DESIGN AND DEVELOPMENT OF USER-FRIENDLY INSTRUCTIONAL SYSTEMS

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ABSTRACT

This paper presents a methodology developed through research, trade studies, and past experience for generating a specification for a "user-friendly" instructional system, taking proper account of specific training objectives, the training syllabus, crew tasks, and aircraft configuration. Instructor control/display requirements are established for each element of each training exercise. The control/display data are then converted into task-oriented formats that fit the overall schematic of the instructional system, task-oriented display and control being the basis of user-friendly instructional system development. At any given time during a training mission, the instructor is confronted only with the data and control options that are pertinent for that particular phase of the training exercise. Factors such as human engineering, decision-making, and workload of the instructor enter into the analysis.

INTRODUCTION

A review of flight simulation literature reveals that the history of flight simulation has been one of constant technological improvements from enhancing fidelity to optimizing simulator utilization. Methodologies for maximizing simulator utilization have been the focus of present-day research for both the simulator industry and the Department of Defense. "Simulator Training Requirements and Effectiveness Study (STRES)" sponsored by HQ Air Force Human Resources Laboratory (AFHRL) is just one example. Since the optimization of simulator utilization is the focus of this paper, it is appropriate to quote from a published paper to establish the existing ideas. For example, Stark and Puig[1] presented a paper at the NTEC/Industry Conference, ten years ago summarizing many of the unique characteristics of training simulators, anticipating much of the effort expended over the next ten years in utilizing these characteristics. The authors said, in part:

"..training simulators are unique tools with unique capabilities and limitations. They can support the development of skills which can be effectively practiced in flight training, and they can also support training in a variety of skills and under circumstances which cannot be safely and/or economically approached in the aircraft. In addition, they have inherent capabilities for optimizing learning which are currently unavailable in the flight environment. The role of simulators as an integral part of current and future training programs has been established beyond question."

"The aircraft, its environment, and its interactions with the crew are represented in the simulator by means of a computer. Because the computer deals with all of the parameters defining the state of the aircraft, the characteristics of the environment, and the performance of the crew, it contains the basic data required to support a highly flexible and effective interface between the student and the instructor. The quality and efficiency of training is largely a function of how well the simulator/instructor interface is implemented. The quality of the interface, in turn, depends heavily on the relevance of the displays and controls at the interface, for the tasks performed in the conduct of training. Many simulator instructor tasks are closely analogous to those performed by the flight instructor, but some are unique to the simulator. In each case, data are available to the simulator instructor which are not available to the flight instructor, and unusual capabilities are available for the control of simulator training conditions. Properly mediated, these data can be used to greatly enhance teaching."

Stark and Puig defined nine basic instructional tasks for flight simulator instructors and flight instructors in the promotion of flight crew training. Optimization of training in both ground and airborne settings requires efficient task-relevant information exchange and training control in each of these tasks:

a) Briefing
b) Demonstration
c) Performance Monitoring and Diagnosis
d) Coaching and Guidance
e) Evaluation
f) Critiquing
g) Simulator Setup
h) Program Modification
i) Communication

In an attempt to improve instructional capabilities of training simulators, a plethora of "advanced training features" have been introduced[2],[3],[4],[5] (see Table 1). These tasks have been accomplished in simulators, over the years, in a variety of ways and the evolution in the implementation of these tasks is well documented in the literature[1],[6].

Instructional System Status, Problem and Solution

Presently, strategic and tactical Weapon System Trainers (WST's) are becoming increasingly complex, with sophisticated hardware and software capabilities, both because of the implementation of high technology in the design and development of weapon systems like the B-52, B-1, AH-64, etc., and because of the complex missions which they support.

Designers of instructional systems are confronted with ambiguities between "want" and "need", and incompatible specifications like "minimum instructor mental workload" and "maximum flexibility in system control".(7) This has resulted in complex instructional systems having minimal utility (training value) and utilization (ease and frequency of use). The primary reasons for this state are an increased instructor mental workload and a lack of instructor training in instructional system utilization. These findings are documented in the several research studies by Cohen(8), Polzella(9), Caro(10) and others.

Table 1 ADVANCED INSTRUCTIONAL FEATURES(9)

BRIEFING FEATURES

Recorded Briefing permits instructor to provide student with information about the simulator and/or a structured training mission through A/V media presentation.

Demonstration permits instructor to demonstrate aircraft maneuver(s) by prerecording and subsequently playing back a standardized segment of simulated flight.

Instructor Pilot Tutorial provides IP with self-paced programmed instruction in the capabilities and use of the flight simulator.

TRAINING MANAGEMENT FEATURES

Total System Freeze permits instructor to suspend simulated flight by freezing all system parameters.

