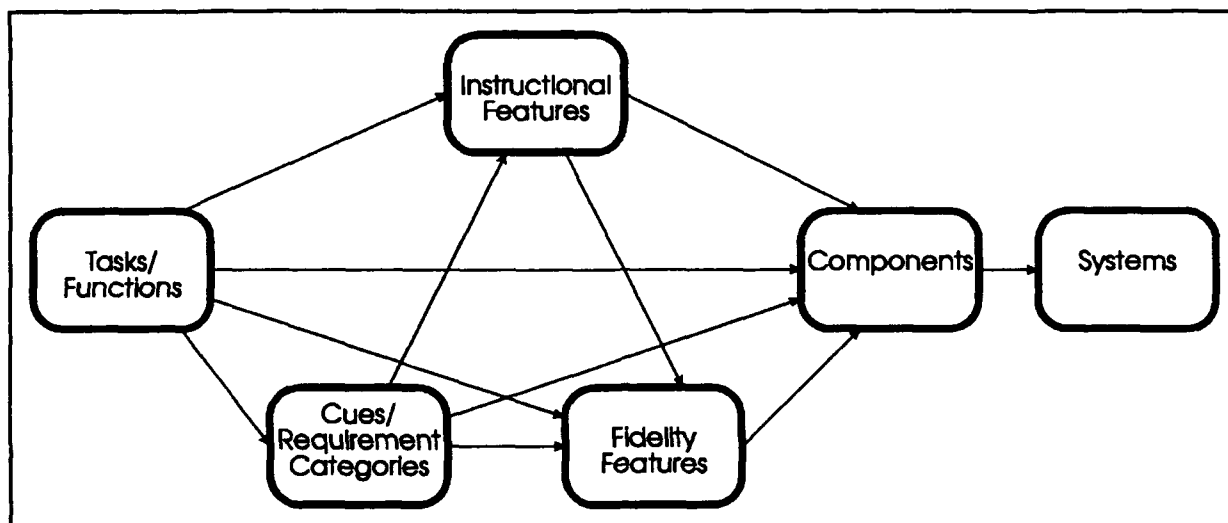


Figure 1. CFP-Aid data elements and links.

Tasks and Functions. A task is the smallest activity that performs a meaningful job function (Department of Defense, 1986). Two examples of tasks are "perform terrain flight approach" and "clear the M-240 machinegun." In the CFP-Aid, the definition of function is drawn from conversation with engineers. Function (when used in this document in reference to the CFP-Aid) refers to any common activity or requirement (e.g., for visual input) for one or more tasks. An example of a function is "weapons and emergency procedures." This function can be used to address several tasks because they include procedures and have similar training device requirements. For example, none of these tasks requires a sophisticated visual display system or complex force feedback on the controls. On the other hand, tasks in this group all require controls and displays that interact appropriately (functional fidelity), and that are positioned as they would be in the actual equipment (physical fidelity; Hays & Singer, 1988). Therefore these tasks have commonalities and can be treated as a single requirement, referred to as a function.

Cues/Requirement category. The requirement category is the category of information that is required to perform a task or function. This information provides critical cues or response feedback necessary for effective learning of the task or function. For example, abnormal engine operating noise may provide a cue for the initiation of an emergency procedure, and should therefore be provided so that the relationship can be learned on the training device. Similarly, force feedback on controls may be required to learn low altitude flight tasks. Requirement categories are often referred to only as "cues" both in the CFP-Aid and in this report.

Instructional feature. An instructional feature is a training device capability that helps an instructor manage training or organize training activities to enhance efficiency. Instructional features are generally unrelated to the realism of a simulation, although in some cases an instructional feature (such as augmented feedback) may enhance or reduce realism at appropriate stages of training for instructional benefit. Automated performance measurement (which measures performance according to some preset standard) is an example of an instructional feature that does not interact with fidelity.

Fidelity feature. A fidelity feature is a dimension on which training devices can present stimuli or response options to students with greater or lesser realism. Examples of fidelity issues are the resolution of the visual display or the number of degrees of motion provided by the platform motion system. Often a certain degree of realism is required for training on a training device to transfer successfully to performance on actual equipment. The level of fidelity required depends on the specific aspects of the task or functions being trained to students and the cues required to learn to perform those tasks or functions.

