THE SEMI-AUTOMATIC INSTRUCTIONAL SYSTEM

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ABSTRACT

This paper outlines Link division's approach to the general training requirements of the B-52 WST, and the specific requirements of the Instructional System. A review of the analysis and design approach is presented, as well as an overview of the resulting Instructional System, including several of the factors which influenced the design and development of the system. Several design goals were established for the Instructional System and, at this writing, the system has undergone several months of limited qualification testing by the Air Force test team, culminating in a production contract award to Link.

INTRODUCTION

As the developmental phase of the B-52 Weapon System Trainer (WST) program nears a close, a training device has emerged which in many ways reflects the dynamic environment of its airborne counterpart. This paper is aimed at helping the audience understand the evolution of this system.

We will first present a brief overview of the aircraft, and then look at some general requirements for the WST as well as more specific Instructional System requirements. The next step is to describe the resulting instructional system which was developed to meet those requirements along with several other influencing factors.

In a program of this complexity and duration, one expects a certain evolution of design goals and system requirements based upon new data and observed system utilization by line crewmembers. This was certainly the case during the development of the B-52 WST. The additional challenges and frustrations of the competitive procurement also added to the general complexity of the effort. Contributing to this is the complexity of the B-52 equipment, requiring six crewmembers (Pilot, Copilot, Navigator, Radar Navigator, Electronic Warfare Officer, and Gunner).

Classified as a heavy strategic bomber, its primary mission is the delivery of strategic weapons wherever such delivery is deemed appropriate. The physical layout of the aircraft segments the crew as shown in Figure I. The Pilot and Copilot are positioned in the forward area of the upper deck, and are responsible for the basic flight control of the aircraft. The Pilot, who occupies the left seat, is also the Aircraft Commander, responsible for the overall mission and crew. The aft area of the upper deck is occupied by a defensive team consisting of Electronic Warfare Officer and Gunner, responsible for the defense of the ship from ground and air-based threats such as anti-aircraft artillary, surface-to-air missiles, air interceptors, and air-launched missiles. The lower deck is occupied by an offensive team, a Radar Navigator and Navigator, responsible for the accurate navigation and direction of the aircraft from takeoff to landing and the direction of the aircraft for release of gravity weapons. The offensive team is also responsible for the Short Range Attack Missiles carried aboard the B-52 for use against ground-based threats in an attempt to improve the penetrating B-52's probability of survival.

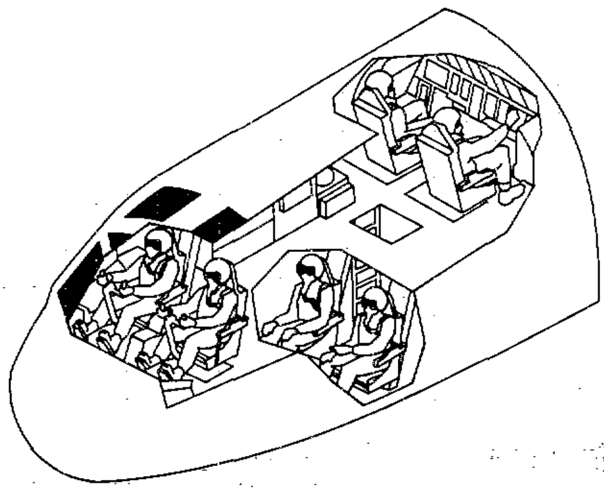


Figure 1 B-52 CREW POSITIONS

The B-52's mission, though simply stated (deliver weapons on a designated target), becomes complicated due to the performance of the aircraft and systems while operating in an external environment of higher (state-of-the-art) technology and additionally due to the intricate coordination of activities required of the crew members.

The prime item development specification for the WST requires the delivery of three separate, but joinable, training devices. A Flight Station with six-degree-of-freedom (6-DOF) motion and digital visual system, an Offensive Station with 3-DOF motion and digital radar landmass system, and a Defensive Station with an interactive threat environment. Each station additionally includes a remote Instructor Station, and a secondary onboard Instructor Station and, of course, a computational system. The physical layout of the aircraft, shown in Figure 2, makes the separation of the crew into three units in a trainer quite attractive. Figure 3 is a schematic representation of the three crew stations which make up the B-52 WST. Since members of the three teams rarely make direct visual contact with a member of another team, the situation in the trainer is not significantly different from that in the actual aircraft.

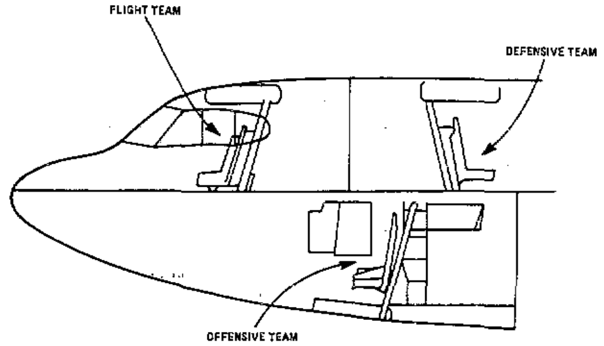


Figure 2 B-52 CREW COMPARTMENTS

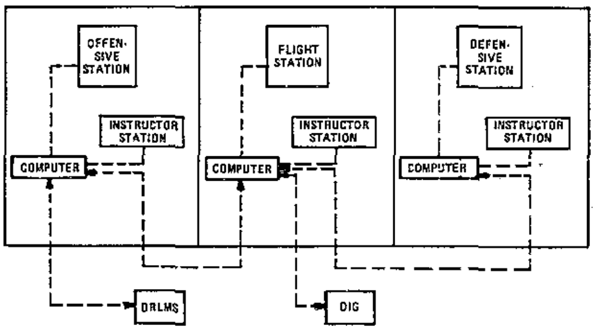


Figure 3 B-52 WST FUNCTIONAL UNITS

Instructional System Requirements/Analysis

The prime item development specification required a system to meet training needs for initial combat crew qualification and for mission qualification and continuing training and to accommodate operation for instruction, proficiency training and evaluation.