Reset permits instructor to return the simulated aircraft to a stored set of conditions and parameters.

Crash and/or Kill Override permits instructor to allow simulated flight to continue without interruption following a "crash" or "kill."

Automated Adaptive Training computer-controlled variations in task difficulty, complexity, and/or sequence based on student's performance.

Programmed Mission Scenarios provide computer-controlled standardized training missions based on preprogrammed event sequences.

VARIATION OF TASK DIFFICULTY FEATURES

Automated Malfunction Insertion permits instructor to preprogram a sequence of aircraft component malfunctions and/or emergency conditions.

Environmental permits instructor to vary environmental conditions such as wind direction and velocity, turbulence, temperature, visibility, etc.

Dynamics permits instructor to vary flight dynamics characteristics such as stability, system gain, cross-coupling, etc.

Motion permits instructor to provide student with platform motion system cues such as roll, pitch, lateral, vertical, etc.

Flight System Freeze permits instructor to simultaneously freeze flight control and propulsion systems, position, altitude, and heading.

Position Freeze permits instructor to simultaneously freeze latitude and longitude.

Attitude Freeze permits instructor to simultaneously freeze pitch, bank, and heading.

Parameter Freeze permits instructor to freeze any one or a combination of flight parameters.

INSTRUCTOR MONITOR AND FEEDBACK FEATURES

Closed Circuit TV permits instructor to monitor student's behavior from the instructor console.

Repeaters/Annunciators provide instructor with replicas or analog representations of flight instruments and controls at the instructor console.

Instructor Console Displays permits instructor to view alphanumeric and/or graphic CRT displays of performance data at the instructor console.

Automated Performance Alert provides instructor with visual and/or auditory signals that indicate specific performance deficiencies.

Over-the-Shoulder Direct Observation by the instructor in on-board IOS implementation.

STUDENT FEEDBACK FEATURES

Record/Playback permits instructor to record and subsequently play back all events that occurred during a segment of simulated flight.

Automated Performance feedback provides student with visual and/or auditory signals (including verbal messages) that identify performance deficiencies.

Automated Voice Controller computer-based technology which simulates the role of controller by combining speech generation, speech recognition, and situation awareness capabilities.

Hard Copy provides a record of alphanumeric and/or graphic performance data from the automated performance measurement system.

The present day status, problems, and search for solutions in the design of instructional systems are summarized in a recent internal memo:(11)

"Simulator instructor stations are sometimes criticized for the workload they impose and the information they conceal, and for their tendency to make simulator training less rather than more efficient and effective. Many of the criticisms are well-founded and while some relate directly to the quality of the processes by which instructor stations are designed and developed, many circumstances are involved in the failure of instructor stations and instructional systems to meet universal and uncritical user acceptance. Most of these circumstances can be modified, given sufficient insight into their etiology and dynamics and when the simulator developer and the customer recognize the ultimate value of good instructional systems and good instructor/simulator interfaces.

"The instructor station is not only one of the user's primary interfaces with our equipment and our design philosophy, but it is also the interface receiving the greatest concentration of attention on the part of the customer, the user, and the casual observer. Equally important, it is the focus of most of the characteristics which transform the simulator from a surrogate for a prime system to a device capable of supporting practice, training, learning and, ultimately, mission effectiveness on the part of the individuals and crews who use it. The instructional system can add to and standardize the conditions under which practice takes place, provide information not otherwise available in the guidance and facilitation of learning, free the instructor from routine administrative and 'housekeeping' functions, and even perform some of the instructional functions he might otherwise have to perform himself given the necessary time, imagination, and motivation.

"The instructional system can also detract from the value of the simulator by increasing the instructor's workload, by providing him with too much, or irrelevant information or by automating functions requiring the insights and flexibility available only through the personal intervention of the instructor. We have all attempted to optimize the instructor/simulator interface through the use of human engineering guides, instructional analyses, and advanced computational, control and display technologies; but we all operate within an impressive set of constraints. The result is sometimes a less-effective system than we all would like, a dissatisfied customer, and a resolve on both sides to 'do it differently next time.'"

What the procurer, user, and designer are seeking is a systematic methodology for designing an instructional system which maximizes the utility and utilization of the training device by decreasing both the instructor mental workload and the need for his training. Instructors should have continuous proficiency training to accomplish their work (instructional tasks) just like any professional person -- doctor, engineer, professor. However, it is the minimization of training required in the operations of the IOS (interactions with hardware) that will maximize the utilization of the simulator. A methodology of design of instructional systems which meets this specification is what we define as "user-friendly."(12),(13) This is the term which some branches of DOD have recently introduced in the specifications for WST's and we assign the above definition to the term "user-friendly:"

TRAINING DEVICE STRUCTURE

The example to be used in this paper is that of an aircrew training device (ATD). An ATD may be partitioned into various trainee stations, as shown in Figure 1. These stations may operate independently or in various stages of integration. The partitioning defines distinct training requirements for each station, and allows for fully integrated crew training missions or isolated station training.