Component. The component is the part of a training system that represents an approach to performing a device function. For the purposes of the CFP-Aid, components are the alternatives that are addressed in the TOD. In performing the TOD, components that address some aspect of the requirement (such as alternative approaches to the required visual display) are compared. The CFP-Aid considers the components that address the same requirement to be in the same family. Examples of component families considered in the CFP-Aid prototype are visual displays, image generation, sound generation, platform motion, and seat motion. Components within a family may differ according to how well they address one or more fidelity requirements. For example, platform motion components differ in the degrees of freedom; image generation systems differ in visual resolution, update rate, and visual content. Other components, such as an Instructional Management Computer, may be required to support the instructional features of the training device.

System. A system is a collection of components, one from each required family, constituting a complete training device design alternative. Systems with different combinations of components are compared in a TOD. A combat mission trainer with helmet-mounted display, a computer generated imagery system, a six degrees-of-freedom motion system, and possibly other components as well, is an example of a system. This system would be compared to another system in which different components were selected for each family. For example, the comparison system could include a less capable computer generated imagery system, and/or a dome visual display system.

CFP-Aid Data Element Links

The elements of the CFP-Aid are associated by links as shown in Figure 1. The links represent the inferential network that guides the operation of the aid. For example, tasks are linked to requirement categories (or cues), instructional features, fidelity issues, and components. The existence of these links means that knowledge of the task may have implications on any of the four other elements to which tasks are linked. A particular task may require a certain kind of cue, or have specific requirements for visual resolution, platform motion, or other fidelity issue. Similarly, the task may require that a specific instructional feature or component be included in any device that is used to train the task.

The types of links that have been included in the model provide it with flexibility that is appropriate for both the early stage of the device design process and the limited research knowledge regarding device requirements. At this stage in the process, it may not always be possible to use a single inferential chain to obtain all device requirements. For example, there is a rich body of knowledge regarding fidelity issues related to the visual and motion components of flight trainers. This knowledge is especially useful for situations in which the flight tasks are relatively well understood and similar to tasks that have been addressed in the research literature. However, if at the time the TOD is performed the targeted tasks are only partially understood then the requirements for device components must be determined using some consideration other than fidelity issues.

The CFP-Aid contains three lines of reasoning that can meet the needs of the TOD: (a) inferences may be made directly from task or function requirements; (b) inferences may be made by considering the cues to which tasks or functions are linked; and (c) inferences may be made considering instructional features to which tasks or functions are linked. In actual applications of the CFP-Aid, we suspect that multiple lines of reasoning will be employed. The eleven lines connecting the elements in Figure 1 represent the inferential links in the CFP-Aid. The following discussions describe each of these links.

Function-Cue links. A function is linked to a particular cue if the cue is required to perform that function. For example, the function, perform emergency procedures, may be linked to visual cues, auditory cues, motion cues, and/or cues from cockpit instruments. In an actual problem, the cues would be specified in greater detail than in the above example.

Function-Instructional feature data links. These links are between task/functions and data records which contain specific information required by the instructional feature rule base.

This allows the rule driven system to identify instructional features based on the information about the task/function.

Function-Fidelity data links. The function-fidelity data links are used by fidelity rule bases. There are currently two types of fidelity rule bases, one that addresses motion and one that addresses visual issues. Functions are linked to data records tailored for one or more of the fidelity rule bases. For example, a function might be linked to a particular data record that described the size and distance of objects that must be detected to perform a particular function. The visual rule base would then analyze the data record to recommend the visual resolution that would be required to present simulated objects of the required size and distance. As fidelity rule bases are added, fidelity data records must be formatted and the capability for linking to the appropriate task or function must be provided.

Function-Component links. This link allows a direct inference from function to components. This link may represent a command directive or other user directed association between functions and components that are not created by the system linking mechanisms (e.g., rulebases). The presence of this link allows the user to tailor the analysis of the CFP-Aid to ensure that a particular component is required by a given function.

Cue-Instructional feature data links. This link is structured in the same fashion as the function-instructional feature data links, and can be used in the same way. The CFP-Aid currently has no instructional feature rule base that is designed to evaluate the instructional feature requirements of individual cues. However, this link provides the capability for future expansion in that area.

Cue-Fidelity feature data links. This link is structured in the same fashion as the function-fidelity feature data links. The CFP-Aid currently has no fidelity rule bases that are designed to evaluate the fidelity requirements for individual cues. As is the case for the cue-instructional feature link, this link provides the capability for future expansion.

Cue-Component links. Cues can be linked directly to components. For example, if performing a function requires a specific auditory cue, such as the sound of a particular engine malfunction, then a training device for that function must incorporate a component that can produce that cue. In this case, the cue would be linked to all components (in an auditory family) that can produce the required cue. This allows the user to initiate the function-cue link, and automatically obtain all required components addressing the requirements of that cue.