Specific capabilities and features included:

1. Remote Instructor Stations for each crew station -- Flight (FIS), Offensive (OIS), Defensive (DIS) -- with each optimized for dedicated operations with its associated student station.

2. Graphic CRT display/function keyboard system to provide for Programming (setup and modification of training mission data); Status of cockpit equipment, student actions, and the training situation; and Plots of aircraft track during various mission phases.

3. Simulator controls for all functions necessary for training.

4. Repeater display for selected equipment, including visual system, Electro-optical Viewing System (EVS) monitor, and radar indicator, as well as selected Defensive Station repeater displays.

5. On-board instructor positions to allow over-the-shoulder instruction and evaluation.

6. Simulation Exercise Control Unit (SECU) to provide the on-board instructor with limited control over the simulation exercise.

7. Instructional Communication System (ICS).

8. Automatic Monitoring of simulation variables and parameters, flight profiles and procedures with hardcopy printout, CRT display, and magnetic disk storage of monitored data for post-mission analysis.

9. Automatic Playback of simulator performance.

10. An automatic radio message system.

11. Automatic malfunction insertion.

12. Capability to record and reset to simulator position and conditions during real-time operation.

13. Freeze/Unfreeze simulated station as well as selected parameters.

14. Hardcopy printout of mission file data and other data pertinent to instruction.

15. Crewmember performance scoring.

Added to these requirements is an additional requirement for analysis of the instructional roles to be filled by the WST, leading to the definition of the basic system structure and specific methods to be used. These specific details as well as overall goals of the instructional system were defined based upon the results of this process. A primary factor in goal definition is the analysis of the skills and activities to be rehearsed in the trainer and the levels of proficiency of those who will be trained. The requirements of the B-52 specification provide a collection of features and capabilities which are meant to support these activities and participants, but in order to properly and effectively implement a system, further study was required.

In the B-52, the primary mission goal and many of the secondary or enabling goals are not rehearsable in the aircraft. This is apart from the normal emergency procedure drills and equipment failure problems which are considered too risky in any aircraft. The analysis of instruction system needs must be grounded primarily on the needs of the crewmembers in retaining a high level of proficiency in this complex environment.

Further, the instructional system designed for the WST requires a significant degree of tactical flexibility. Not only do the methods of modern warfare change frequently, but the basic tools also are subject to development. The promise of the cruise missile and state-of-the-art avionics systems hold the possibility of vast changes in the role of the B-52 crewmember. Since the effects of these new developments on the B-52's detailed training requirements are at present certain, the basic system developed for the WST had to respond effectively and easily at a moderate cost to fairly significant changes in the employment role of the B-52 Weapon System.

For those not familiar with details of the B-52 WST procurement, it was administered by the United States Air Force as a competitive flyoff between the Boeing-Wichita Co. and Singer-Link Division, both of whom designed and built protoype

WST's. These trainers were then both subjected to testing by Air Force personnel, culminating in a final flyoff conducted by actual SAC line crew-members. Throughout the development, Air Force guidance was severely limited so as to avoid giving an edge to one competitor over another.

As a result, very little official guidance or feedback on proposed modifications and deviations could be provided, and areas of the specification which were goal-oriented could be interpreted in ways which our analysis indicated would provide the most effective system. Other areas which were very specific not only in the goal, but also in specific implementation techniques, were more troublesome, since often more effective means were available. One such area was in simulation of an air refueling rendezvous, where a specific model was described, although alternative mthods not only simplified the problem, but in fact resulted in a more faithful reproduction of real-world events. In the competitive environment, there is considerable pressure to conform to specification dictates precisely, so alternative approaches were examined closely before acceptance or rejection.

The specification, as a primary design source document, provided a wealth of information on the requirements of the system. To add to this source, a number of other data sources were combined to provide an overall picture of the instructional needs of B-52 users. Sources such as Instructional System Development (ISD) Analysis performed for the Strategic Air Command in 1974 provided valuable guidance in evaluating typical task elements and problem areas in the training programs then in existence for new B-52 crewmembers. Other military sources, such as the Education Training Requirements (ETR) document, further enumerated individual task elements for the operational crewmember.

The conclusion reached through this process contrasts the B-52 WST with other multistation trainers. Although the three stations which comprise the B-52 WST are designed for use in independent as well as integrated training, a major factor in their design is the interrelationship of tasks among the crew members. In separated training situations, the instructor is burdened with the responsibility for role-playing to provide the required assistance or hindrance which would normally come from other crewmembers. As the time comes to integrate individual skills into a mission-objective-oriented skill package, the interplay among the crew becomes a major factor.