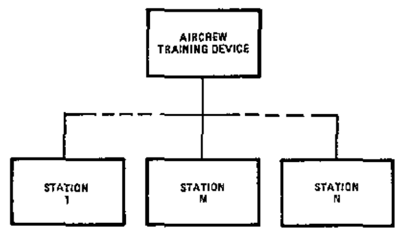


Figure 1 TRAINING DEVICE STRUCTURE

A user environment and a training system environment exist within each station. The former supports the instructor(s) and crew. The latter supports the instructional and simulated aircraft systems. Figure 2 identifies four interfaces which provide for communication among the elements. The horizontal lines represent data/information transmission. Line 1 defines the communication which occurs between the instructor(s) and crew. The vertical lines represent control and feedback occurring throughout the system. Line 2 defines interfaces for the manipulation of aircraft controls which affect the simulated aircraft systems, resulting in feedback being sent to the crew (e.g., motion and visual cues, instrument readings, etc.).

Line 3 represents the data transferred between the instructional system and the simulated aircraft systems. The data transferred from the

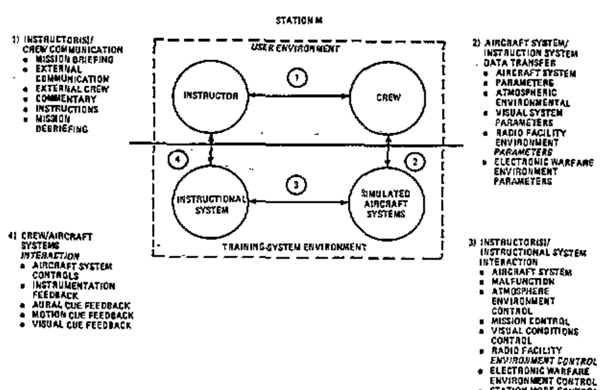


Figure 2 STATION STRUCTURE

instructional system to the simulated aircraft affects the performance (e.g., malfunctions, winds, etc.) and environment(s) which exist in the simulated aircraft systems (e.g., visual, aural cue, motion, etc.). The data transferred from the simulated aircraft systems to the instructional system provides status information as it relates to aircraft systems and environments. Line 4 represents the interaction between the instructor(s) and the instructional system. These interactions relate directly to the instructional features provided through the instructor/operator station (IOS). It is this set of interactions which must be examined to define the attributes of a user-friendly system.

THE USER-FRIENDLY SYSTEM

In any man-machine interaction system, the properties of a user-friendly system are understood to be: 1) ease of use, 2) naturalness, 3) ease of understanding, 4) helpfulness, and 5) increased performance (speed and accuracy). These subjective properties are embedded in our quantified definition of a user-friendly instructional system: minimization of both the instructor mental workload and the requirement for special training for maximization of utility and utilization of the ATD which in turn results in training effectiveness of the ATD. The term "mental workload" is multidimensional owing to the complexity of human information processing and decision-making systems, and it can encompass a variety of environmental, procedural, and operator factors which interact to determine the level of instructor performance (speed and accuracy)[14],[15].

The activities taking place at the IOS are exchanges of information between complex subsystems (i.e., human, machine and task) across an interface. This concept presumes the interface to be continuous, and that all necessary and pertinent information is available to the instructor in the appropriate format at any time in the training session. In return, the operator must decide on the nature and timing of inputs to be made to achieve instructional objectives by appropriate machine activity, and to deliver the necessary commands to the machine subsystem by means of suitable control devices.

The logical, task-oriented placement of several of these devices is more effective than simply accumulating them in a complex conglomeration on an IOS.[16],[17] An IOS extremely well suited for basic flight training may be totally unfit (although all necessary instrumentation is present) for advanced tactics training. The reason for this suitability or lack of suitability is the workload stress imposed upon the operator.

Simply stated, workload stress is the time pressure imposed on an operator by a discrepancy between the amount of work to be done and the time remaining in which to do it. This time pressure depends on parameters such as the task complexity and the importance of the task. Stress affects operator performance. Thus, an operator may be able to easily conduct a flight training mission on an IOS, but in conducting an advanced tactics training mission on the same IOS the operator may be confronted with an arrangement of interface devices which needs more time to operate than the operator can give.

