THE FACILITIES AUTOMATED SCHEDULING TOOL (FAST)

by

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(ABSTRACT)

A systems engineering life-cycle approach is used to design the Facilities Automated Scheduling Tool (FAST) for the Facilities Branch of the ABC Company. The emphasis of the proposed design is the human factors criteria that are used to optimize the human-computer interface (HCI).

The need identified by the Facilities Branch is that the current manual project tracking system takes three weeks to gather the information required to initiate a request for change (RFC). Paperwork is cumbersome, data files are difficult to locate, and the Facilities Specialists are inundated with fragmented reports filed away in cabinets that are taking up what little free space the office has left. Therefore, the requirements for the system are established, options considered, and a recommended design is achieved which will reduce the number of file cabinets by 80%, enable a project to be input into the system in fifteen minutes, and reduce the number of

data input specialists from three to one, saving the company time and money.

FAST is essential to the Facilities Branch for optimal efficiency and cost-effective performance. Furthermore, many different operators need the system to track their specific projects. Most of these Facilities Specialists are not "regular" computer users, therefore, user-friendliness is of critical importance. Analyzing human factors options and presenting trade-offs is of utmost importance to ensure FAST will be used properly. If the user becomes frustrated with the system, the tool will no longer be useful to the operator or the Facilities Branch.

Both the hardware and software configurations of FAST are examined for user-friendliness and efficiency. The ABC Company has a service contract with IBM, where all the hardware equipment is bought. Therefore, an IBM platform is assumed for FAST. However, various screen designs and workstation arrangements are examined in order to produce a safe, comfortable, reliable, and efficient system that will save the ABC Company time and money.

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1.0 INTRODUCTION

The ABC Company, located in East Windsor, New Jersey, employs over 1,500 people and is responsible for operating and maintaining a classified software system with over 100,000 lines of code. The East Windsor facility is subdivided into seven departments as pictured in Figure 1. The departments are operations, hardware maintenance, software development, engineering support, marketing and business development, finance, and facilities.

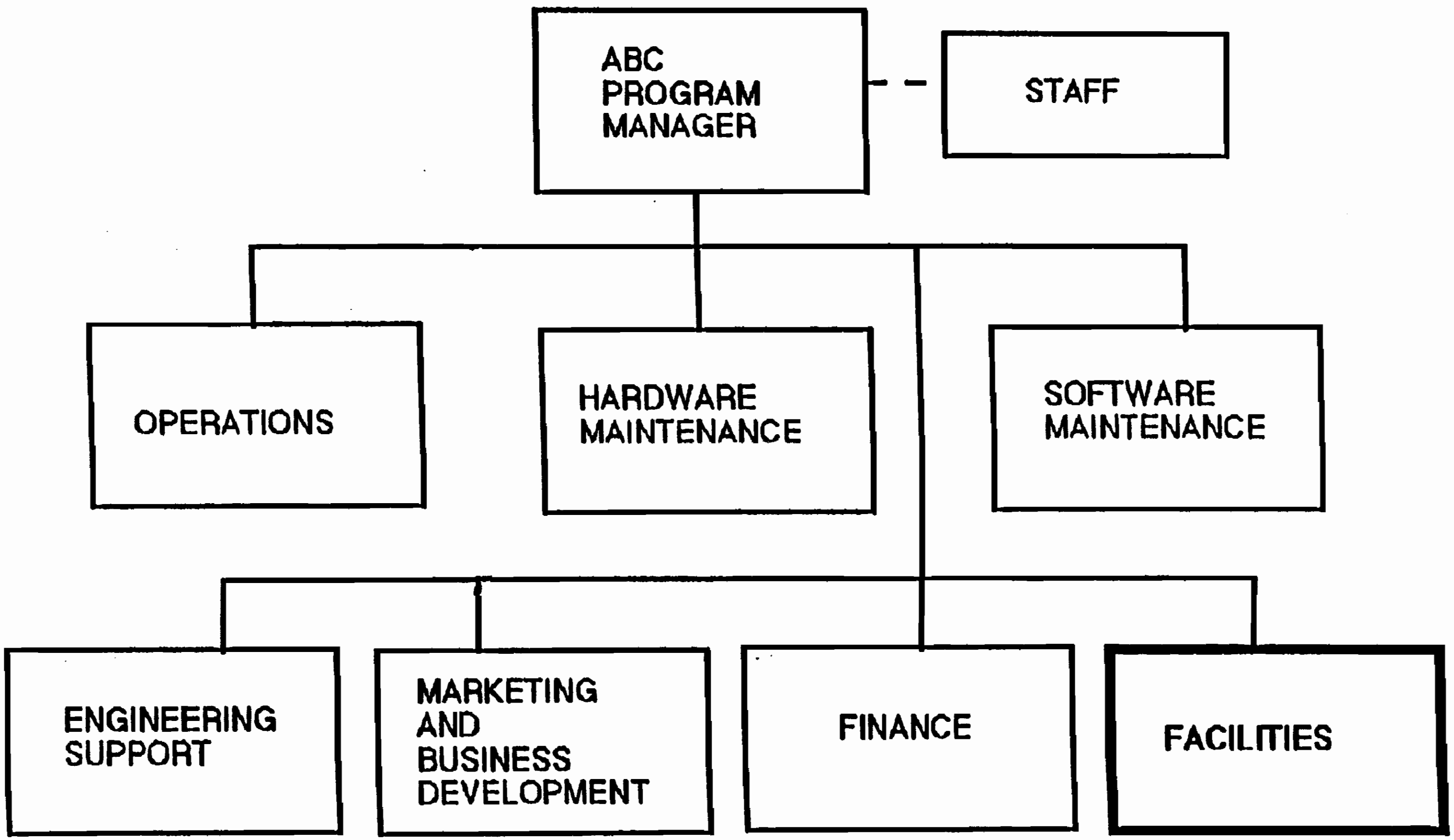


Figure 1. ABC Organizational Chart

1.1 The Facilities Branch

The Facilities Branch supports the other six departments to ensure that the East Windsor facility continues running safely and efficiently, twenty-four hours a day, seven days a week. The Facilities Branch organizational chart is shown in Figure 2. The branch is responsible for four major functions, which include facilities planning, engineering, operations and maintenance, and design. The majority of the work that the Facilities Branch performs is either making a change to an existing facility or constructing a new structure.

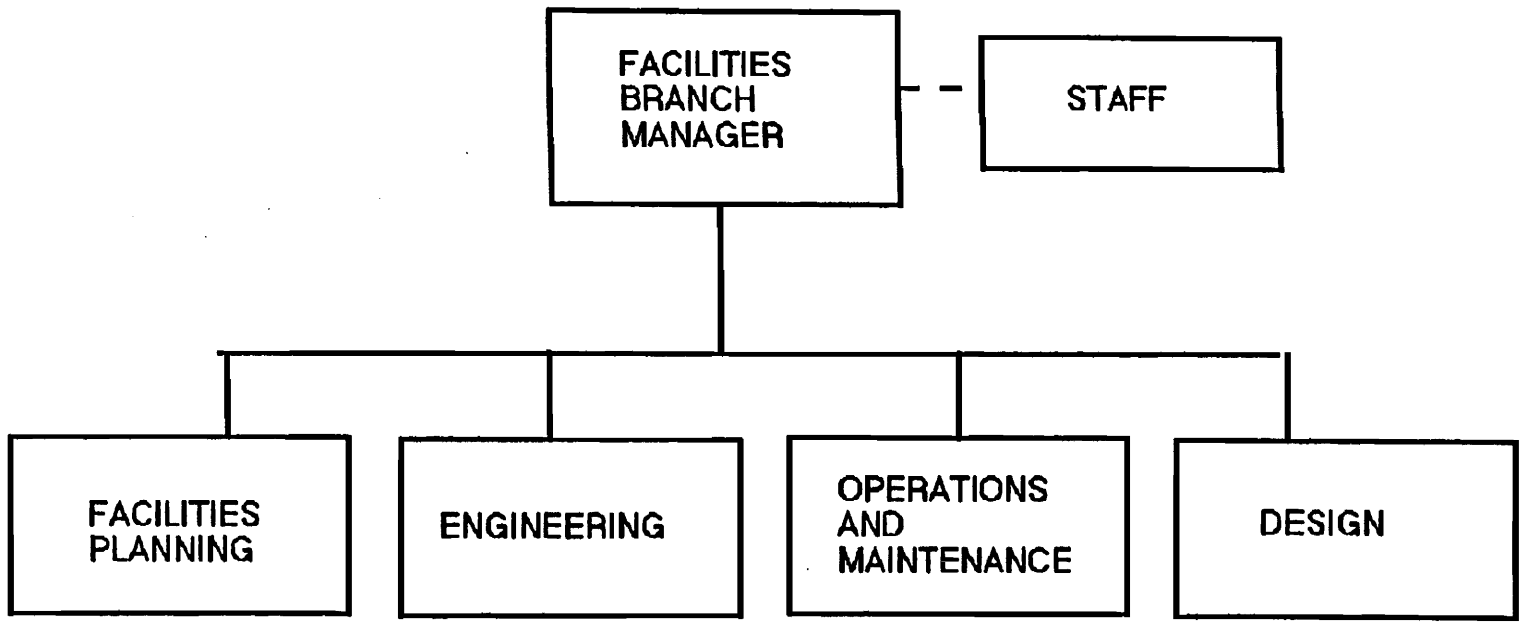


Figure 2. Facilities Branch Organizational Chart.

1.2 The Modification Process

Modifying a facility is required when an occupying group either moves out of the facility or moves to another area within the facility. Another possibility is that an external group moves into the facility. If insufficient room arrangement, size, or services exists for the new occupants, modifications are made to accommodate these changes. Furthermore, when a section of the facility becomes empty because occupants relocate, that section may be altered slightly or radically changed to accommodate new occupants. The requirements of the new tenants must be identified, authority must be granted to make the appropriate changes to the facility, a schedule must be produced, and a budget must be established.

A modification, referred to as a request for change (RFC), is proposed as a pre-RFC concept by the person in authority requesting the change. The Facilities Branch planning committee reviews the RFC to investigate any problems created by the proposed change. If a problem is identified, an action item is produced which tasks the appropriate person to solve the problem. The problem could be cost, schedule, or construction related.

Once the actions are resolved and a suitable solution is found, a Rough Order of Magnitude (ROM) is produced which estimates how much the modification will cost. A formal RFC is written, approved by the Facilities Branch planning committee, and released to the engineering group who will schedule the modification and assign personnel to the project. The RFC is also handed to the design team who will blue-print the modification, make the necessary procurements, perform the construction and verify that the modification meets the specifications required by the occupants.

Continual statusing is performed during the course of the modification. A monthly status meeting is held by the Change Control Board (CCB) to review the modification. If problems in schedule, cost, or feasibility arise, action items are assigned to investigate the problem and recommend a solution. The RFC is then returned to the design group to continue working the design process. Once the design is completed and approved, the RFC is passed to the production team to begin modifying the facility.

The Facilities Branch, in effect, is following a life-cycle approach when processing an RFC through the initial concept and design phases. The pre-RFC concept equates to the definition of need and operations concept. An iterative approach is used to work out any problems with the RFC, similar to various design reviews and trade-off analyses. Options are considered and studies performed to ensure the requirements defined by the RFC are satisfied. Once the formal RFC is approved, a system design is created by the design group. This design is verified and passed to the production team for system development. The RFC process is shown in Figure 3.