To fine-tune the mission-critical skills, the true complexity of the mission environment must be allowed to unfold. The situation here is sharply different from that existing in a multi-student system trainer, where a number of students are performing their missions in a completely unrelated way. The coordination tasks for the instructors in an integrated WST are considerable and require direct support in the design of the machine.

Another major requirement exists for rapid and direct transition amoung the available operating modes of the WST. This transition assumes key importance with the realization that WST time is utilized best by developing training scenarios which exploit mode transitions to bring the trainees together for complex mission elements while allowing independent pursuit of relatively non-coordinated tasks.

In developing the design goals for the WST, the primary goals were based upon the complex task structure in the trainees' required skill inventory, and the complex environment in which the crew must be placed. Based upon a consideration of these factors, many secondary or derived requirements emerged which were significant to the implementation techniques used for the Instructional System software. A good example of this is related to the previous discussion of trainer mode control.

What emerges from a study of this problem is a group of central design considerations. These are the fundamental goals which all secondary goals and specific system requirements are built upon. Table 1 reviews some central elements of the WST goal/approach structure. Due to the highly complex task structure which the WST instructor must monitor, his role as an evaluator and diagnostician must be optimized. The required simulation injects the simulated aircraft into a fairly complex environment. To the greatest extent possible, the environment must be controlled automatically, with status clearly and easily reported to the instructor.

Finally, since the mission of the B-52 and the interrelationship of tasks for the B-52 crew is so complex, an easy method must be available

TABLE 1 DESIGN GOALS/APPROACH SUMMARY

SIMPLIFY OPERATION O SINGLE KEY PAGE SELECTION O COLOR-CODED KEY FUNCTIONS O USE OF SPECIAL FUNCTION KEYS STANDARDIZE INSTRUCTION O PRE-SPECIFIED LIBRARY MISSIONS O PRE-SPECIFIED INSTRUCTIONAL DATA O PERFORMANCE STATUS AND MONITORING O PROCEDURE MONITORING O HARDCOPY PRINTOUT O CONFIGURATION CONTROL	REDUCE INSTRUCTOR TASK LOADING O MISSION SEQUENCE/EVENTS O MALFUNCTION ACTIVATION AND DELECTION O PROCEDURE MONITORING O VOICE MESSAGES O PERFORMANCE MONITORING AND RECORDING O DISPLAY UPDATING O CONTROL FUNCTIONS SIMPLIFY DATA GENERATION PROCEDURES O STANDARDIZED INPUT FORMATS O PRE-FORMATTED DATA INPUT SHEETS O DISPLAY PAGE/DATA CORRELATION O DATA VALIDATION	OPTIMIZE INSTRUCTIONAL MEDIA O CONTROL PANEL CONFIGURATION O CRT DISPLAY ORGANIZATION AND CONTENT O LOGICAL CONTROL INTERACTIONS O AUTOMATION OF CONTROL INPUTS

whereby careful planning of a training session may be performed prior to the training period, easily recalled for use, and executed in a straightforward manner. Improvisation is tolerated by the system to allow for interactive tailoring of the training situation based on trainee performance, but the key design factor is the persistent notion that the interdependence of the elements in the WST makes any but the most thoughtful changes to a planned sceanario risky and argues for a system which allows thoughtful investment of instructor efforts as a course developer/mission planner before the student arrives.

Thus the primary goal is the reduction of instructor task loading in simulator-unique duties. As a fallout of this priority, the system further must assist the instructor to the greatest extent possible in the gathering of a broad body of data, meaningful in the evaluation of the trainees' performance not only in terms of the quality of results, but also useful in the diagnosis of problem source areas.

FACTORS INFLUENCING THE DESIGN AND DEVELOPMENT

Early in the analysis phase it became evident that a number of conflicting factors would affect the design, development, and ultimate performance of the Instructional System.

Since it was determined that the primary emphasis would be placed on usability of the system by the instructors, control/operation was an area of concern. It was once considered "sound" human engineering to approach design of controls from the "form follows function" position and provide different types of controls for dedicated functions (e.g., automobile windshield washer/wiper controls should differ from exterior light controls). Each should be optimized for its individual functions but sufficiently different so that they do not confuse the operator.

However, since the operation of each control must be learned, as the number of controls and controllable items increases, consideration of required learning time quickly diminishes the desire for different controls. The need to simplify operation was established as a design goal. As a result, only a few different interface/control functions were specified and the detailed system design was forced to satisfy requirements using the specified functions. Since it is a relatively easy software task to monitor inputs for valid form and sequence, the burden of insuring that inappropriate or accidental use did not result in disaster (or frustrated instructors) was placed on the software. Although manual control of many items was required (and is desirable in some instances) the need to minimize instructor task loading by automation was established as a design goal. The Automatic Mission System was conceived as the mechanism to achieve these reductions in task loading by "programming" events and sequences to control such items as malfunction insertion and deletion, voice message activation, procedure and performance monitoring, external environmental conditions control, and CRT display updating.

The key to developing a useful automatic mission is in planning. Since instructors would be the planners and developers, the system design approach required data generation procedures in a form usable by instructors rather than programmers.

Because of the competitive nature of the program, the WST had to be operational for the start of customer testing. Therefore, the schedule became the primary driver.

Also because of the competition, design direction and approval, normally a customer function, was replaced by a "review and comment" position by the Air Force, and responsibility for design decisions was a contractor function.