Instructional feature-Fidelity feature links. This link is available for establishment by the fidelity rule bases in much

the same fashion as other links to fidelity features. Theoretically, if inclusion of an instructional feature would have an effect on a fidelity dimension, the information about that instructional feature would be used by rules to evaluate the fidelity requirements. The CFP-Aid currently has no fidelity rule bases that are designed to evaluate the fidelity requirements of individual instructional features. This capability is provided for future expansion.

Instructional feature-Component links. This link addresses the component implications of specific instructional features. Some instructional features require hardware components such as instructor/operator stations or course management computers. Still other instructional features require software components which may or may not be of sufficient magnitude to be a consideration in the TOD. This link allows the identification of special component considerations based on required instructional features.

Fidelity feature-Component links. The results of the operation of fidelity rule bases are linked directly to all components that satisfy that particular fidelity requirement. For example, if the motion rule base indicates that platform motion is required, but that three degrees of freedom is sufficient, then the results will be linked to all platform motion components offering three degrees of freedom or greater. Thus the links indicate the sufficiency of the component, rather than its necessity.

Component-System links. Component-system links are generated when CFP-Aid is run. The aid can generate all possible combinations of candidate components to form system alternatives. The total number of system alternatives is the product of the number of available components in each component family, which can be extensive if there are several options for each family. Usually, the user will eliminate many of these alternatives before conducting any analysis. The links define the system alternatives in terms of the components.

CFP-Aid Processes

Select training requirements. The CFP-Aid supports the selection of training requirements by three methods: (a) direct entry of required tasks or functions, (b) selection of training requirements from a master list of functions, and (c) selection of training requirements based on selected Military Occupational Specialty (MOS), Additional Skill Indicator (ASI), and Skill Qualification Indicator (SQI). Selected training requirements may be reviewed and modified at any time. In addition, the user may use several MOS, ASI, or SQI as the basis of the training requirements by performing multiple selections.

The task/functions database is designed to be cumulative. That is, the more the aid is used and the more tasks and functions are added, the more useful it should become. Continued use will create additional functions linked to additional MOS, ASI, and SQI, and more functions and cues linked to device components. This in turn will make the identification and selection of training requirements easier and the aid more valuable to the developer.

Examine training requirement. The system helps organize and examine training requirements by supporting the specification of requirement categories or cues. The cues represent information that is required for an individual to perform a specific task/function. The CFP-Aid supports three methods of selecting cues: (a) The CFP-Aid may select cues automatically, based on existing links from tasks/functions; (b) the user may select cues from a master list of cues, creating a new set of links; and (c) the user may add new cues to the database directly, linking these cues to specific tasks or functions. The user may review and modify the list of selected cues at any time, and add or delete cues as necessary.

Identify effective instructional features and fidelity levels. The aid will help the user to (a) identify instructional features through the rules incorporated into the system, and (b) identify required fidelity levels for visual and motion characteristics (the rule bases currently implemented). (For information about adding further rule bases to the system, see Appendix C, Page, Blacksten, Elder, Sticha, & Singer, in publication). The system uses the rule bases to link requirements to candidate system component alternatives. The user may also directly create links from functions, cues, instructional features, or fidelity features to candidate components.

The expert system rule bases operate in three modes: automatically based on preselected and stored data, automatically with user confirmation of stored data, and manually based on user supplied data. In automatic operation, the rule base is consulted using data from the CFP-Aid database. No user interaction is required, unless the values for required data are not known. The automatic, with confirm, option is the same as automatic operation, except that the user can examine the input data for each rule before the rule is used. The user may make changes to the input data at that time. In the third option, the user supplies all of the data required by the rule base, answering the rule driven questions one by one.

The instructional features analysis is based on the rule base developed for the OSBATS model. Recommendations are made for each task or function based on instructional feature data. Although the CFP-Aid allows links from cues to instructional

features, none of these links are present in the delivered database because the instructional feature rule base was designed to consider task data. Making instructional feature recommendations regarding cues would require developing a new instructional feature rule base, or modifying the existing rule base, to accept cue specific information.

As discussed previously, the aid currently contains fidelity rule bases for identifying only motion and visual components. These two rule bases were obtained by revising portions of the fidelity rule base developed in the OSBATS model. The structure of the CFP-Aid is designed to support additional rule bases as they are developed. These rule bases make fidelity recommendations for each function based on fidelity specific data. The fidelity rule bases also work in the three modes discussed above: automatically, automatically with user confirmation, and manually with user supplied data.