An axiom developed for the analysis of spacecraft crew workloads has been:

> "A qualified person, that is, a properly trained and prepared simulator instructor or operator, can, and will achieve, error-free performance in any IOS task, using almost any interface equipment, provided he/she has unlimited time. In all other cases, his/her performance and the probability of achieving the objectives defined by the training requirements will be a function of his/her total (physical and mental) workload arising from the instructional, operative, and monitoring tasks assigned to him/her and from the physical and temporal relationships applicable during the performance of these tasks."[23]

Thus, time and the effects of excess time or insufficient time are the principal criteria in the development of the evaluation methodology.

Whether or not optimal or even essential compatibility exists at the IOS is by no means obvious from its physical appearance derived from an ergonomic analysis. The designer needs a tool to systematically assess the suitability of IOS equipment and functional features for each typical task that may be assigned to the instructor, and to test this suitability in the context of the activities of a representative task profile. This approach permits the analysis and comparison of all functional aspects and design details of the IOS as conservers or consumers of time, or more precisely, uncommitted instructor workload capacity. The "cost" of insufficient information or inadequate machine support appears as excessive time required to complete a given task, since the instructor has to perform additional work to establish the necessary conditions for satisfactory system performance.

The considerations of man-machine compatibility and performance are almost endless. Most IOS activities, however, may be grouped accurately into the following five categories:

1) Perception. Becoming aware of new information

2) Recognition. Evaluating, understanding, or decoding information

3) Decision making. Intellectual activity leading to a change in behavior

4) Action. Physical activity leading to a command input to the machine

5) Monitoring. A combination of perception and recognition to ascertain that the desired activity is being obtained.

The effects the interface devices, or the layout of the interface within an IOS, have on the instructor are of great importance in evaluating the design of an IOS.

In order to carry out the instructional tasks, the instructor interacts with the hardware (usually a keyboard, CRT, etc.) at the IOS. These interactions may be complex or simple and correspondingly consume his time. Therefore each function within the system must be evaluated to determine which level of interaction is required. Interactions may be examined by identifying the level of automation, feedback, keystrokes required (assuming a keyboard is used), and required operational training.

Figure 3 describes instructor interactions with the hardware aspects in terms of several levels of complexity of the interactions. The complex interactions providing feedback require a moderate level of automation, a high level of feedback, and a high level of keystrokes. The simple interactions providing minimal actions require a high level of automation, a low level of feedback, and a low level of keystrokes. This approach may confuse the instructor due to lack of feedback. It requires minimal training but lacks flexibility because it is totally automated. The simple interactions providing controlled action require a high level of automation, a moderate level of feedback, and a moderate level of keystrokes.

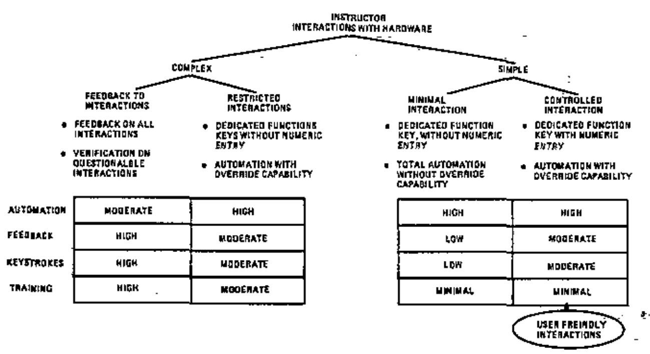


Figure 3 USER-FRIENDLY INTERACTION

Of these four alternatives presented, the instructional system with simple interactions providing controlled actions *manifests as a user-friendly* instructional system. This approach drives the designer to embed the user's requirements into the interface. The implementation of a user-friendly instructional system is accomplished by a delicate balance of automation and manual control. Automation calls forth the structuring of the missions (Figure 4). How the instructional system is automated is the foundation for the implementation of user-friendly concepts.

IMPLEMENTATION OF USER-FRIENDLY CONCEPTS

The philosophy underlying the implementation of user-friendly concepts for instructional systems requires the designer to acquire a deep insight into planned aircraft missions and training scenarios. This is because the primary goal is to minimize formal instructional training and also to minimize instructor mental workload. These attributes can be provided by requiring of the instructor, at any given time in the mission, the minimum amount of information processing and decision-making. This ultimately requires a clear understanding of the missions and training scenarios which the user intends to carry out in the ATD so that they can be partitioned into segments containing just enough instructional features which are synthesized by the appropriate parameters (see Figure 4). Without the deep knowledge of the intended missions and training scenarios, specific training objectives, the training syllabus, crew tasks, and aircraft configuration, the designer will be at a loss.