Another factor which influenced the B-52 WST development was the contract-required development of a KC-135 trainer. The Instructional System specifications for the KC-135 were very similar to those in the B-52 specification. However, the detailed simulation and training systems functions were considerably different. This implied the highest feasible degree of commonality among systems.

Another consideration was the major and minor system updates which might be required to keep the B-52 viable during the next decade or two. These would require associated modification of the WST, implying a high degree of flexibility.

Additionally, the system complexity alluded to previously in the summary of requirements would be a prime factor affecting the development process. Although not a direct concern of the subject at hand, since the majority of work was in software development, this deserves at least a brief discussion.

Normal software development practice requires that the building of a system proceed through distinct phases:

1. Determine system requirements
2. Formulate design concept/approach
3. Develop preliminary design, function allocation, and interface
4. Formulate system test approach
5. Develop detail design/test criteria
6. Code/test components
7. Install/verify system
8. Integrate/test system with other systems

Although there is always some apparent retrograde motion between phases throughout the development process, the process is manageable with appropriate milestones and constraints identified.

This normally smooth process was complicated by the fact that to meet the schedule it was necessary to start software design and development before the instructional system analysis had completely defined the system requirements. A system which maximized designed-in flexibility was necessary to accommodate late-arriving requirements as well as any future modifications. At the same time, as much commonality among the B-52/ KC-135 stations as possible seemed a necessity.

The general approach taken to developing the software drew from the concepts of top-down design, structural programming, and programming teams. However, much of the rigor associated with these techniques was not applied. Software design started, by necessity, at the top by developing a structure which could accommodate anticipated requirements and perform anticipated functions with minimum impact on computer resources. Generalized systems were developed by a team. This provided several advantages. Programmers obtained general overall knowledge of several systems preparing them for the development to come. As more specific requirements were supplied their implementation didn't require starting from scratch. Also, as priorities changed it was easier to adapt.

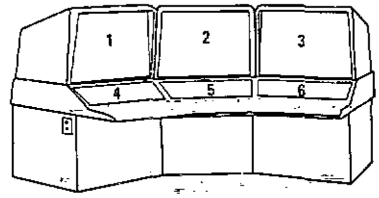
Without the rigor of many detailed design reviews and accompanying documentation to provide management visibility, it became a frustrating environment to manage.

INSTRUCTIONAL SYSTEM OVERVIEW

In reviewing the WST system, it is useful to consider the basic structure of the Instructional System, and consider some of the most influential of the system's features.

The WST instructional system is based on a remote instructor position as the primary operating location. An on-board position is provided, but is viewed only as a secondary location. The remote instructor console, shown in Figure 4, provides the instructor with extensive control and monitor capabilities. The console consists of a functional keyboard, which is used to command the display of various "pages" on the two CRT's of the display system. Switchlight controls in the panel provide control and status information for various functions such as the motion system, trainer mode, and the instructor communication system. Monitors allow the instructor to monitor scenes displayed to the trainee by the visual or radar systems.

In order to describe in a useful way the characteristics of the system, four particularly significant views are presented, each looking primarily at a key system feature.



PANEL	FIS	PANEL	OIS
1.	VISUAL REPEATER		
	EVS MONITOR	1.	RADAR REPEATER
	SPEAKER		SPEAKER
2.	GRAPHIC CRT	2.	GRAPHIC CRT
3.	GRAPHIC CRT	3.	GRAPHIC CRT
4.	AIR REFUEL CONTROLS	4.	
	VISUAL/EVS CONTROLS		EVS CONTROLS
	MOTION CONTROLS		MOTION CONTROLS
	MASTER DATA RESET		MASTER DATA RESET
	STATUS/CAUTION LTS.		STATUS/CAUTION LTS.
	LIGHTING CONTROLS		LIGHTING CONTROLS
	EMERGENCY STOP		EMERGENCY STOP
5.	FUNCTION KEYBOARD	5.	FUNCTION KEYBOARD
	SIMULATOR CONTROLS		SIMULATOR CONTROLS
	TRAINING CONTROLS		TRAINING CONTROLS
	CRT/KYBD ASSIGN		CRT/KYBD ASSIGN
6.	JOYSTICK/SELECTION	6.	JOYSTICK/SELECTION
	COMM SYSTEMS CONTROLS		COMM SYSTEM CONTROLS

Figure 4 B-52 REMOTE INSTRUCTOR CONSOLE

The most fundamental area of interest is the operation of the display system and keyboard. Since the system reliability is of pervasive interest, virtually all status displays and control functions are accessed via the CRT system in order to avoid the maintenance problems associated with hardware instrument repeaters and controls. The Flight Instructor Station keyboard is shown in Figure 5. The keyboard system employs a very simple operating scheme. The main keyboard is used to command the display of CRT "pages" by a single key selection.

Keys are grouped into various classes by location and a color code scheme. The left area contains white programming keys, used for control and setup features such as initialization, visual control, and various atmospheric conditions. These are prime candidates for automation to reduce control task loading. In order to simplify the page fetch operaion, many categories use an index scheme to allow quick advance to the desired page. The keys on the upper right are color-coded blue and command the display of plot function pages.