The aid also provides justification for the recommendations made. The justification consists of a brief description of each rule that was used to select the instructional features that were required for a function. Justification may be examined for a single function or cue, as selected by the user.

Finally, the user may also specify direct links between functions and components. This capability is implemented in a general data maintenance procedure that allows the user to enter new function data or edit the existing function data.

Assist in Cost, Effectiveness, Risk, and Schedule (CERS) analysis. The system aids evaluation of component cost, effectiveness, risk, and schedule factors by displaying graphs and tabular charts for each factor. Graphs and tabular displays generated by the CFP-Aid can be used to build training device system alternatives from selected components. Each factor in the CERS analysis can be examined separately in a graph and in a spreadsheet. Similar displays are available at the training device system level. In addition, the CFP-Aid supports trade-off analyses at that level. The trade-off analyses generate a weighted average of cost, effectiveness, risk, and schedule factors. CFP-Aid allows the user to tailor the analyses by editing the estimates or the weights (importance) for these factors.

The factors of the training device system CERS are derived from the corresponding factors in the component analyses. System cost is obtained by summing the cost of the components included in a system. System effectiveness is obtained by finding the total number of tasks, cues, instructional features, and fidelity features that link or point (as described in the linking structures, above) to one of the components in the system. Risk is combined as a probability of development failure; that is, the

probability of development failure for the entire training device is the highest probability assigned to components development failure. Finally, schedule is combined by simply assuming that all component Research and Development (R&D) activities are conducted in parallel; the overall schedule is therefore the longest of the component schedules.

An overall analysis presents a summary of the results in a single graph that combines measures of effectiveness (MOEs) for cost, effectiveness, risk and schedule. The MOEs are normalized, which means that a larger number indicates a better system. This makes the MOEs for cost, risk, and schedule inversely related to the raw measures of these factors. As is the case with component analyses, the spreadsheets may be used to get a more precise view of the numbers that are shown in the graph, to modify any of the individual input data, and to set adjustment weights.

Document requirements and analysis results. The output documentation provides a trace or audit trail of selections and analysis results. The final results are organized in outline form which may be printed or saved as a text file. That text file can then be edited using word processing software.

The outline is based on sections required for the TOD documentation. The user may edit the sections included in the outline, and add more sections. The user also may link each analysis to one or more sections. For example, the results of the function selection module may be linked to the "Requirements" section of the outline. When the outline is printed out, it will contain the specific functions that were selected, and the time that they were selected.

Each analysis in the CFP-Aid contributes to the outline being generated. Because modules can be used several times, it is possible to save the results each time, producing a cumulative record of all analyses performed using the CFP-Aid. In this way the outline can provide an audit trail of the analyses performed for the project. When the analyses are completed, the user may regenerate the final outline, so that it shows only the most recent results.

CFP-Aid Data

Many of the data structures for the CFP-Aid come directly from the OSBATS model. However, those data structures and the data manipulation mechanisms are different in the CFP-Aid. Specifically, training device components in the OSBATS model are selected based on their technical performance (interpreted as learning effectiveness) compared to fidelity or instructional feature requirements. Specific learning and transfer models were developed to assess the effectiveness of instructional features and fidelity levels. These models were feasible because the two

links into components considered by the OSBATS model were directly related to learning and transfer considerations. These links were all model based and were not stored in the data base for future reference or use.

The CFP-Aid data has four links to components, including links from tasks and cues, in addition to the links considered by OSBATS. Because of this variety of links to components, it was not feasible to implement the learning and transfer model evaluation that was used in OSBATS. Extension of that model to the CFP-Aid would be a reasonable extension of the OSBATS model.

The initial design for the CFP-Aid incorporated most of the data variables required by OSBATS. However, some of these variables are not required by the prototype aid. The variables are still maintained in the structure, and are available for future enhancements to the system.

Evaluation

The evaluation of the CFP-Aid system was based on extensive interaction with engineers during system use. The goal of the evaluation was to have users evaluate the user interface, as well as the functionality and usability of CFP-Aid. We also evaluated the system by obtaining subjective estimates of how well it supports required functions in the TOD process. The evaluation results provide the basis for recommendations to management for revision and use of the aid on the job.