The literature search revealed a common thread expressed by almost everyone: Caro and Pohlmann(18), Fuller(19), Cohen(8), Polzella(9) and others recommend that the user should communicate with the designer from the beginning in the design and development of the IS

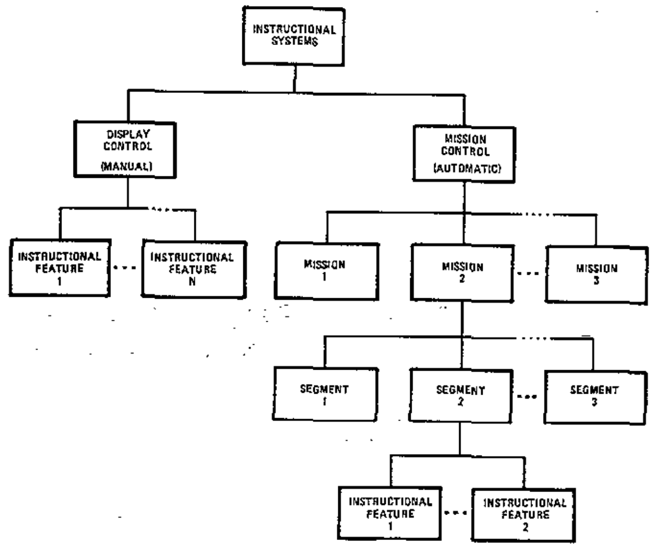
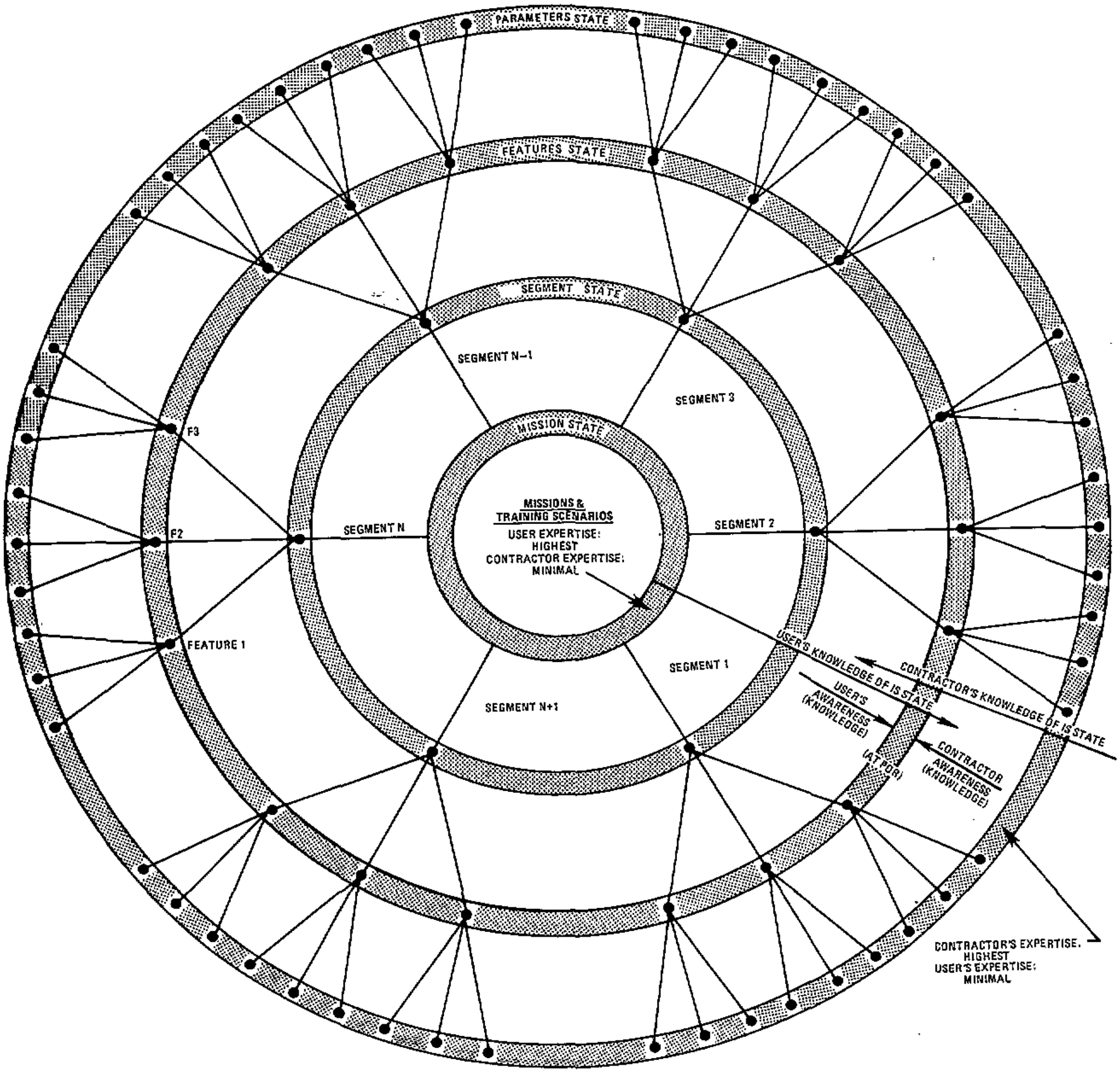