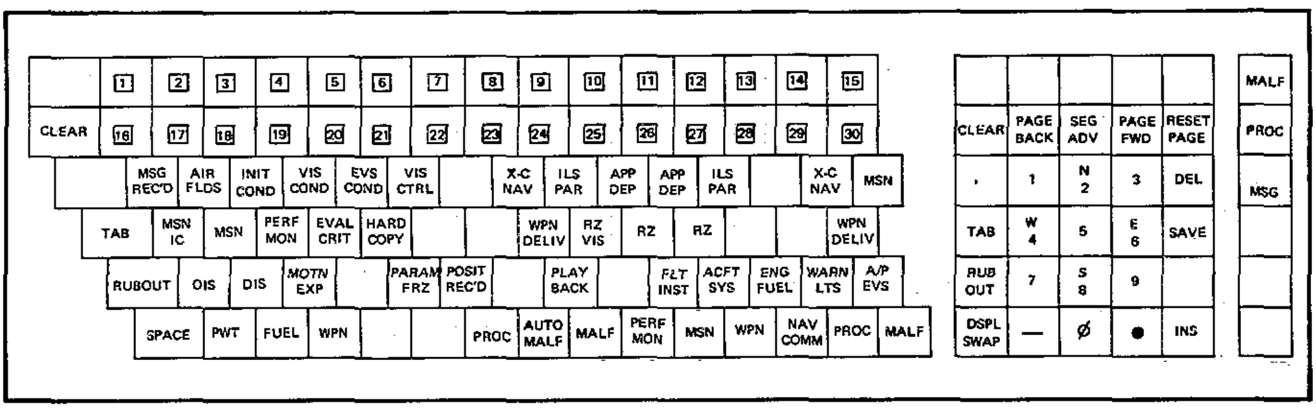


Figure 5 B-52 FLIGHT INSTRUCTOR STATION KEYBOARD

These provide a maplike display of the simulated aircraft's position. This type of display is an aspect of a trainer which goes beyond real-world hardware, since flight instructors rarely have access to such an easily used display of positional information.

The remainder of the main keyboard, color-coded in grey and black, houses keys which command the display of status data. The black-key pages contain training sortie data such as automatic mission, automatic performance monitor, procedure (checklist) monitor, or malfunction system status displays. These are trainer-unique features which are classes of information not available in real-world flight. The grey-key pages allow the instructor to monitor on-board instruments and switches. The use of CRT displays for this purpose provides acurate, easily accessed data with high reliability. Comprehensive coverage insures that the instructor can monitor cockpit activities without actually being present in the cockpit, thus avoiding the effect of an instructor's presence.

Although each of the CRT page formats shown in Figure 6 is identified as a programming, status, or plot style, these distinctions are derived more from customary use than from any system contraint. Different paging (forward and back) advantages inherent in these styles provide for their main differences. The "ALERT" area on each provides a non-page dependent area for important messages alerting the instructor to system activity, such as motion system warnings, automatic system events, or other key milestones. Rather than discuss the specific content of the CRT page collection, a category list has been included in Table 2 to provide some idea of the relative size and diversity of the library with which the instructor interacts.

TABLE 2 DISPLAY PAGE CATEGORIES

PROGRAMMING	STATUS
MISSIONS	F FLIGHT INSTRUMENTS
INITIAL CONDITIONS	F AIRCRAFT SYSTEMS
AIRFIELDS	F ENGINE/FUEL
F VISUAL/EVS	F WARNING LIGHTS
PWT	F AUTO PILOT/EVS
F FUEL	O RADAR/EVS
WEAPONS	O NAV/ASTROCOMPASS
O CELESTIAL	O BOMB/AGM
O AUTO TO AND LND	O BOMB SCORE
O FLIGHT CONTROL	O AGM SCORE
PERFORMANCE MONITOR	PERFORMANCE MONITOR
EVALUATION CRITERIA	MISSION
HARDCOPY	WEAPON
MALFUNCTIONS	NAV/COMM
PROCEDURES	PROCEDURES
MOTION EXPOSURE	MALFUNCTIONS
PARAMETER FREEZE	
POSITION RECORD	PLOT
PLAYBACK	
F MESSAGE RECORD	X-C NAVIGATION
O RADAR PREDICTION	ILS/PAR
O SRAM BY-PASS	APPROACH/DEPARTURE
O BNS JAMMING	RENDEZVOUS
	WEAPON DELIVERY