Approach

Subjects. Four project directors from PM-TRADE participated in the study. They were two males and two females familiar with training device analysis and design, between 25 and 35 years old, and had a high level of experience and comfort working with computers.

Study materials. The evaluation required the subjects to complete a series of surveys and questionnaires. The first survey is the *Interface Evaluation Checklist (IEC)*, by Ravden and Johnson (1989), which evaluates the user interface for usability along nine dimensions. The nine dimensions are Visual Clarity, Consistency, Compatibility, Informative Feedback, Explicitness, Appropriate Functionality, Flexibility and Control, Error Prevention and Correction, and User Guidance and Support. The second instrument is the *Acceptance of CFP-Aid Survey*, a modified version of a set of questionnaires created by Companion (1990). The acceptance survey gathered subjective ratings of projected utility, ease of use, relevance to the job, and effectiveness in aiding the TOD process. The last instrument, a *Process Questionnaire* developed specifically for this effort, gathered information about the level of task and subtask support provided

by CFP-Aid for the TOD process. The questions targeted areas where CFP-Aid could affect time/effort, influence product quality, change data requirements, and address regular processes or activities.

Procedures

The evaluators participated in six 2-hour sessions conducted over a two-week period. The evaluation divided the six sessions into three phases: Training Sessions, Operation Sessions, and a Termination Session.

Phase I: Training. Phase I of the evaluation provided the evaluators with two Training sessions that used the CFP-Aid User's Guide (Elder, Sticha, Page, and Singer, in publication) as training material. In *Training Session 1*, the evaluators followed a guided walk through of CFP-Aid's screens and functions. *Training Session 2* provided the evaluators with in-depth, hands-on experience in operating CFP-Aid. The session required evaluators to create a hypothetical TOD situation and run the Requirements, Components and Analysis modules of CFP-Aid.

Phase II: Operation. Phase II of the evaluation provided the evaluators with three operational sessions in which they recreated a TOD situation based on their previous experience. The use of a realistic TOD situation provided an ecologically valid context to the evaluation. By the end of the Operational Phase the evaluators had viewed each screen and used each CFP-Aid function a minimum of three times.

In *Operation Session 1* the evaluators began encoding the needed database items (MOS, ASI, SQI, tasks, functions, components, and cues) for the selected TOD project. The session required the evaluator to make all necessary system inputs, the experimenter provided only limited guidance. In *Operation Session 2*, the evaluators continued work on the selected TOD project by performing a series of predefined exercises designed to explore the Requirements, Component, and Documentation modules of CFP-Aid. The second session ended with the evaluators completing three sections of the IEC. In *Operation Session 3* the evaluators completed work on the TOD project by performing additional exercises within the Analysis and Documentation modules of CFP-Aid. The third session ended with the evaluators examining the output document produced by CFP-Aid, and completing five sections of the IEC.

Phase III: Termination. The *Termination Session* did not require the evaluator to operate CFP-Aid. Rather, the evaluators completed the remaining sections of the IEC, and filled out the Process Questionnaire and the Acceptance Survey. A unstructured interview was then conducted to obtain the evaluator's general

opinions on the usability and acceptance of CFP-Aid in their organization.

Results

The number of respondents (four) used in the evaluation precludes the use of standard statistical analyses. Therefore, the results section presents a summary of the evaluator's median or modal responses to the Interface Evaluation Checklist, the Acceptance Survey, and the Process Survey. As an example, if one rating was very satisfactory, two were moderately satisfactory, and one was neutral; moderately satisfactory is reported for the dimension. A review of the evaluator's overall consensus (the most frequent comment) about the CFP-Aid, obtained in the Termination Session, is provided last.

Interface Evaluation Checklist. The Interface Evaluation Checklist (Ravden and Johnson, 1989) provided ratings about nine different interface characteristics. The evaluator's rating of the characteristics are presented below, with an identification of System Usability Problems.

The evaluators rated the overall level of system *Consistency, Flexibility and Control, Explicitness, and User Guidance and Support* as **moderately satisfactory**. The application of color codes, screen formats, control actions, and cursor locations remained consistent throughout the system. The evaluators found it easy to "undo" actions, and to step back to a previous processing stage. The users believed that the system provided an acceptable amount of control when requesting information, and when carrying out a sequence of activities. The menu structure was judged to be an easy means of navigation.