Figure 4 INSTRUCTIONAL SYSTEM STRUCTURE

and IOS. Figure 5 portrays the synthesis of the model of user-designer communications in the development process of the user-friendly instructional system. It illustrates the hierarchy of states of knowledge of missions and training *scenarios and the evolutionary course of user* and contractor awareness of knowledge states during the design and development of instructional systems. In the beginning of the design process, the user's awareness of the intended missions and training scenarios which the instructional system should implement is highest, *whereas the designer's awareness is minimum.* Based on the minimum knowledge of missions (literal specification may be understood but its intent may not be revealed), the contractor starts designing and hence his awareness of the parameter state of knowledge is maximum and that of the user is minimum. As the design progresses, awareness of the *hierarchy of states of* knowledge on the part of both the user and the designer increases. As the scheduled design milestones are met, the user's awareness of the states of design increases and the feedback to the designer (of the intentions of the specification) will be timely. This process of interaction results in the enhancement of the awareness of each other's states of knowledge throughout the design and development phase, and this



PROPER SCHEDULE SEQUENCE SYNCHRONIZATION OF EVENTS (PDR, MOCKUP, CDR – – – HSI) AND MILESTONES IN THE DESIGN PHASES OF INSTRUCTIONAL SYSTEMS IS CRITICAL TO THE DEVELOPMENT OF A USER–FRIENDLY INSTRUCTIONAL SYSTEM

Figure 5 EVOLUTIONARY COURSE OF USER AND CONTRACTOR AWARENESS OF KNOWLEDGE STATES OF INSTRUCTIONAL SYSTEM DURING ITS DESIGN AND DEVELOPMENT *is essential to the achievement of a user-friendly implementation of state-of-the-art technology in the instructional system.*

Mission Generation

Based on the user's information, a mission analysis must be conducted in order to produce training mission scenario requirements, mission functional performance requirements, and mission file data requirements.

Operational mission requirements are analyzed as a first step toward defining the simulator mission capability. The structuring of these requirements within the framework of a training timeline helps reveal the significant functions, operations, and procedures to be simulated.

The training mission scenario analysis generates:

a) Mission segments and major functions/operations.

b) A tabulation of crew tasks and procedures related to functions/operations.

c) Simulator operational requirements (modes, controls, ...) related to the training mission.

d) A mission event sequence patterned after an operational mission timeline, but reduced in simulator time (See Figure 6).

e) Simulator operational requirements correlated with the mission event sequence.

f) A training mission flight profile detailing the event sequence from take-off to landing.

g) Mission scenario activities, highlighted with training modes of operation related to each mission segment.

Once the mission system and missions are defined, attention is directed to the on-line and off-line systems which support and work in conjunction with the mission system. Instructional systems are composed of both on-line and off-line systems. The primary off-line system is the mission generation system. It is a very important tool in defining, checking, and flying an error-free simulator mission segment. Software modules that can be used to slew the simulated aircraft through the mission to verify that mission data will be activated at the appropriate time are extremely useful (Figure 6). Graphic depictions such as that in Figure 7 can also be used to aid the instructor in verifying mission-related features and parameters. On-line instructional features may be classified as supporting display control (manual interaction) mode or mission control (automated) mode. The display control mode provides the instructor with the ability to monitor and initiate actions which have been defined in the mission generation system environment.

To effectively use the simulator, a series of different missions are collected and made available for use during training. The instructor has the option to select from a menu of missions and the trainer can be initialized to the training exercise desired. Once the trainer is initialized, the mission execution can begin with minimal interaction by the instructor, thus allowing the instructor to carry out the intended instructional tasks (freed from control of the simulator, etc.).

Figure 4 illustrates the structure of the display control (manual) mode and the mission control (automated) mode. The instructional features available in the display control mode should also be available in the mission control mode. The simplicity of the interaction with the instructional system establishes severe requirements for the hardware and software elements of the system.