F - FLIGHT ONLY O - OFFENSIVE ONLY

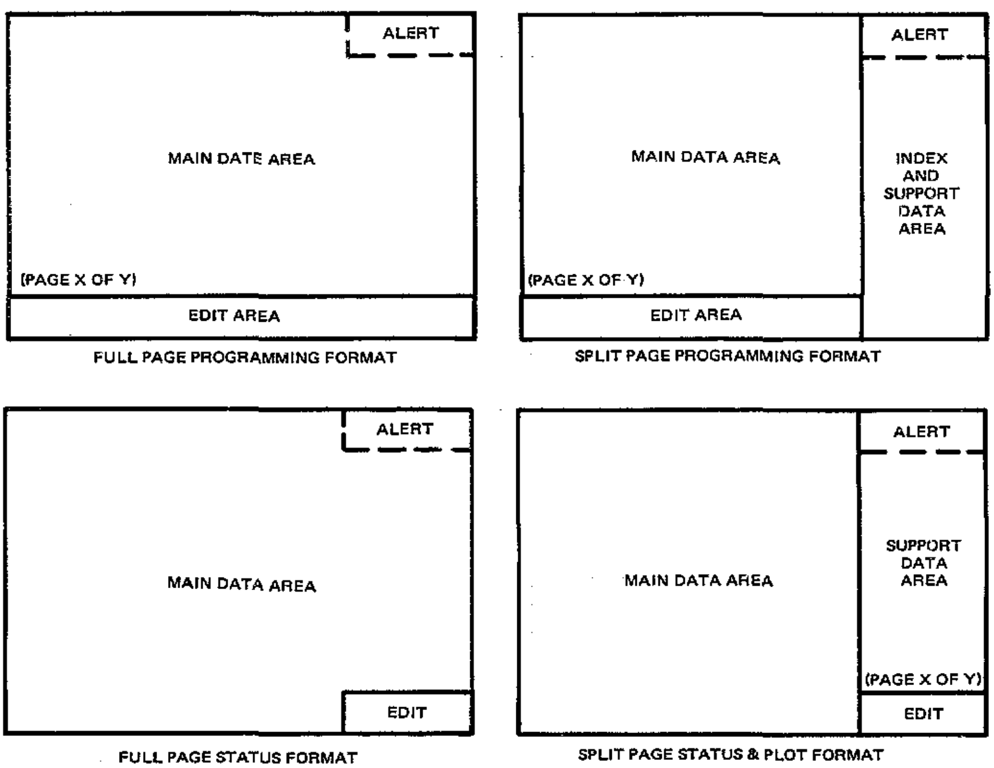


Figure 6 CRT PAGE FORMATS

The wide range of CRT pages provides for interesting diversity, but without the ability to interact, instructors are certainly not going to have the control they need. The small numeric keypad, seen in Figure 5 at the extreme right, and the two rows of numbered special function keys along the top of the functional keyboard provide this ability. Each CRT page item which may be modified is identified by an "item number."

Where variable data is to be edited, such as in the specifying of visibility (for visual scene), the item number is identified via the numeric keypad. This causes the item of interest to be displayed in the Edit area. New data may then be keyed into the system. Here is where various checks are made to detect errors of format, number of characters, and magnitude of the input. In the event that an error is detected, the input is rejected, and an error message appears to inform the user of the error. It is this safeguarding of input at the keyboard, along with the voiding of any fatal keystroke sequences, which provide the foundation for system reliabilty.

Just as many data items require the input of numeric values, many require merely the selection between two states or from an index. This is an area where the WST instructional system departs from the specification in the dominance of the special function keys rather than of a light pen. The use of light pens is fairly common, and is described in the WST specification. The Flight and Offensive Instructor Stations, however, exclusively rely on special function keys to allow selection from menus or to switch between alternate states of boolean items. The advantages of this alternative include increased reliability and ease of use, reduced instructor hand-arm motion, and lower life-cycle cost.

Virtually all system transactions are conducted via these two media, all conforming to a common set of format schemes. Table 3 enumerates a display and control system summary, with operator options and CRT system capabilites. Although the number of interactive fields is large and the different parameters themselves varied, only a small number of distinct data interaction formats are permitted. This commonality of syntax directly supports the reliability, ease of operation, and speed of training goals defined for this system. This allows him (or her) to actually begin using the trainer and develop "on the job." This minimizes the amount of system operation training required so that the bulk of an instructor's training can be devoted to the effective use of a synthetic trainer as a training aid.

TABLE 3 INSTRUCTOR DISPLAY/CONTROL SYSTEM

FUNCTION KEYBOARD	ALPHA-NUMERIC/GRAPHIC CRT's
O PAGE SELECTION PAGE FORWARD/PAGE BACK RESET PAGE DISPLAY SWAP	O FORMATS FULL PAGE (12"H X 16"W) SPLIT PAGE (12"H X 12"W, 12"H X 4"W)
O DATA MODIFICATION NUMERIC PAD CLEAR/TAB/RUBOUT INSERT/DELETE/SAVE	O PAGE TYPES INDEX SINGLE PAGE MULTIPLE PAGE
O SPECIAL FUNCTION KEYS PAGE SELECT VIA INDEX DATA MODIFICATION SUB-SYSTEM CONTROL	O PAGE CATEGORIES PROGRAMMING STATUS PLOT
O DIRECT DATA ACCESS MALFUNCTIONS PROCEDURES MESSAGES	O APPLICATIONS SET-UP AND CONTROL EQUIPMENT STATUS TRAINING STATUS MISSION PHASE PROFILES

Another key area of WST performance is in the direct control by instructor/operators of the mode or degree of integration of the WST stations. Instructor control of the trainer must be simple, quick, minimally error-prone, and most important, extremely reliable. The system must also insure that no instructor's lesson is interrupted by another station operator. The system developed reflects these requirements in its operation. Mode changes in an upward direction -- i.e., Independent to Integrated (all three stations together) -- require the consent of the instructor at each involved station. No effects of a mode change are felt at a station until its instructor consents by depression of a mode selection switchlight.

Three switchlights, one for each mode, are used at each station. The software which operates behind this simple exterior is of considerable complexity. Since a number of request and status flags are used to communicate each station's situation, and further, since a given station may experience momentary losses of communication with the others (or complete failure), the transfer of status data is continuous rather than based on change. This precludes any "out of sync" situation due to a missed signal. Further, automatic "downmode" is designed in. If a system failure occurs at one station, the remaining "healthy" systems do not continue to look for data from the failed station, but rather step down to the next lower mode.