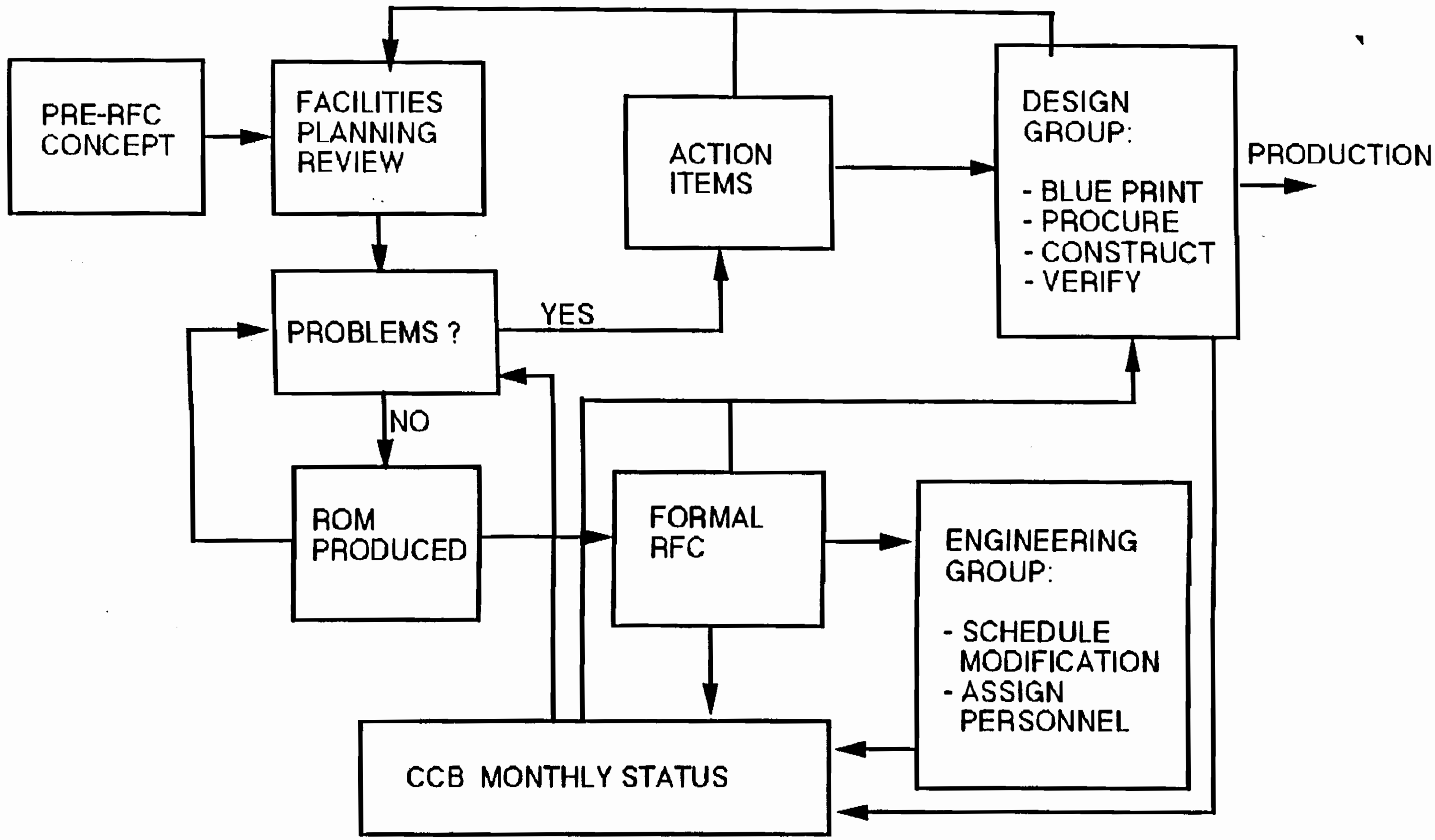


Figure 3. The RFC Process.

1.3 The System Life-Cycle

A system life-cycle approach provides a method for selecting an optimal system for the Facilities Branch's scheduling needs, by identifying the customer's needs, defining requirements, and making the appropriate trade-offs to create the design that best satisfies those needs. Maximizing speed and efficiency are the key factors in selecting a system for the Facilities Branch. Human factors concerns are critical in the selection process because the most cost-effective system for the Facilities Branch is one that is efficient, reliable, and user-friendly.

The development of the Facilities Automated Scheduling Tool (FAST) begins with the identification of need. Once the need is properly defined, system planning determines the specifications of FAST. An initial operations concept and system requirements are determined. Once the requirements are established, research is conducted to analyze the requirements and perform trade-off studies. Military and industrial standards are investigated to find factors that can be incorporated into the design of FAST. Much of the research concentrates on human factors and the human-computer interface (HCI). The emphasis is on finding the proper combination of variables that will satisfy the greatest number of users. However, as this report will reveal, satisfying everyone's needs is impossible; therefore, compromises and trade-offs must be made to produce a system that is at least compliant with the requirements.

Numerous design reviews are held to discuss the design possibilities and the positive and negative aspects of each. Although identification of need, conceptual design, human factors research, requirements definition, functional analysis, HCI trade-off studies, HCI feasibility studies, preliminary design, and detailed design do not constitute the entire system life-cycle, these are the phases that are discussed in this paper. The goal is to examine the human factors requirements of the system and propose a design that will meet these requirements most effectively.

However, as a point of interest, the system life-cycle continues from the design phase to production. Quality control ensures that the highest quality product is developed. Throughout production, testing is performed. Data is collected and analyzed to evaluate the system. Corrective actions are taken if necessary. Once system test is complete, the system is operational. Logistics maintains spare parts and servicing procedures to maintain the system. [5] If a problem arises, the situation is corrected as quickly as possible.

FAST is designed for ten years of operation, beginning in year two and ending in year eleven, with system disposal. The first year involves system planning, research, design, and production. The FAST system life-cycle is presented in Figure 4. A more detailed elaboration of the development functions of the entire system life-cycle is shown in Figure 5.

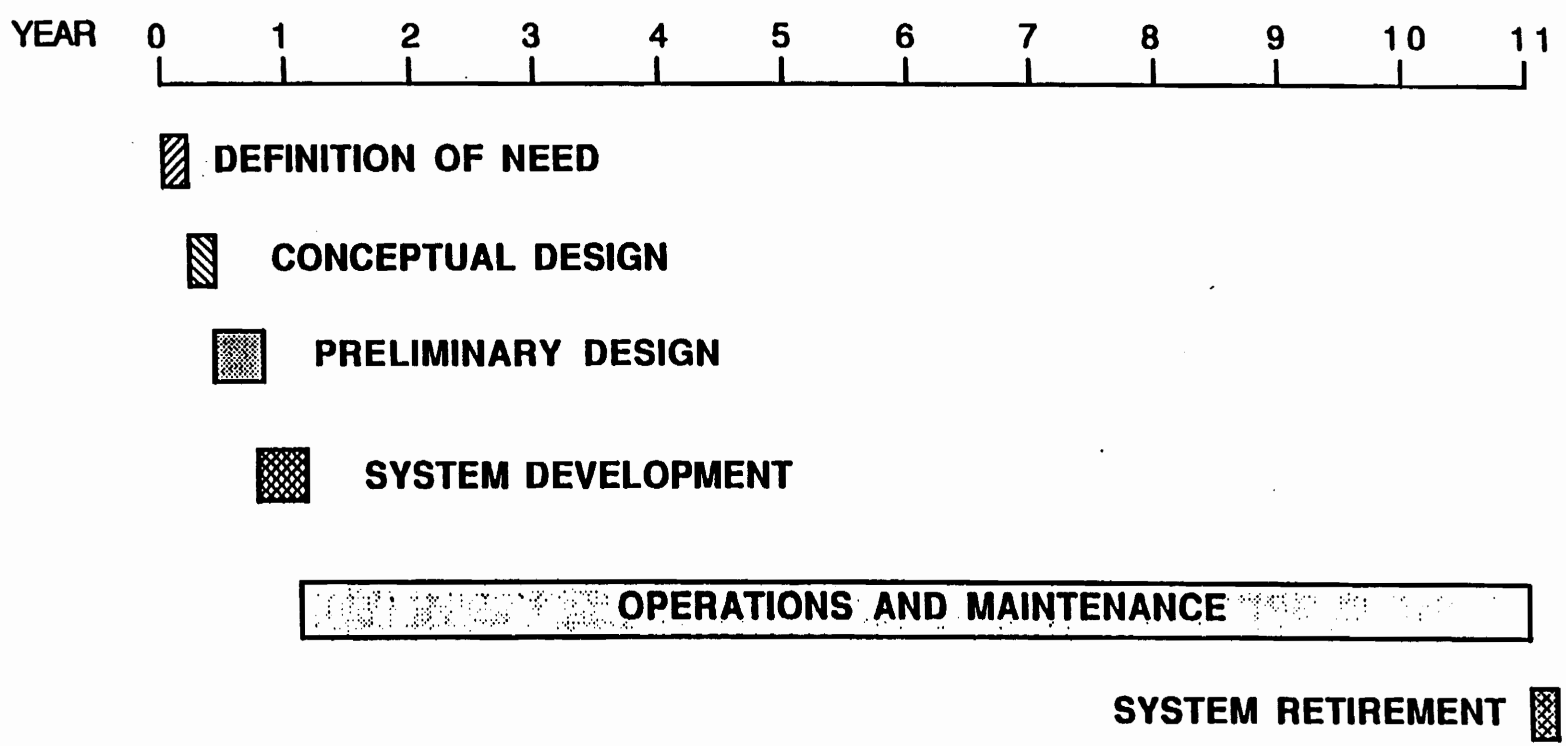
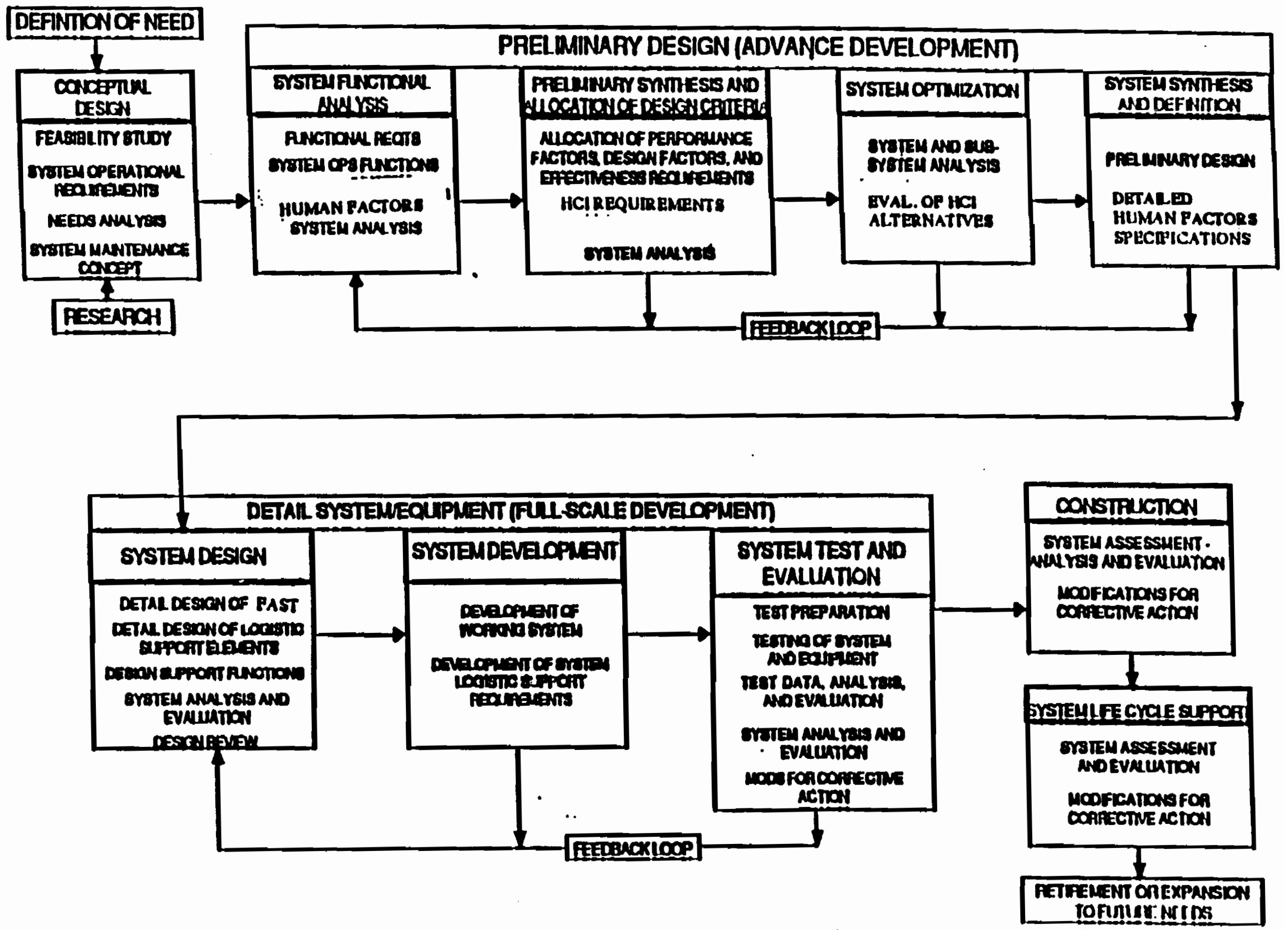


Figure 4. FAST System Life-Cycle.