Although the evaluators rated these characteristics as moderately satisfactory, they noted some deficits. The first was that users could not tailor the interface system, color codes were not flexible, and the system did not provide shortcuts for experienced users. These are relatively harsh criteria for a developmental prototype system. A more relevant comment provided by the evaluators was that the system provided inadequate on-line help facilities. In addition, the hard copy user guide was judged to have insufficient in depth coverage, and did not always provide adequate explanations concerning user and system errors. As a result, the evaluators occasionally had difficulty understanding the jargon used by CFP-Aid.

The evaluators rated the level of system *Functionality* as **moderately satisfactory to neutral**. The evaluators judged that the CFP-Aid possessed appropriate screen formats and the functionality required to support system tasks. The sequence of activities required to complete a task paralleled user expectations and perceptions of the tasks. The neutral portion

of the rating stemmed from the evaluators being unsure of what stage CFP-Aid had reached when processing a command. The system did not provide all the appropriate task information at start up, nor did it allow them to access this information when needed. Lastly, the reasoning for sequencing certain screens was not transparent, resulting in a lack of immediate comprehension for the overall structure of CFP-Aid.

The evaluators rated the level of *Informative Feedback*, and *Error Prevention and Correction* provided by the system as **neutral**. This rating was due to instructions and CFP-Aid prompts that were unclear, and error messages that did not clearly explain why or where an error occurred. When the system identified an error the steps needed to correct the error were unclear. Status messages about system processing were perceived to be static and uninformative. The messages did not provide time to completion information nor clearly inform the evaluators of the completion of a requested action. The users felt that the system insufficiently validated inputs and did not detect or correct input errors before processing. The system provided few error blocks, and also permitted unauthorized actions by the evaluators. Errors made in one section of the system could cause undetected processing errors in other modules. However, the system was judged adequate in protecting against the most common errors.

The evaluators rated the *Visual Clarity* of the prototype as **very satisfactory**, and the level of system *Consistency* as **very to moderately satisfactory**. Appropriate screen formats, and necessary functionality, provided adequate support to complete tasks. The use of menu panel titles presented clearly identifiable screens, and the logical organization of the screens into clearly aligned columns made the presented information easy to see and read. The format of the displayed information followed established conventions (dates, telephone numbers, etc...), and used units that the user normally worked with (dollars, meters, scales). Cursor movement corresponded directly to user inputs, and were similar to those encountered in other systems. In general the evaluators felt that CFP-Aid provided uncluttered screens, used color effectively, and presented cleanly drawn graphics.

When asked about *System Usability Problems* the evaluators judged that the system functioned **satisfactorily**, although some minor problems were identified (see above). The limited set of screen colors were judged as making the system screens easy to watch, system response times were judged appropriate, information stayed on screen long enough read, and the evaluators had no difficulty understanding what was going on. The input devices were judged easy to use, and the screen formats presented most of the required task information. These factors were judged as keeping the user's memory requirements low.

User Acceptance Survey. The Acceptance Survey for the CFP-Aid provided ratings for seven different areas; Overall Reaction, User Acceptance, Screens, Terminology, Learning to use CFP-Aid, Using CFP-Aid, and reactions to the CFP-Aid Output. Again, the results are reported in terms of the evaluators consensus. Consensus was judged as before with the most frequent or central response being reported.

The evaluator's *Overall Reaction* to the usefulness and productivity of the system was **neutral**. Their ratings indicated that they found the system easy to use and useful, but thought that the system provided inadequate power and flexibility. (This comment seems to reflect their comprehension of the system as fielded software rather than prototype software.) In accordance with those ratings was the rating of CFP-Aid's level of potential *User Acceptance*. In general they indicated comfort in working with CFP-Aid, judging that it might increase job effectiveness. Although they could work with CFP-Aid, they also indicated that they could conduct a TOD as well using current STRICOM procedures.

The evaluator's reaction to the *CFP-Aid Screens, Terminology, and Learning to Use CFP-Aid* were **positive**. The evaluators found the menu screens to be logical organized and clearly presented. The ratings showed that the labels used for the different functions were clear, and the information prompts were moderately helpful. The terminology used was judged consistent, but not judged to be very helpful. The evaluators found it easy to explore and learn new features within the system. However, they did feel CFP-Aid was lacking in the amount of instructional material provided.

The evaluators ratings indicated that *Using CFP-Aid* was not too difficult, and they felt that the system performed tasks in a straight forward manner. The evaluators judged the feedback provided as acceptable. The memory requirements for the evaluators was judged to be low, and the error messages were considered to be helpful, when provided. Overall, the reactions of the evaluators to the *CFP-Aid Outputs* were **negative**. They claimed that the presentation format of the outputs made it difficult for them to determine the usefulness of the outputs. The format was judged to be confusing and difficult to understand by two of the four evaluators.