Another key software characteristic is a data priority system. Since each station has the capability of operating as a stand-alone device, each computes all parameters required for its simulation environment. Each station has specialized areas where greater detail is required. but in general, when the stations are combined to form the Integrated WST, many parameters are computed in all three computer complexes. Consider latitude/longitude and weapon load. All three stations compute position based upon flight vector inputs. Both the Flight Station (for weight and balance) and the Offensive Station (primarily for weapon delivery gear) maintain a library of weapon loads and track real-time weapon status. To avoid confusion and anomalies during joinups and for Initializations in Integrated mode, priority is assigned for each parameter to the station most concerned or involved with that given piece of data. In our examples, Flight controls the latitude/longitude pair, while Offensive controls the weapon load. A system is currently envisioned which allows the designation of parameter priorities in real time by the instructor. This promises to inject even more flexibility into "mulit-mode" mission joinups.

In the course of the discussion we have seen that a considerable portion of the CRT/keyboard system capability is utilized for control of the simulation and training enviroment. The desire for a system with wide ranging flexibility, very simple operation, and low instructor task loading provides a considerable challenge.

The extensive use of automation in eliminating instructor interaction and reducing task loading in the setup and control of the trainer's simulated environment was desired by the Air Force. This is an area where the flexibility for system configurations and training session events is of a strategic rather than tactical nature. By using a system which formalizes required data specifications, but allows a wide variety of data, one can reduce the instructor's real-time task, provide great system flexibility, but also allow for extensive compatibility testing and development of the situations produced. The embodiment of this concept is the use of a mission data base to specify the environmental, task-related, problem-related, and evaluative characteristics of a training session.

By setting forth the characteristcs of a session in advance, the complex interelationships in the crew task structure may be monitored through the thoughtful creation of a problem scenario, complete with appropriate procedural and performance-based evaluative monitoring.

As noted earlier, the intense intertwining of tasks in B-52 crew activities requires that training problems and monitoring techniques be extremely well planned and coordinated. Automatic systems to monitor crewmember performance in checklist procedures, weapon delivery accuracy, and navigation accuracy against recorded parameter values are all included in the WST, but in order to control these features, the WST Mission System was developed.

The Mission System may be viewed as "automatic" in that it performs a host of functions with virtually no help from the instructor. During a training session, having selected and activated one of the available missions, the instructor is free to observe as the system unfolds the problems in the selected lesson plan. The system controls the insertion and deletion of malfunctions, the monitoring of checklist procedures and parameters, and the transmission of digital-voice messages. Other options allow the control of simulated environmental systems such as visual system conditions, wind, atmospheric pressure, turbulence, and temperature.

The system operates by reducing the entire WST mission to a series of elements called maneuvers and still shorter elements known as segments. This structure may be seen in Figure 7. Maneuvers are "sub-missions" which include a complete set of initialization data. This allows a mission to be entered at any maneuver boundary rather than requiring that a mission always start at the very beginning. The basic operating unit of the mission is the segment. Segments are started and ended by the successful fulfillment of conditional statements. Activities within a segment, whether it be a malfunction insertion, a wind change, or a parameter-set activation, are triggered by the reaching of some parameter's required value. The Mission System is the framework of real-time programs which operates to make this happen. The real structure for the training session comes from the data upon which the Mission System operates. The parameters to monitor, the malfunctions to insert, all the system initialization data, and, most importantly, all of the trigger parameters and threshold values are the Mission Data Base.

In considering the Mission Data Base, a fundamental architectural quality of the WST is illustrated. Wherever possible, software has been developed which utilizes a data base in carrying out its activities rather than doing so through the use of specific data implicitly written into the simulation programs. Areas which utilize this structure are numerous, and impact the total system by allowing considerable change potential without the need to alter simulation code. Implementing this scheme required that real-time programs fetch and operate with data files placed on the operating disk-packs by off-line data generation processors. The system, therefore, cannot be considered as the real-time control programs, status displays, and data bases alone, but must also include the off-line processors which build the data base, and the planning procedure. This is one reason why the "automatic" Mission System, and hence the Instructional System as a whole, is better thought of as "semi-automatic." The lure of carefree operation of the real-time lesson carries with it a subtle but inevitable snare.

The Mission lesson plan must be painstakingly and precisely prepared. Events are planned which develop into the desired scenario, and then they must be predicated on appropriate parameter triggers so that the mission flows in spite of student errors. Not an impossible chore, but one which requires complete and thoughtful planning. Who better to do this than the instructor himself? Therefore, the Off-Line Mission Generation processors accept planning data which has been transferred directly from planning forms designed to be used by WST instructors. The listing produced by the processors reprints the mission data base with error messages for illogical or out-of-limit inputs in a format similar to that used on the form so the instructor can review it for errors and make corrections as well as use it in test-flying the mission. The only steps in mission generation requiring computer support are the running of the processors and copying of the data are base files to the real-time operating disk, tasks which take

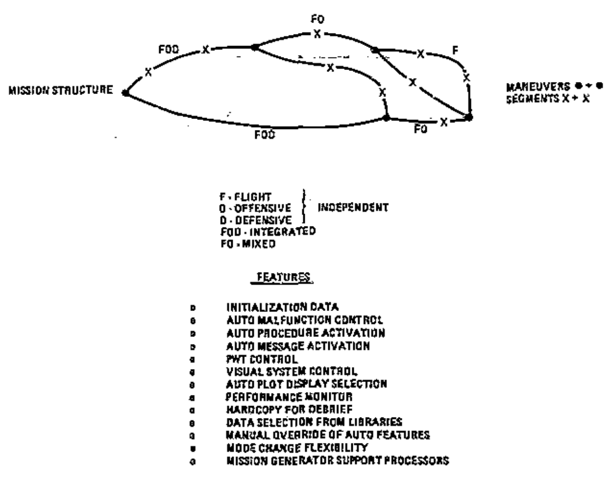


Figure 7 AUTOMATIC MISSION SYSTEM

only minutes. No software support personnel are required. Air Force instructors using the system during qualification test had good results with extremely short training.