<u>Figure 5. FAST Development Progression.</u>

Blanchard, B.S., and Fabrycky, W.J., <u>Systems Engineering and Analysis</u>, Prentice-Hall, Englewood Cliffs, NJ, 1981.

1.4 Organization of Report

This report is organized into two major sections. Section one is conceptual design. The customer need is identified and system requirements are defined. Once an initial concept is generated, human factors concerns are examined.

Section two, which consists of most of this report, is dedicated to the HCI element of the system design. Assuming IBM equipment (a hardware procurement contract exists with IBM), an optimal workstation configuration is proposed, including angles and heights of equipment, field of view, and chair positions. Screen displays are recommended for quick and easy information identification and data manipulation. Environmental considerations are also examined to determine the "best" light and heat settings to encourage optimal comfort and performance.

2.0 CONCEPTUAL DESIGN

Conceptual design, the first phase in the system life-cycle, is accomplished through a needs analysis followed by a definition of requirements. By interviewing the Facilities Specialists, the needs of the personnel are identified, and the requirements of the system are determined.

2.1 Identification of Need

The Facilities Branch tracks over 1,000 projects. Approximately 100 new projects are requested each year. The current manual method for maintaining project data is insufficient. One new project takes three weeks to collect and input the necessary data into the system. The Facilities Branch requires the project to be inserted into the system in 15 minutes. Papers are misplaced or lost, making editing and updating current files difficult. No connectivity exists to allow for contingencies so that all linked files are updated simultaneously, resulting in gross inconsistencies. These inconsistencies must be reduced by 99%. Furthermore, the projects are maintained in over twenty file cabinets which are eliminating all free space in the office. The Facilities Branch wants these file cabinets reduced by 80%. Custom reports are required to be generated in one hour's notice. Finally, three data input specialists support the manual project tracking system. A specific requirement by the manager of the Facilities Branch specifies that the system must be automated so that one specialist can perform the duties previously performed by three, thereby enabling the other two to accomplish other important tasks.

Therefore, an automated system is required that allows one operator to quickly and efficiently control and track all modification data. The system must allow the operator to add a RFC to the system, locate an existing RFC for status and updating, delete a RFC, archive a RFC, and/or move a RFC in the schedule. Through the manipulation of data, the operator must be able to generate schedules and reports with little difficulty. FAST is created to accomplish this task!

Although FAST is an automation of the currently manual method of information management, a specific minimum processing speed has not been specified by the Facilities Specialists. Because many of these personnel are novice computer operators, the main concern is the HCI elements of the system. The users want to be comfortable, able to work the system easily, and be more productive in their jobs. If the operators are more satisfied with their job and less stressed about the paperwork they are required to accomplish every day, the job will be more enjoyable, retention of employees will be greater, medical problems will decrease, and the company profits will increase.

2.2 Human Factors Considerations

Human factors, also referred to as ergonomics, [6] focuses on human beings and their interaction with products, facilities, procedures, and environments. The capabilities of humans are matched to the things people use and the environment they live in to provide a safe, comfortable, and productive environment.

The Facilities Branch employs individuals with different backgrounds, training, skills, and attributes. When designing a system the needs of the majority must be considered, so that the largest number of people are satisfied with the system, resulting in higher productivity for the company. Trade-offs must be examined between an automated and a manual system. Different degrees of automation exist to satisfy the customer's needs. Figure 6 is a schematic of the Human-Computer Interface (HCI). Physiological, psychological, and anthropometric (physical dimensions of the human body) all must be considered when designing a comfortable, reliable, and efficient system.

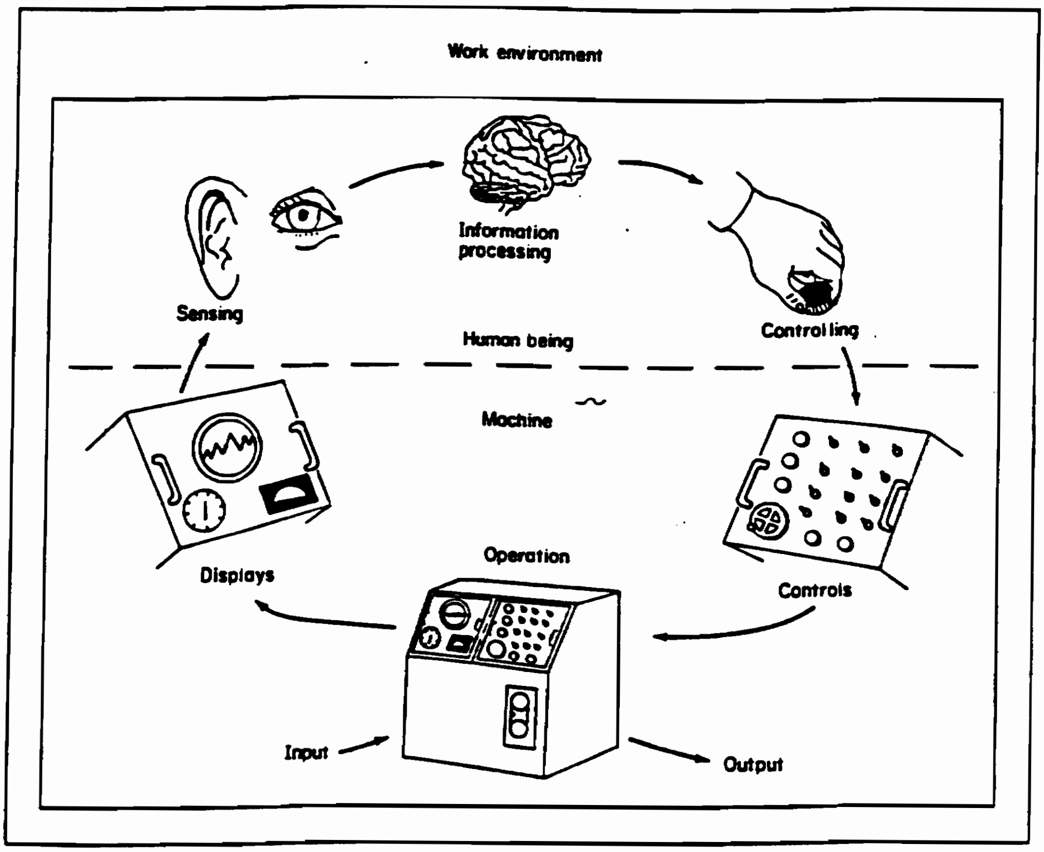


Figure 6. Schematic of the Human-Computer Interface.

Sanders, M.S., and McCormick, E.J., Human Factors in Engineering and Design, McGraw-Hill, New York, NY, 1987.

2.3 Requirements Definition

Through the numerous interviews that were conducted with the Facilities Specialists, the system operating characteristics and requirements are defined. The requirements are portrayed in terms of operational requirements and human factors characteristics.

The following section details the requirements as stated during the interviews of the Facilities Specialists:

a. The system must provide automated information management of facilities modification data.

b. The main menu must appear when logon takes place to allow the desired function to be entered immediately.

c. A quick reference guide must list all the open projects.

d. Links must exist to provide real-time updating to all files.

e. When a new RFC is entered into the system, the RFC number must be inserted into the new project list.

f. When a project file is updated, a *WARNING* flag must appear on the screen indicating that a change has been made.

g. After a RFC has been approved. the entry in the new project list is deleted and inserted in the open RFC list.

h. Sorting of the RFC list must be allowed by begin construction date, RFC name, or RFC number.

i. Scrolling must be provided to allow for viewing of lengthy descriptions and comments.

j. The master schedule must automatically adjust when RFCs are added. deleted, or delayed.

k. Important milestones must be tagged with a special flag.

l. Reports for construction schedules must be quickly and easily generated.

m. Closed RFCs must be archived in a history file.

n. The system must be user friendly.

o. The system must be capable of storing over 1,000 projects per year.

p. Data back-up must be conducted automatically or manually once a week.

q. The system must utilize an open software approach.

r. IBM hardware must be used.

s. Training must be completed in one week by specified system developers.

t. Cost is considered negligible in this report since no hardware or software acquisition is required, and reduction in operator manpower from three individuals to one negates development manpower.

Functional flow diagrams, shown in Figures 7 through 13, portray the operational requirements of FAST. They are designated as top level, first level, second level, and third level, with references linking each level to the next. As the level increases, the functions are expanded to reveal more detail. The lowest level is linked back to the top level to show the looping nature of the different functions. The numbering scheme identifies the different functions and allows the traceability of each of the more detailed functional breakouts to the top level function.