Process Survey. The Process Survey provided information about the analyst's reactions to CFP-Aid in three distinct phases of the TOD process: Data Collection, TOD Analysis, and Documentation. A synopsis is provided for each topic area.

The evaluator's ratings indicated that CFP-Aid had the potential to aid the collection of information for the TOD. They believed that use would increase slightly the number of hours

required to do a TOD, in order to accumulate the additional data. However, they also judged that using the system might improve a user's technical understanding of a new device and related systems. The CFP-Aid was judged to have the potential to help obtain both user and school inputs when determining training device requirements and identifying task and functions to train. The evaluators felt that CFP-Aid showed a potential to identify existing data sources, and organize and retain this data once gathered. The evaluators judged that this would aid in the identification of technical options while conducting the market survey. Overall, the projected increase in time to perform seems to be balanced by the increase in detail, improved understanding of requirements, and the aid in obtaining inputs for the training requirements.

Ratings indicated that the evaluators felt that CFP-Aid could provide assistance when conducting a TOD analysis. They judged that the system might assist in identifying and organizing existing data and previously gained knowledge. They indicated that conducting a technical risk analysis using the CFP-Aid may improve the identification of new and existing technologies as system options. Their ratings showed that they felt the system provided assistance when conducting technical risk reviews and prototype tests. Although the system doesn't provide assistance in determining contractor quality or in the determination of component availability (which were not design goals), the system was judged to provide some assistance in conducting schedule vs. requirement analysis, and cost vs. requirement analysis.

The evaluators provided a variety of responses concerning the output document produced by CFP-Aid. They gave positive ratings concerning the potential of the output to assist in creating the TOD documentation, tracking required trade-offs, and in providing additional detail to the documentation. They felt that the CFP-Aid could provide the strongest assistance and value by contributing as a technical resource. Otherwise the evaluators were neutral concerning CFP-Aid's potential ability to assist in the identifying security needs, Tempest requirements, or the consideration of other agencies inputs (items present on the surveys and questionnaires that were irrelevant to the design goals, and recognized as such).

Conclusion

Although the CFP-Aid incorporates many of the analyses and data from the OSBATS, there are several critical distinctions between the two models. The primary distinction is that the CFP-Aid design is based on existing analysis requirements, and addresses the expressed needs of individuals that are responsible for the required analyses. This feature makes the CFP-Aid different from any existing cost effectiveness model for training device design or evaluation.

The second critical distinction is that the CFP-Aid supports multiple methods of inferring the need for specific system components. Other models, such as OSBATS, support a single line of reasoning from task characteristics to device requirements. The multiple links in the CFP-Aid and the possibility for multiple rule bases allow for a very rich analysis structure that can use the data that are available as the basis of its recommendations.

Discussion of Evaluation Results

The goal of the evaluation was to have prospective users evaluate the user interface, functionality, and usability of the CFP-Aid. Overall, the results indicated positive to neutral ratings for all major categories, except for the unsatisfactory rating for level of informative feedback provided. The results show that the system has an adequate user interface, adequate coherent functioning, and potential in assisting the user during the TOD process. The results also provide important information for guiding future development.

The user interface supports the encoding of collected data, and aids the user in conducting the required analyses. The interface contains few surprises and provides adequate cues for the users. The method of input is consistent, and the information presented in the screens is formatted clearly. The appropriate use of color, text columns, labels, and user expectations in the design of the interface produced a software package that was easy to use.

In general the system functions according to user expectations and provides adequate support for TOD procedures. Although the prototype functioned well, several system deficits were identified. The biggest hindrance to system operation is the lack of helpful support documentation, both on and off-line. Unfortunately, GURU (Micro Data Base Systems, Inc., 1991) does not support context dependent on-line help features. The off-line documentation is being revised, and can easily be improved. The outline documentation produced by the prototype seems to lead to user confusion, although the output matches "good" TOD's. The rigid output format, and the large amount of information included, seemed to make the documentation difficult to read and understand. All of these issues can be rectified through user guidance and intervention.

It is worth noting that the evaluators felt CFP-Aid could be used to train a new engineer on the TOD process. A tutorial using the CFP-Aid could provide work exercises using an existing TOD to provide the new engineer with more structure and guidance than is presently provided. Use of the prototype in this way may reduce the time required by senior staff to guide the new engineers through the TOD process. This in itself may

provide enough benefit to support the further refinement or development of CFP-Aid.