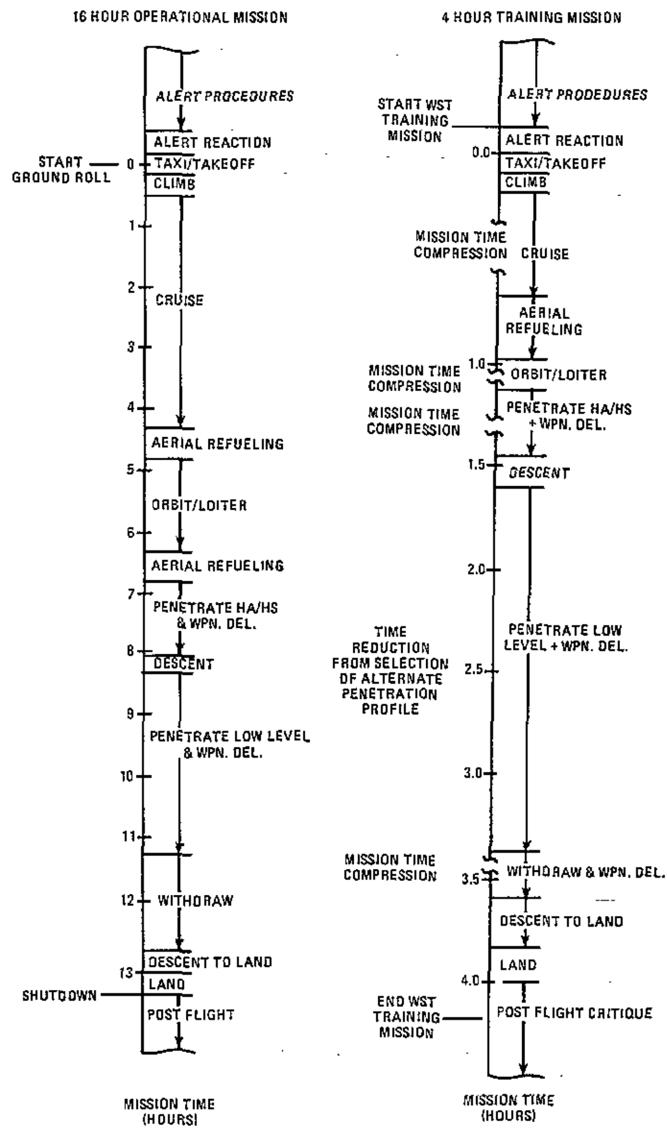


Figure 6 OPERATIONAL AND TRAINING MISSION TIMELINES

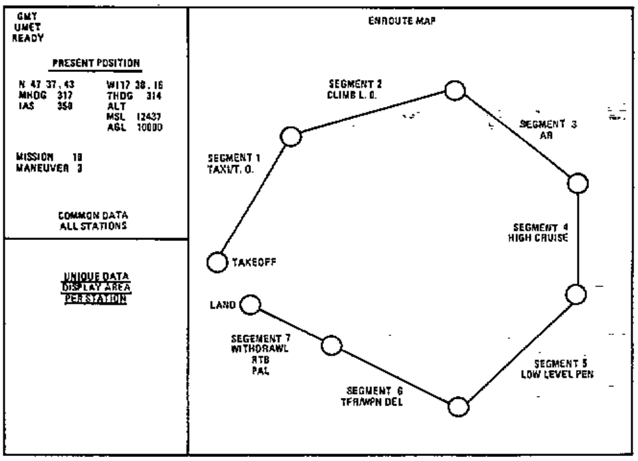


Figure 7 GRAPHIC MISSION DISPLAY

Software

The non-real-time (non-training) mission generation system must provide the environment and events associated with each segment. Thus most of the instructional system complexity is embedded within the mission generation system software. In order to provide controlled interaction (see Figure 3), special IOS software must be in place to operate in conjunction with the preprogrammed mission with verification of the syntax (e.g., range) and semantics (e.g., interrelationships) of the data entered via the IOS. The controlled interactions also depend on mission-related data to dictate which instructional features are available to the instructor during a particular segment.

The instructional system software has the task of interfacing with the selected hardware and implementing the display/control and mission control modes. The requirements which the user defines must be embedded within the software to such a level of detail that the user will have a controlled interaction with the hardware.

Hardware

The selection of IOS hardware is critical to the design of a user-friendly system. The primary limiting factor in computer-based control panels has been the human being operating the system. The problem was not that the operator was incapable, but that the communication between the person and the computer could be slow and difficult and often required a good deal of operator training. The vast array of controls necessary in a complex system could be overwhelming -- even to a highly trained operator -- and confusion and possible error were often the obvious, though unwanted, results. Our research and analysis recommends a multifunction interactive programmable pushbutton panel (or equivalent) (MIP^3) with an implementation of three hierarchical levels[20] of keystrokes which successfully lead the instructor step by step in carrying out his preplanned instructional tasks with minimum workload.