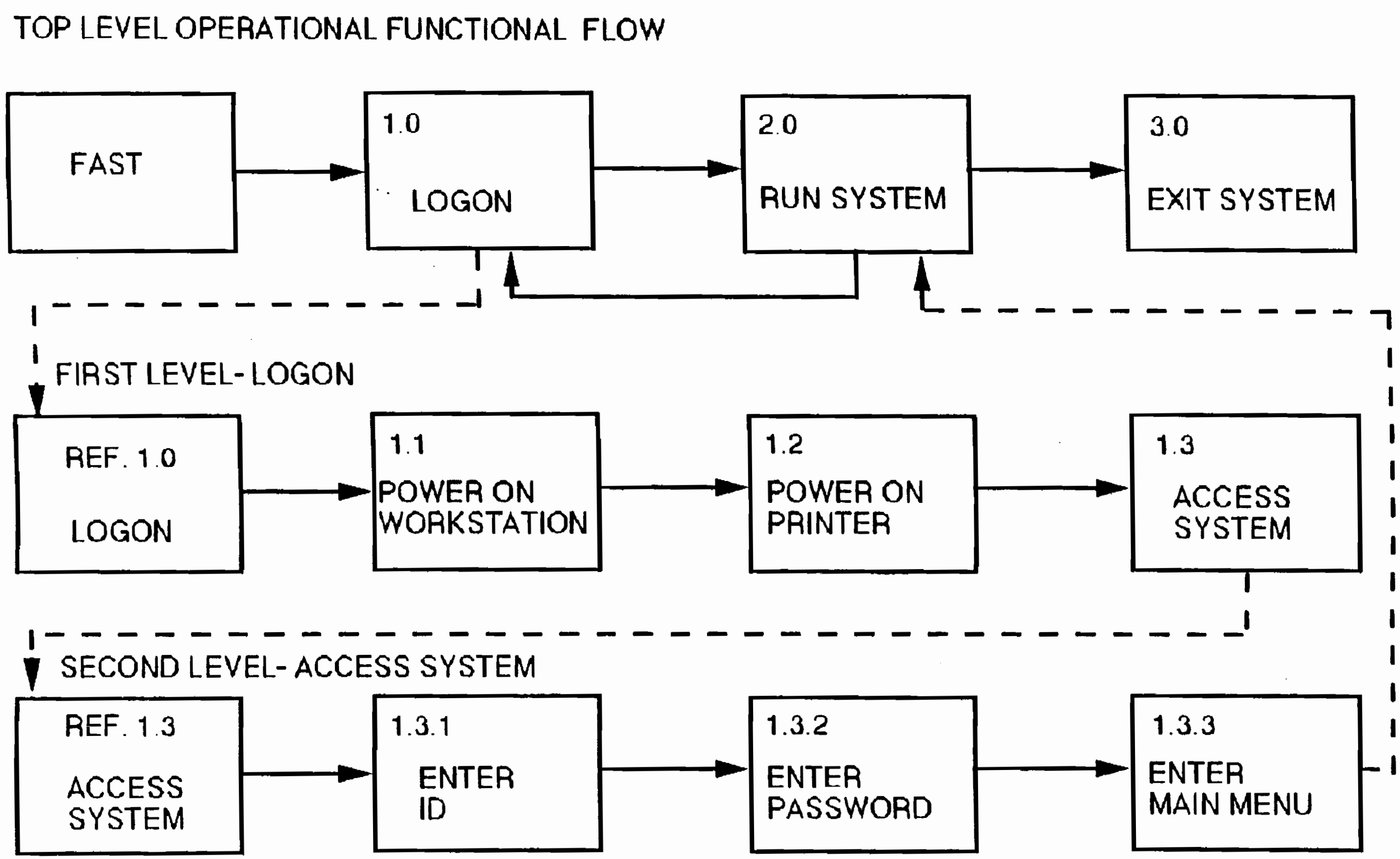


Figure 7. Operational Functional Flow.

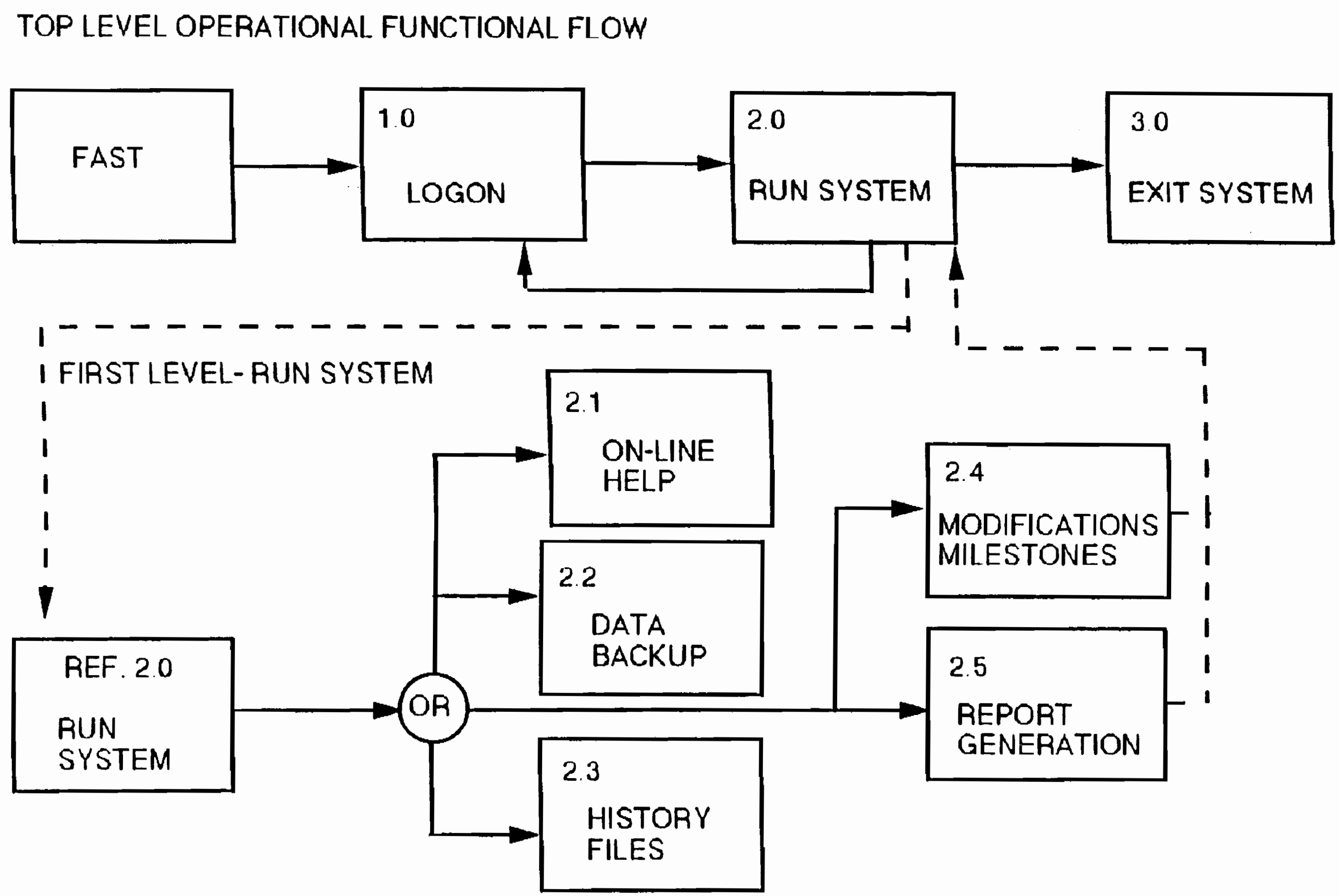


Figure 8. Run System Functional Flow.

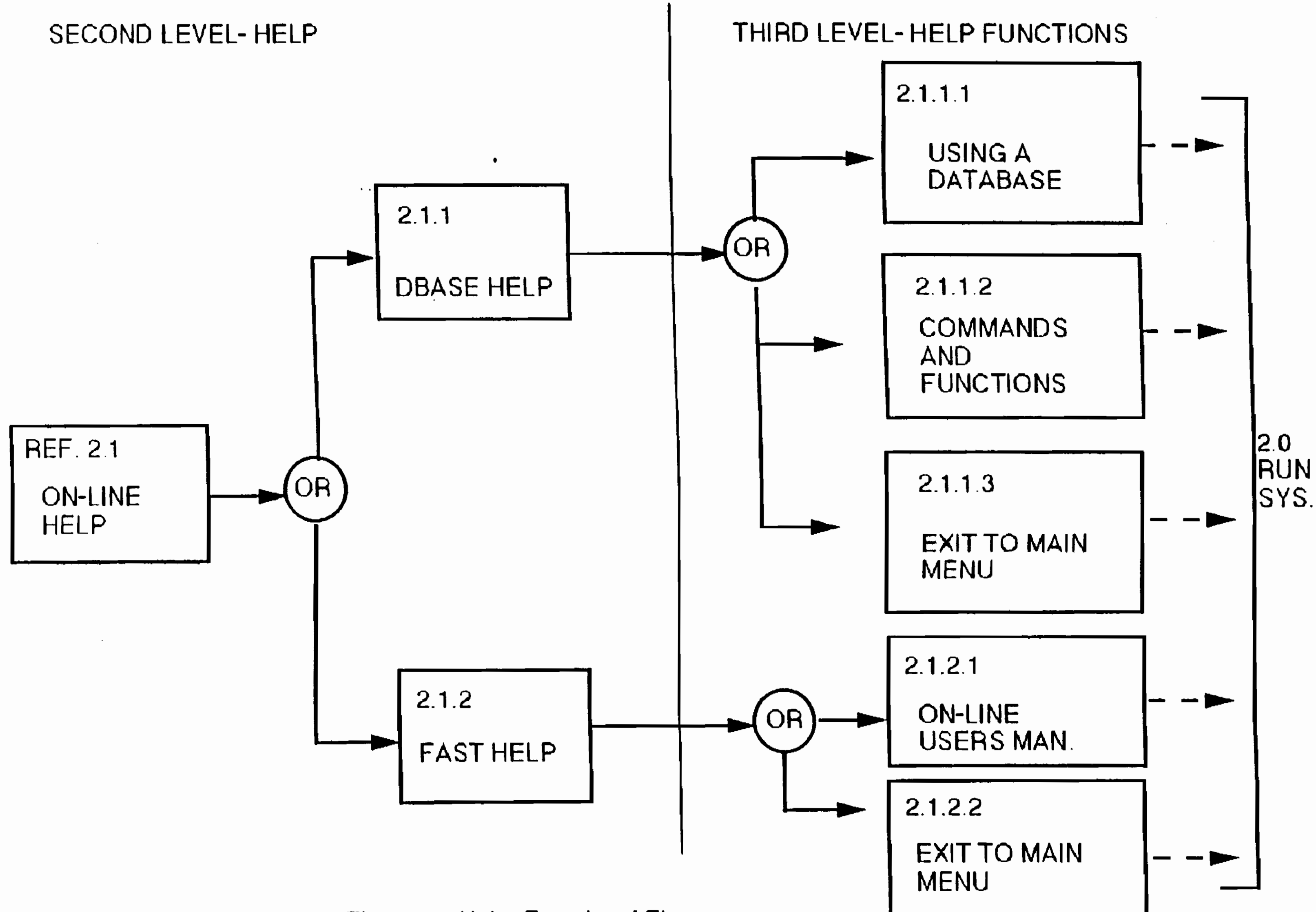


Figure 9. Help Functional Flow.