The Challenge of Implementation

Because it was designed for an existing part of the training device design process, the CFP-Aid should avoid many of the barriers to adoption that were experienced with OSBATS and other training cost effectiveness models. However, there are still substantial challenges to the use of the CFP-Aid as a regular part of the Concept Formulation Process. These challenges concern a user's understanding of the CFP-Aid system, the requirements for data entry, and the need for output tailored to the desires of the user. A major challenge also arises from the non-standardized requirements of the Concept Formulation Process as practiced at STRICOM.

Even though the design of the CFP-Aid was based on engineer's descriptions of the TOD process, it contains several novel concepts that were not taken directly from current practices. For example, the CFP-Aid has a much greater emphasis on tasks and functions than was mandated from user interviews and TOD documentation. Furthermore, the multiple paths between modeling elements is slightly different from current procedures, as well as from any other model of which we are aware. As mentioned above, it will be necessary to ensure that users have a firm understanding of the processes supported by the CFP-Aid and the methods which support those processes.

The CFP-Aid requires significant data entry when it is used for the first few times in a domain. As it is used and the databases grow, the requirements for new data should decrease. However, initial data entry may be a barrier to adoption of the aid. Consequently, we recommend that ARI assist the early applications of the aid by providing data entry support.

Closely related to the data entry issue is the issue of maintaining and assuring the integrity of the databases. The prototype software is designed for individual use, thus minimizing the concern for database maintenance. However, an operational CFP-Aid would be used by many people who would share databases. Consequently, procedures for data maintenance, specification of system administrator roles, and database update procedures will need to be developed.

The CFP-Aid provides a uniform procedure for conducting the TOD. Although there is considerable flexibility in the operation of the aid, it is unlikely that the aid will accommodate the complete range of TOD analyses that are currently conducted by STRICOM. Limits in the flexibility will need to be identified and reduced or eliminated in any operational version of the CFP-

Aid. In addition, it will be beneficial to establish a greater degree of uniformity in the TOD process.

Future Research and Development

Future research and development of the CFP-Aid will depend on the acceptance of the prototype by STRICOM. It is likely that use of the prototype software will lead to the generation of a list of research and development needs that is much more useful than any list that could be developed at this time. Nevertheless, there are several areas for potential further development that can be mentioned as a result of the development efforts.

- Increased flexibility in analyses and output. This option would allow the user greater flexibility in performing CERS analysis, including the ability to specify the factors that are considered and to format analysis output according to user specifications. Current capabilities allow the user to modify the weights of a fixed set of factors within a single analysis format.
- More comprehensive effectiveness model. This option would combine information from tasks, cues, instructional features, and fidelity issues to obtain a more precise measure of effectiveness than is currently used.
- Families of tasks and cues. In the prototype CFP-Aid, components are organized into families that perform similar functions, such as visual display, image generation, and so forth. This option would extend that organization to tasks and cues in order to provide the user with greater flexibility in reviewing and selecting them.
- Flexible rule base operation. Increasing the flexibility of the rule base design should make the rules applicable to a wider variety of functions, allow the user more capability to adjust rule base output, and allow the application of the rule bases to be tailored to the specific needs of the TOD being performed.
- Addition of rule bases. Adding rule bases to the system is fundamental to its ability to adequately address real world training domains. Applications could be pursued using the linking functions in the database, but this would drastically reduce the benefits to be accrued from using the system.

Final Comments

Any second generation system should improve upon the user documentation, provide a complete database of tasks, cues, and

components with the system, and provide more thorough guidance in conducting an analysis. These simple changes will increase the level of user confidence and result in better acceptance. Other than improving the documentation the following capabilities could be provided: a) a source list for cost, risk, effectiveness, and schedule data, b) allow users to verify current database information, c) provide a means, or set up a procedure for automatic database updates, d) provide system short-cuts for experienced users, and e) improve the error protection and correction procedures.

Although the evaluators judged CFP-Aid capable of assisting design engineers in conducting a TOD, they recognized that its use will change their job. The prototype provides a stable structure and requires specific types of information through implementing standard procedures. Presently, to conduct a good TOD requires tedious record keeping and vast amounts of experience within a structure that is far from standard. The CFP-Aid provides help identifying and collecting needed information, and helps determine priorities for its use. With CFP-Aid the information requirements are fixed and sources for the information are identified. If the system is implemented, what used to be a highly variable process will become a short set of easily accomplished tasks.

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