MIP^3 provides an interface that promotes the best possible communication between the operator and the system. This type of system offers unlimited programmable multifunction capability. Because each device can display multiple legends within a system, the operator only needs to be concerned with the specific legends which require attention at a given time. Control legends dealing with other functions will not clutter his scope of concentration until they become necessary.

MIP^3 devices are programmed to take the instructor through each segment of a mission in sequence, beginning with pre-flight instrument checks and concluding with engine shut-down procedures. The instructor doesn't need to memorize a checklist or consult a printed one -- the computer software can now handle those details and guide the instructor through the proper sequences.

Using the appropriate legends, the instructional system can lead the instructor through the necessary operations one step at a time. And since the actual number of controls can be greatly reduced with MIP^3, distracting visual clutter can be cut to a minimum, allowing the instructor to devote his complete attention to the communication at hand. This feature can be especially useful when programming priority functions into the mission.

For example, if the computer detects a malfunction -- like a change in cabin pressure -- it can alert the instructor by signalling him in a mode reserved for just such a situation. It can then guide him through an appropriate series of operations. When there is no problem, this data does not need to be taking up space, where in an ordinary control panel system warning controls must always be visible even though used infrequently.

In a situation such as the above MIP^3 pushbuttons could be programmed to ignore all signals from the instructor until he has responded to the priority function. He cannot make an error because the computer -- through MIP^3 -- leads him through each step, offering only alternatives involving the problem at hand and excluding incorrect and irrelevant options.

Dedicated controls simply cannot handle the sheer volume of information that would be involved, to say nothing of the resulting chaos on the control panel.

The majority of control functions can be handled with 16 programmable legend switches. The legends on the programmable legend switch matrix, two lines of four characters each, are under computer control, and depressing one of them changes one or more of the following:

- The simulator state
- The CRT display
- The legends on the unit's two-line display
- The legends on the unit's switch matrix itself

Programmable switches help instructors coming off the flight line with minimal training to teach effectively, while giving more experienced instructors access to an extensive array of instructional features. To meet both of these heretofore contradictory requirements, the design of a user-friendly instructor station provides that:

- All the actions or choices that are plausible and legal at a given time are represented by legends on the matrix
- No other actions are possible: there are no legends for them
- Depressing any switch with a legend effects a useful action, as all of the legends are oriented to action, not information

Generally, fewer than 16 switches have legends on them; depressing a switch with no legend will have no effect.

The instructor, instead of being intimidated by a huge, complex control panel, has no more (and usually fewer) than 16 switches to choose from for primary simulator and display control.

MIP³ allows access to the maximum capability of a system and transmission of messages involving its many operations in a clearly understandable, easy-to-follow way. Many additional programs never before possible can be incorporated, and often in less space than before. Here is where the creativity of the system designer really comes into play ... if only he knows what the user intends to do. This is what we envision as a user-friendly system.

RECOMMENDATIONS

The problem of engineering the flow of events which present information to instructors and allow them to exert control over the ATD seems to be at the heart of deficiencies in today's complex trainers. In future systems, probably nowhere will the conflicting requirements of allowing for flexible usage and of providing for standardized instruction need to be more delicately balanced than at the instructor's interface to the device. System designers will have to be both selective and efficient in their choice of what to display at a given time and what information to require from instructors[21].

We have presented a methodology for designing such an instructional system, with a delicate balance of automation and manual control, automation being cooperative, its performance in consonance with that of the user, providing at any given moment of the mission appropriate recommendations, not commands.[22] Acceptance by the user is a critical factor in determining the economic viability of the system, and this instructional system turns out to be an accepting, "forgiving," nonautocratic, and, above all, adaptive and motivating system -- in short, user-friendly.

The user-friendly aspect of the instructional system results in efficient resource utilization of the ATD with minimum instructor mental workload and training. For its implementation, the following recommendations are made:

1) The user should have well defined typical mission scenarios in the information available to the design team in the beginning of the design phase. (Figure 6)

2) Realistic design criteria should be generated by the user-designer team,[7] directed towards maximum effectiveness in mission training.

3) The design and development of instructional systems should be considered as an iterative process and an operational mockup model based on the front-end analysis should be made available for a continuous evolutionary design process by the designer. The user training team should remain involved with the designer team throughout the engineering design, construction, and user acceptance processes to ensure the implementation of training requirements.

4) The user-designer team should develop a low-cost model based on instructional mission and task analysis which reflects the level of interaction required by the user and should serve as a basis of development for the designer. Such a model will help avoid the barriers between the user's awareness and the designer's awareness and encapsulates the team development process. This model should be available for examination throughout the IOS development and user acceptance.

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