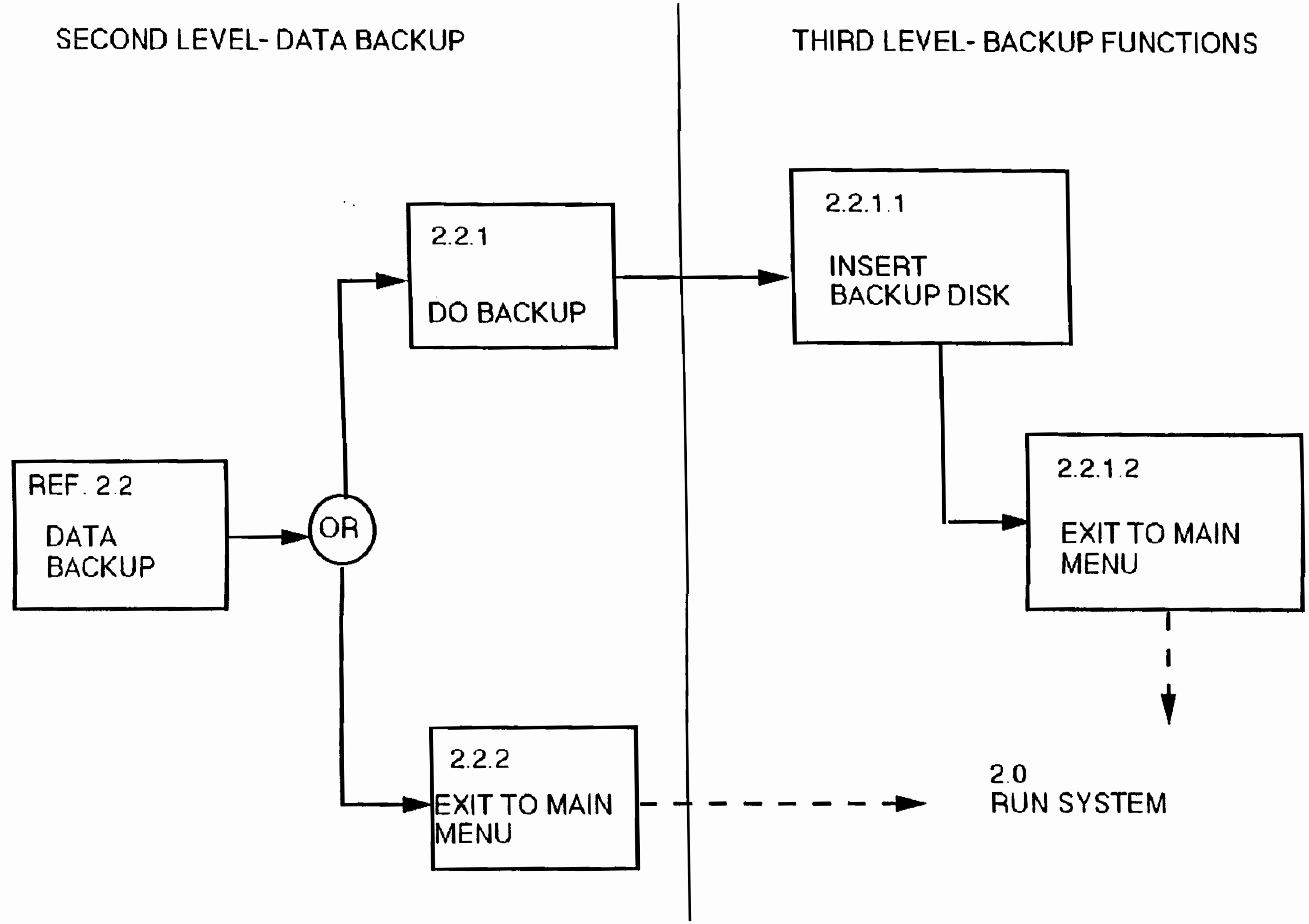


Figure 10. Data Backup Functional Flow.

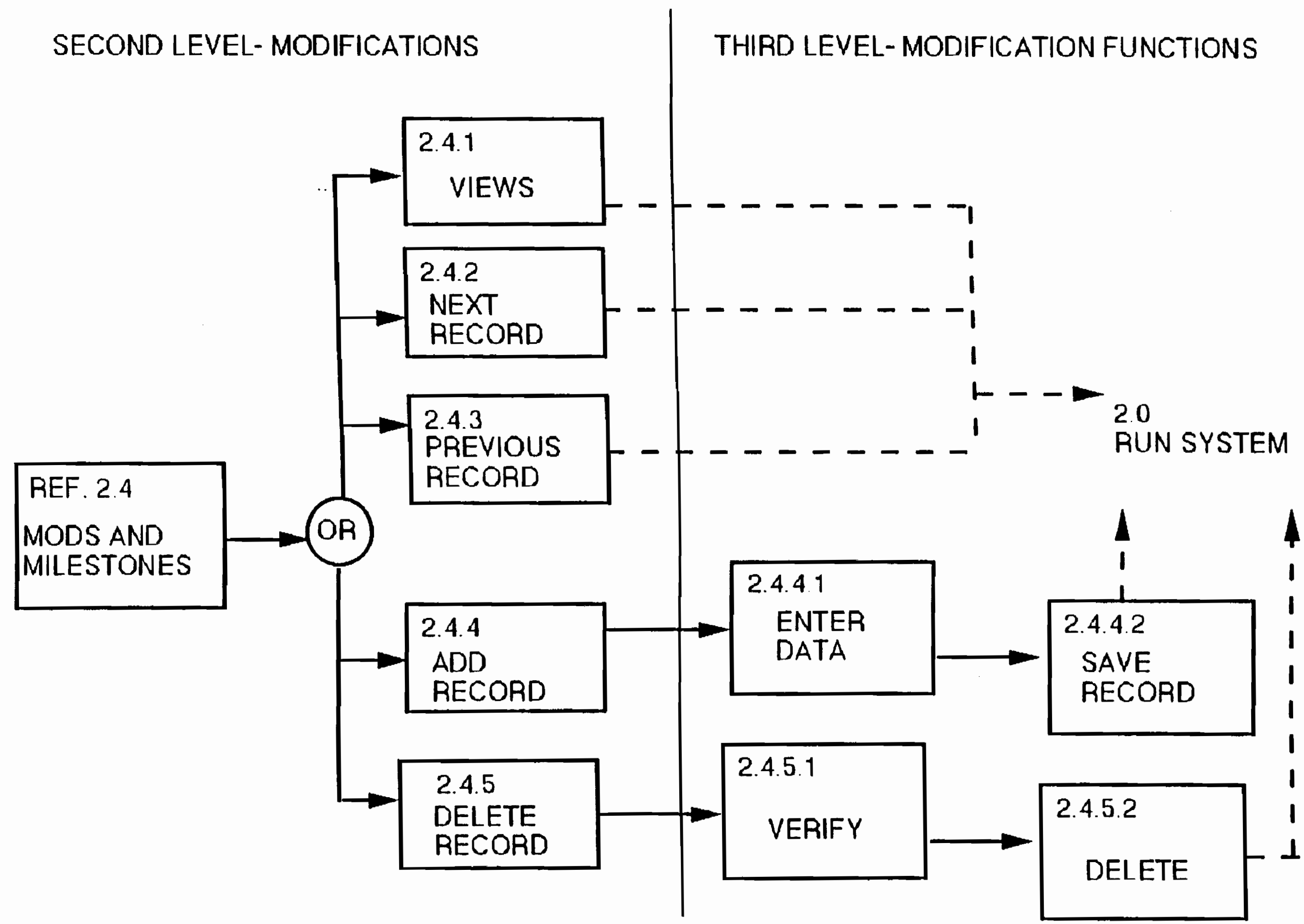


Figure 11. Modification Functional Flow

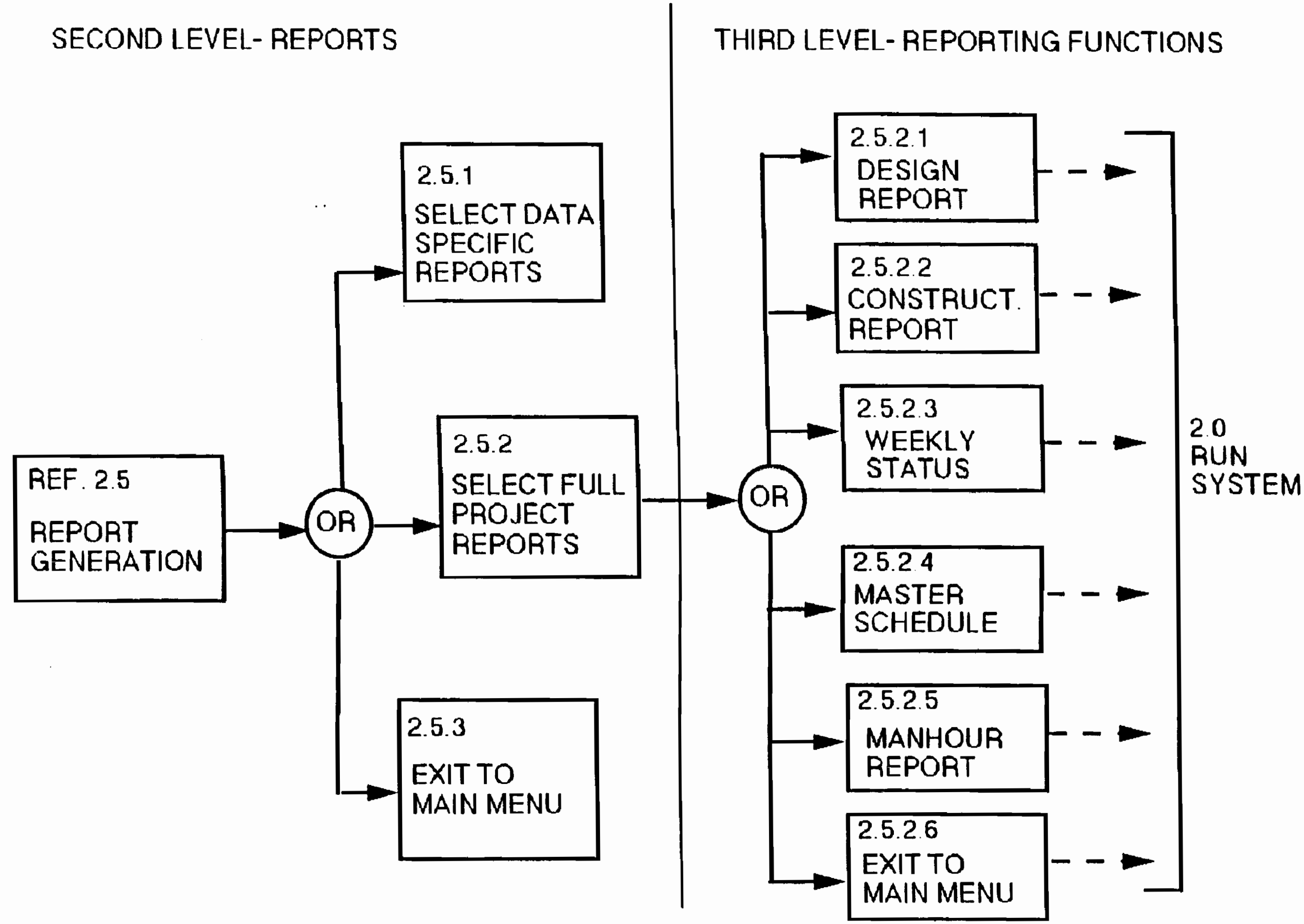


Figure 12. Reporting Functional Flow.