An added dividend from the use of this structure is the easy adaptability to new tactical scenarios, new aircraft equipment, and developmental error correction. Although new aircraft equipment may require the alteration of simulation programs and additions to Instruction System monitoring modules, design of scenarios exploiting new capabilities or new tactical doctrine is easily accommodated. This important feature has already proved useful during WST development.

Because considerable development effort has been continued throughout the testing phase, various bits of new information have been accumulated which caused the content of data base structures to change. The use of this structure continues to allow a high degree of flexibility in the system, and provides system designers with the ability to defer many specific scenario decisions which were not supported by solid factual or clearly decisive information.

One of the most significant shifts in WST design philosophy has been the elevation of the Mission System as the prime instructional data source for the trainer. This can be seen from two considerations.

First, the complex interaction between the task activities of the various crewmembers and the high level of simulation-unique control capability argue for a carefully planned lesson plan to fully exploit the system even for the most basic of part-task training. This holds true for just about all elements of the operational skills inventory of the B-52 crewmember.

Second, the Mission Planning task has proved to be easy enough to permit the development of mission data bases for almost any and all purposes. The mission data base is easily adaptable to a data base consisting of segment after segment of takeoffs, refuelings, bomb runs, etc. The mission data base, then, is more accurately viewed as a "training sortie" data base rather than being limited to a "mission" which brings to mind the typical Strategic Air Command sortie. Thus the WST has emerged as a "mission" trainer, with training sessions based upon carefully planned lessons, automated execution of these lesson plans, and maximum use of the instructor/operator for fine-tuning of the trainer's responses and evaluative observation.

In order to meet the challenges of the B-52's complex instructional requirements, the automation of training lessons was required. With this comes the need for careful and insightful planning. Although we offer a highly structured and promising training tool, the value lies in the planning. The entire thrust of automation is not only structure and order, but also the freeing of the instructor. Here we can see the other challenge. The instructor can no longer satisfy his responsibilities by operating the trainer, since that's being done for him. He is now challenged to observe, diagnose, and advise -- in short, to instruct. This is a second reason to discard the notion of the "automatic" instructional system. At best one can strive for a semi-automatic system, and the best system is only a tool in the hands of an instructor. It requires two men in the "man/machine interface," one at plan-time, and one at run-time. Both play such an intimate role in the success of a training exercise that it is not unfair to regard them as parts of the overall system.

Although the competition is over, there is continued development in the WST, making improvements in the design for follow-on production units. Two key design enhancements which are anticipated will be briefly presented to conclude this report.

Observations and comments during Air Force qualification testing, both from test crews and from previously untrained Link personnel, seem to indicate that in spite of the volume of data available to the instructor*, the CRT Display/Function Keyboard system operation is relatively easy to learn. However, to properly utilize the available data in a training situation will undoubtedly require a significant learning period. Two basic improvements to this system have been proposed: 1) a rearrangement of page access keys to provide more obvious and quicker access to the most often used pages, and 2) a specially formatted instructor handbook to aid in using the system capabilities more effectively. The automatic procedure monitoring system, although compliant with the specification requirements, did not seem to provide sufficient information for an instructor at the remote console to determine the student's actions in performing many of the procedures. For example, since the procedure monitor only observed the programmed checklist steps and logged them when detected as complete, the student could inadvertently operate other controls which affected his performance on the procedure without the instructor being aware of the action. Also, when considering the large number of published procedures, about 143 on the Flight Station alone, and the probable future change activity, keeping the procedure system current with the aircraft would become a major effort.

An alternate system which meets some but not all requirements, but which promises to alleviate

*The CRT Display/Function Keyboard system, which is the primary man-machine interface, contained the following items and quantities for the FIS and OIS:

ITEM	FIS	OIS
CRT PAGES	166	139
INTERACTIVE ITEMS (LESS MALFS)	914	1055
SYSTEM MALFUNCTIONS	1424	629
STATUS ITEMS	929	1592
TOTAL # VARIABLES	3267	3276

most of the problems whith the current system, is being investigated.

Although configuration control of software during the prototype development was generally better than on any other recent simulator, if the full complement of 17 B-52 WST's is produced, the need for a much more automated process is evident, and such a process is being pursued.

The design and development of a Weapon Systems Trainer (WST) for the B-52 in the environment of a competitive procurement was both challenging and frustrating. Since the primary objective of the WST is to aid SAC Instructors in the continued training of combat crewmembers, the success of the trainer and the fulfillment of the major goals will be best judged after a period of actual training exposure. We are anxiously awaiting the opportunity to further develop this system.

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