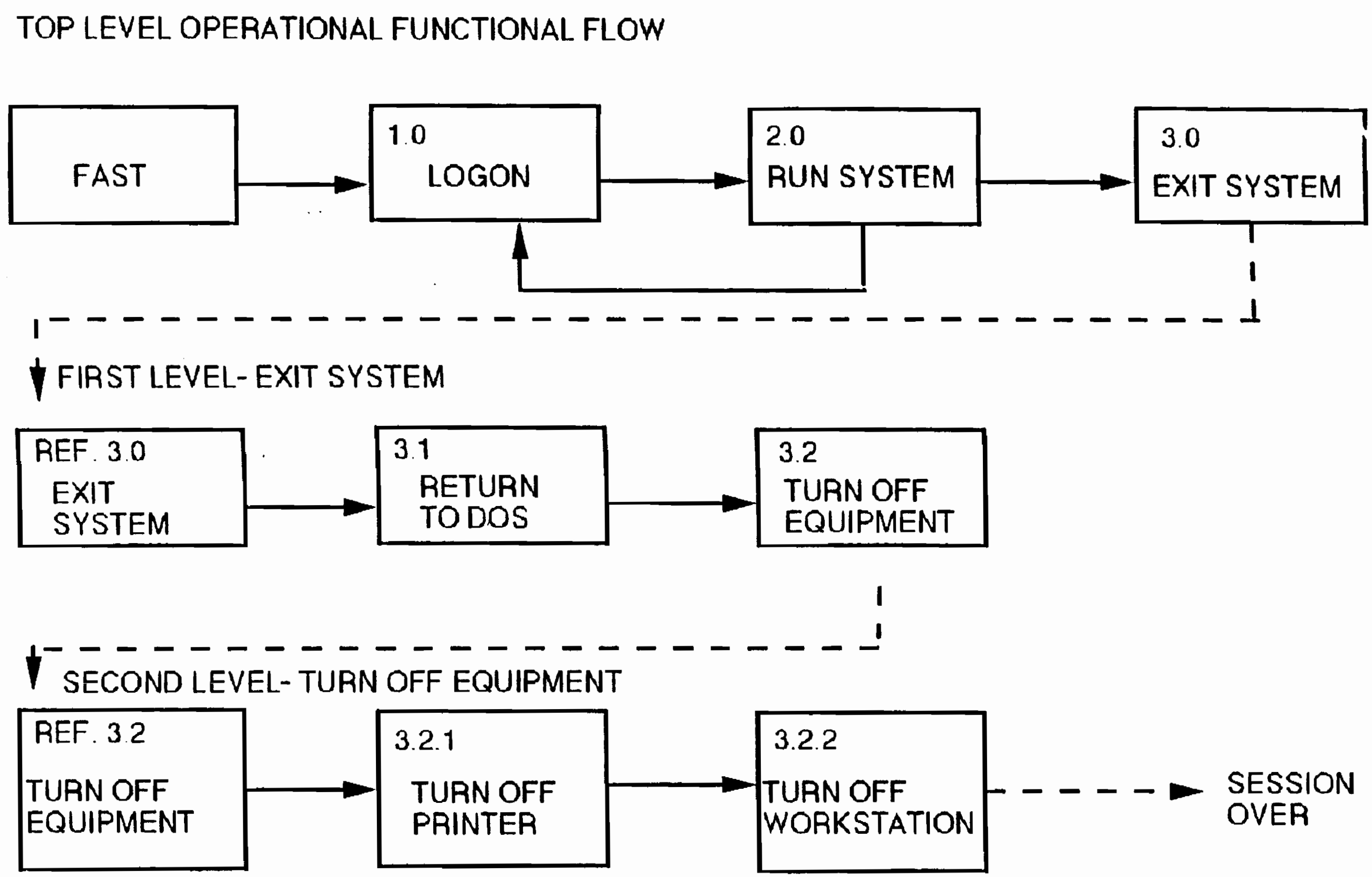


Figure 13. Exit/Logoff Functional Flow

From the functional flow diagrams, which describe *what* is happening as the operator proceeds from one task to the next, operational sequence diagrams (OSDs) are created. OSDs explain *how* the user operates the system, progressing from one function to the next.

For example, referring back to Figure 9, the Help Functional Flow, a more detailed operational sequence diagram explains how the user initiates the help function and proceeds to select the topic of interest. The design of an on-line help function is necessary so that at any point in time, the user can receive assistance if he/she gets into trouble. Waiting for someone to take the time to help, or locating the user's manual among all the other papers and notebooks in the office often requires a couple of hours. By creating the on-line function, the user, within minutes, can hit the designated function key or move the cursor with the mouse to the help function and click.

Once the help function has been initiated, a number of topics can be selected. A list of topics is presented and that topic can be chosen by either cursoring to the appropriate line and clicking with the mouse button or typing in the topic on which help is desired. If a particular topic is not listed, the operator can simply type in a key word and the computer will be able to search the list and match the word with the topic area closest in meaning. Figure 14 pictures the OSD for the on-line help function.

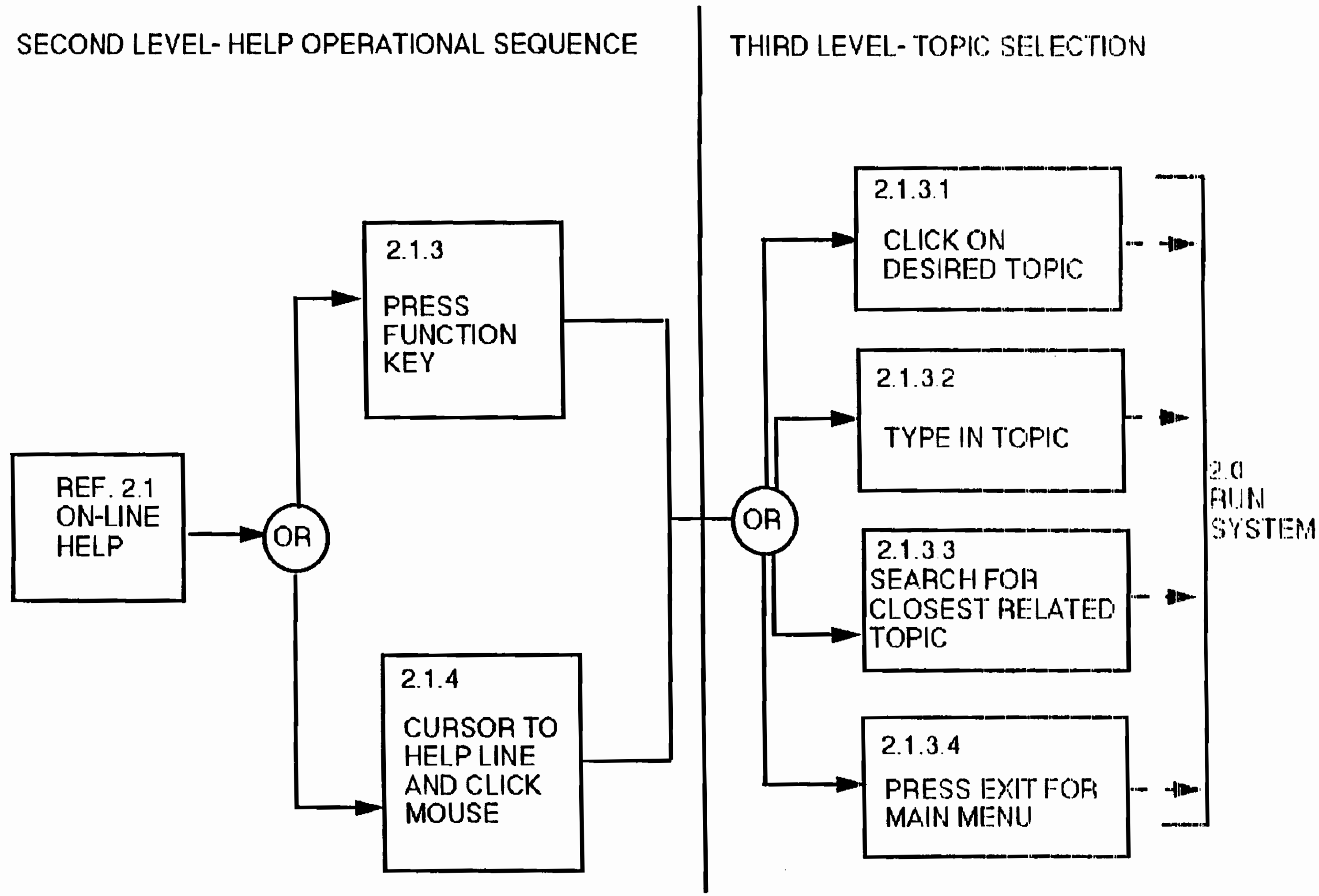


Figure 14. Help Operational Sequence Diagram

3.0 HUMAN-COMPUTER INTERFACE

Computers today are used for a broad range of applications. User interface design guidelines can not be applied usefully in every situation. Some computers may only communicate with other computers, and not directly with humans, while others must interface regularly with the human element.

When there is no user interface, then no user interface design guidelines are needed. However, the computer systems that do interface with humans must be designed to help those users perform specific tasks. Applications of such systems range from relatively simple data entry and retrieval to more complex monitoring and control tasks.

FAST is a system which is designed to meet the specific needs of the Facilities Specialists, the users of the system. Therefore, the Human-Computer Interface (HCI) is the most critical element in the design of FAST. If the workstation configuration is not comfortable, the system easy to learn, and user-friendly, the performance of the Facilities Specialists will be much less than optimal, and they may neglect to use FAST and continue to work using their own tedious manual methods.

3.1 Design Guidelines

As experience has been gained in the use of on-line computer systems, some experts have attempted to set standards ("rules of thumb") for HCI design. Military agencies began requiring regulations and documentation of these standards in various MIL-STD reports. [9] More recently, industrial and commercial organizations, and the general community of people who develop and use information systems, are interested in HCI guidelines. [1] Most organizations are utilizing current human factors standards to design systems that comply with the requirements defined by the customer.

In order to satisfy the requirements of the Facilities Branch, research has revealed various design characteristics that can serve as guidelines for FAST. Only guidelines that are relevant to the FAST application are discussed in this report. Some of the guidelines have been "tailored" to address the specific design requirements of FAST. By tailoring industry and military guidelines for the HCI element of FAST, the optimal system is designed to meet the information management needs of the Facilities Branch.

3.2 Anthropometry and Work Space Design

Anthropometry deals with the measurement of the dimensions of the human body. In designing FAST, the user population with its varying anthropometric dimensions must be considered in the work space design. This design determines human comfort, efficiency, and ultimately, operator performance. The guidelines and standards of the American National Standards Institute (ANSI) are tailored to address the requirements of the Facilities Branch. [1]

The console design considerations account for the extreme anthropometric range extending from the 95th percentile male to the 5th percentile female. This range means that 95% of the male population falls *below* the upper limit of the range and 95% of the female population falls *above* the lower limit of the range. This range is chosen because it will satisfy the majority of individuals who will use FAST, and qualified employees will not have to be turned down because of physical characteristics. These dimensions are presented in Table 1.

Table 1. Anthropometric Ranges for Men and Women.

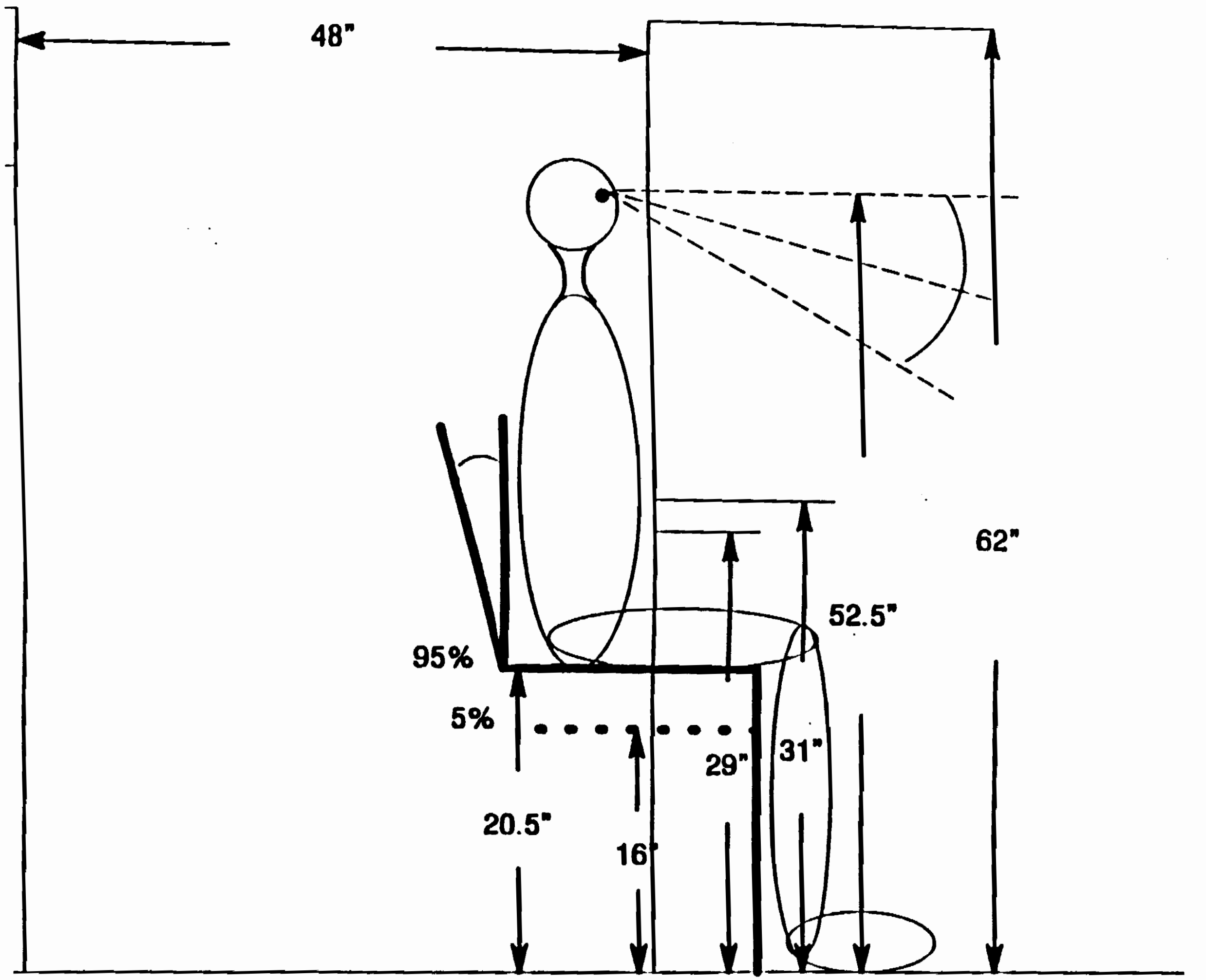
Body feature	Dimension, in						Dimension, cm*					
	Male, percentile			Female, percentile			Male, percentile			Female, percentile		
	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th
1 Height	63.6	68.3	72.8	59.0	62.9	67.1	162	173	185	150	160	170
2 Sitting height, erect	33.2	35.7	38.0	30.9	33.4	35.7	84	91	97	79	85	91
3 Sitting height, normal	31.6	34.1	36.6	29.6	32.3	34.7	80	87	93	75	82	88
4 Knee height	19.3	21.4	23.4	17.9	19.6	21.5	49	54	59	46	50	55
5 Popliteal height	15.5	17.3	19.3	14.0	15.7	17.5	39	44	49	36	40	45
6 Elbow-rest height	7.4	9.5	11.6	7.1	9.2	11.0	19	24	30	18	23	28
7 Thigh-clearance height	4.3	5.7	6.9	4.1	5.4	6.9	11	15	18	10	14	18
8 Buttock-knee length	21.3	23.3	25.2	20.4	22.4	24.6	54	59	64	52	57	63
9 Buttock-popliteal length	17.3	19.5	21.6	17.0	18.9	21.0	44	50	55	43	48	53
10 Elbow-to-elbow breadth	13.7	16.5	19.9	12.3	15.1	19.3	35	42	51	31	38	49
11 Seat breadth	12.2	14.0	15.9	12.3	14.3	17.1	31	36	40	31	36	43
12 Weight†	120	166	217	104	137	199	58	75	98	47	62	90

†Weight give in pounds (first six columns) and kilograms (last six columns.).
*Centimeter values rounded to whole numbers.
Source: U.S. Public Health Service, 1965.

Other considerations for work space design include the work surface, chair dimensions, and room settings. Adequate space for reading and writing, peripherals, and extra storage space are required for greatest flexibility. Adjustable chairs are needed to satisfy the different sitting positions of individuals and allow the greatest mobility. Variable lighting, temperature, and appealing room aesthetics are important for reducing fatigue and stress.

3.2.1 Optimal Working Dimensions

Through careful consideration of these human factors, Figure 15 pictures the work space limits that apply to the majority of operators. The 95th percentile male sitting height is presented in bold (20.5"), with the dotted line represents the 5th percentile female sitting height (16"). [3] The standard desk height is between 29" for women and 31" for men. The top of the console should be no higher than 52.5" for see-over capability, and an overhead shelf height should be no higher than 62" for accessibility. Finally, the distance from the desk to the rear wall should be no shorter than 48" to provide enough flexibility for movement into and out of the work space. [9]



<u>Figure 15. Work Space Limits For Men and Women.</u>
US Military Standards, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities", MIL-STD-1472D, 1981.

The desired line of sight for optimal performance is 15 degrees below horizontal and straight ahead. Optimum field of view is 15 degrees right, left, up, and down which is the area visible without moving the eyes. Good field of view is 35 degrees right, left, up, or down, which is the area visible with eye movement only. The range outside the good field of view is the fair field of view which is visible with the head movement only. Finally, additional field of view is available by combining head and eye movement. Figure 16 pictures the recommended field of view. [9]

Figure 17 represents the optimal viewing zone based on the recommended field of view angles and a distance of 20" between the user and the screen. A 10.5" square represents the optimal viewing zone, which is located just below the horizontal and straight ahead. Beyond this optimal zone, a 20" x 23" good viewing zone exists. Finally, just beyond this zone lies the 29.5" x 35" fair viewing zone. [9] All of the information that must be viewed by the operator should be located within these viewing zones, with the most important information in the optimal viewing zone. These fields of view and viewing zones are important considerations in the design of FAST.

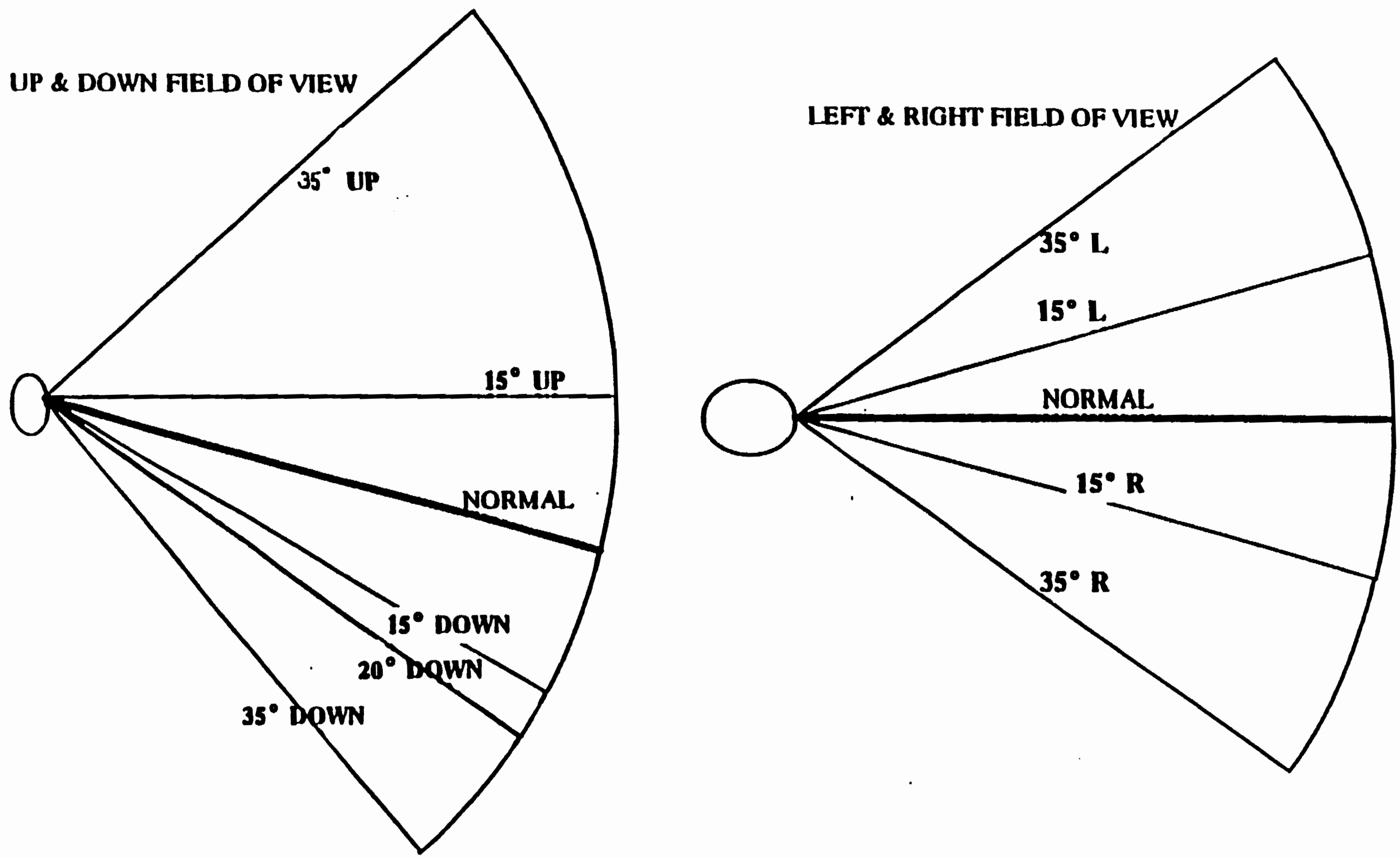
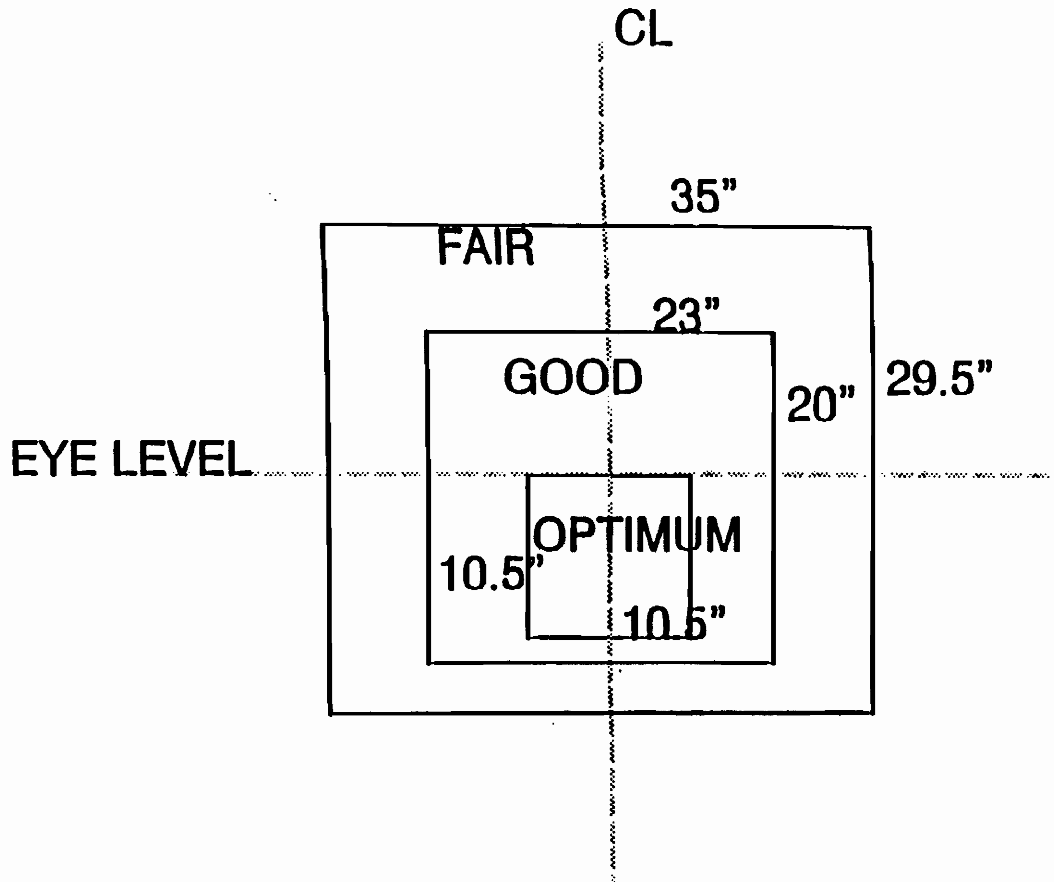


Figure 16. Recommended Field of View.

US Military Standards, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities", MIL-STD-1472D, 1981.



<u>Figure 17. Recommended Viewing Zone.</u>

US Military Standards, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities", MIL-STD-1472D, 1981.

For optimal viewing, the workstation monitor should be placed in the optimal line of sight. The IBM color monitor that is owned by the Facilities Branch and must be used in the FAST system has a 15" X 11" screen, a 19" X 19" outside dimension, swivel capabilities, and an anti-glare screen. The size of the screen allows large files to be displayed on the screen simultaneously, while allowing the operator to view over the screen. The swivel capabilities allow other users or second operators to view the screen as well as the primary operator. Figure 18 shows optimal placement of the monitor.

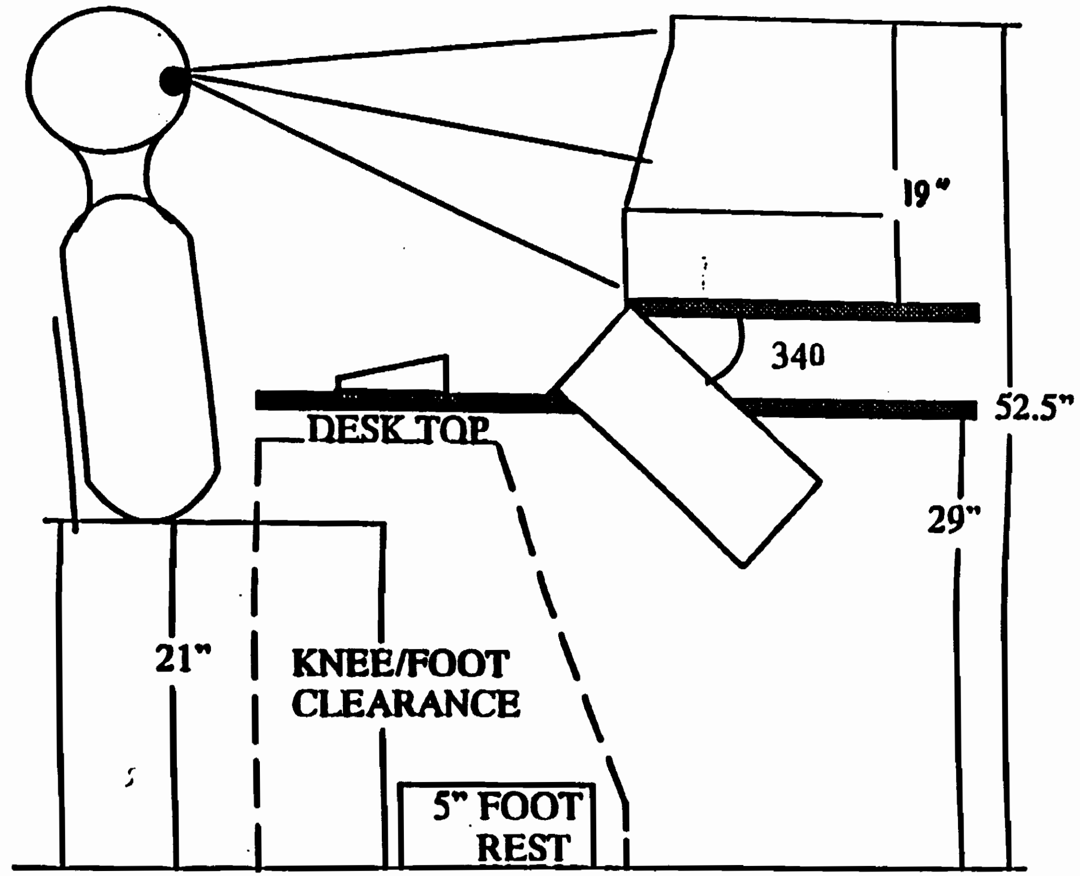
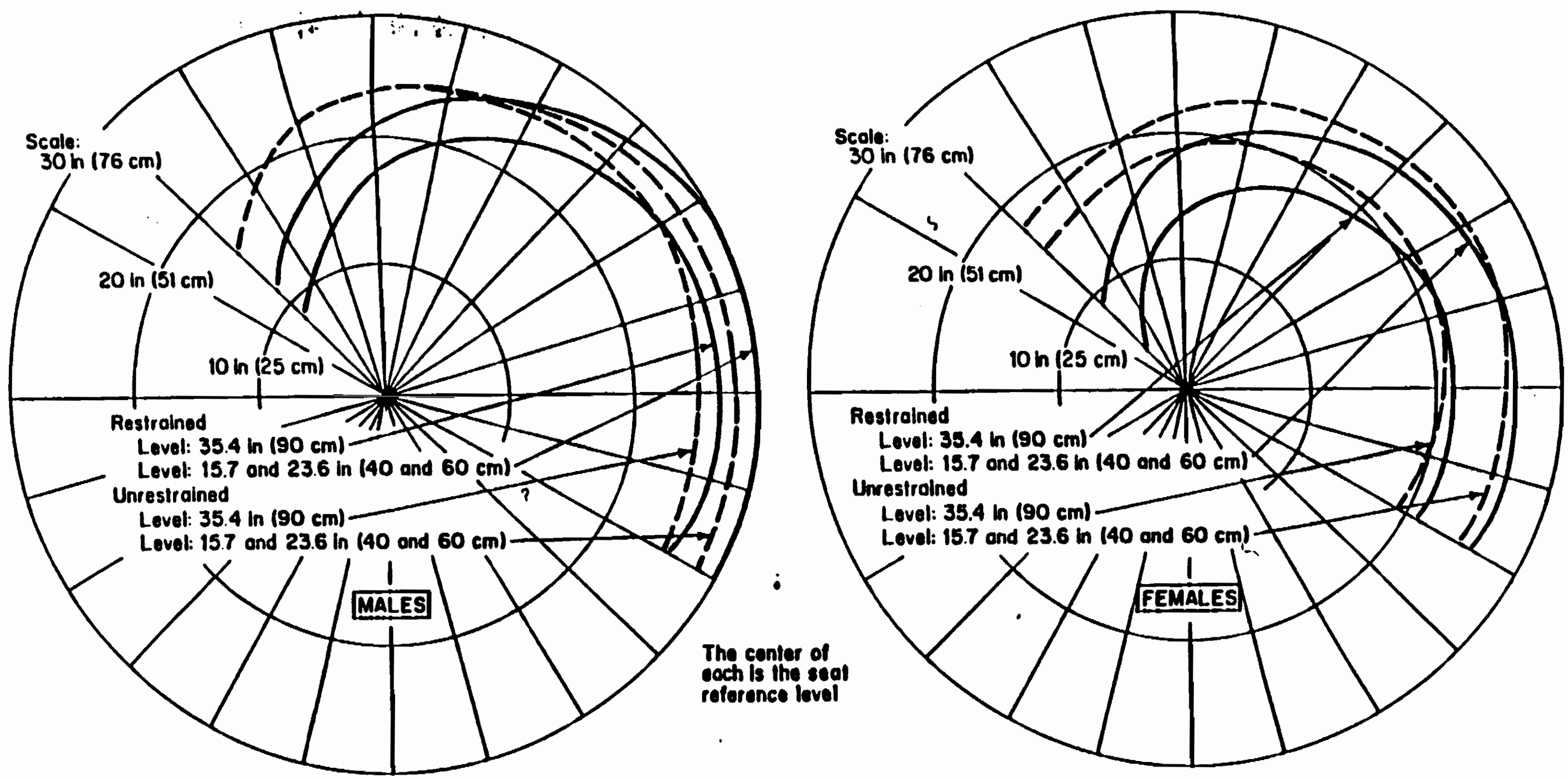


Figure 18. Optimal Monitor Placement.
US Military Standards, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities", MIL-STD-1472D, 1981.

3.2.2 Work Space Envelope

One of the most important human factors concerns in the development of FAST is the work space envelope, which is the space surrounding the operator. [6] The limits of the work space envelope for the seated operators of FAST are determined by their functional arm reaches. The reaches for the 5th percentile male and female are shown in Figure 19. By considering these reaches, which incorporate 95% of the population, the work space envelope is designed so the operator can access the keyboard, disk drives, mouse, and printer without excessive strenuous movement.

The monitor and keyboard are placed directly in front of the user, the printer and other peripherals are placed on the left panel, and the right panel remains open for writing and reading material, since most users are right-handed. The panels should all be about three feet long which enables most operators to reach anything on any of the panels without getting up from the seat. Figure 20 pictures the standard horizontal wrap-around console configuration which is recommended in the design of FAST.



<u>Figure 19. Functional Arm Reaches for Men and Women.</u>

Sanders, M.S., and McCormick, E.J., <u>Human Factors in Engineering and Design</u>, McGraw-Hill, New York, NY, 1987.

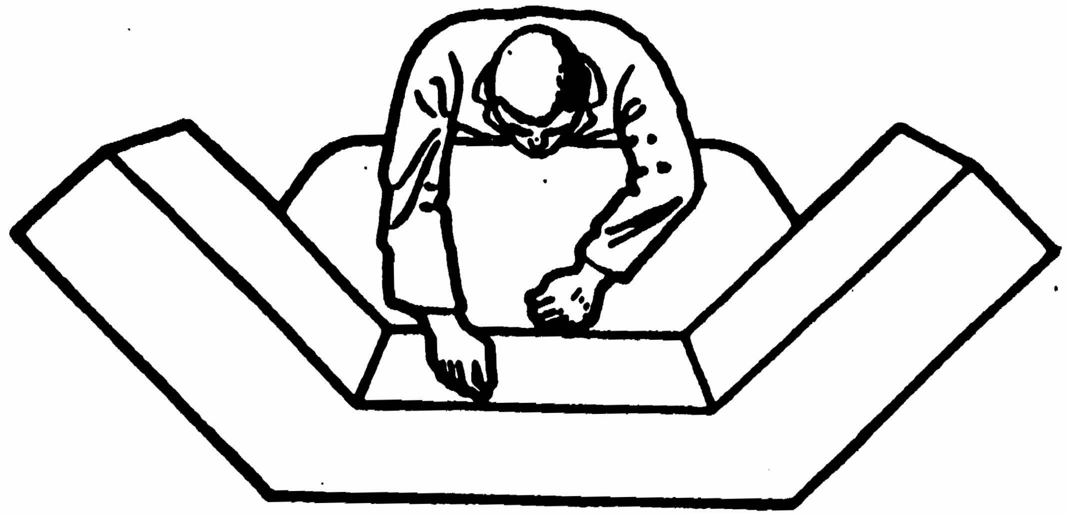


Figure 20. Wrap-Around Console.

"Second TDRSS Ground Terminal Human Factors Design Review", GE Aerospace, General Electric Company, Valley Forge, PA, 1990.

3.2.3 Seating Considerations

The chair position can not be overlooked as an important human factors concern for operator comfort during long periods of system operation. The seat must have a full range of adjustable features to allow the greatest flexibility of motion. Optimal seat height is 15" to 20" with a back rest, lumbar support, and arm rests.[6]

Lumbar (lower section of the spine) support forces the operator into the lordotic posture. In the lordotic posture, the back is bent forward (ie. concave) as when the back is arched backward. This minimizes pressure between the vertebrae and allows the operator more comfort to sit for longer periods of time. The angle of the back rest should be adjustable from 10-30 degrees from the vertical, the back rest height should be a minimum of 9", the seat back angle should be adjustable from 100-120 degrees, and the arm rest height should be about 10" from the seat. [6]

Furthermore, the width of the seat cushion is important to provide the proper padding, comfort, and fit for the operators. Arm rest width should be a minimum of 2", seat width should be 18-19", and backrest width should be a minimum of 14" to provide for 95% of men and women to serve as operators of the system. [6] These recommended chair design dimensions are based on current, available industry standards and are pictured in Figure 21.

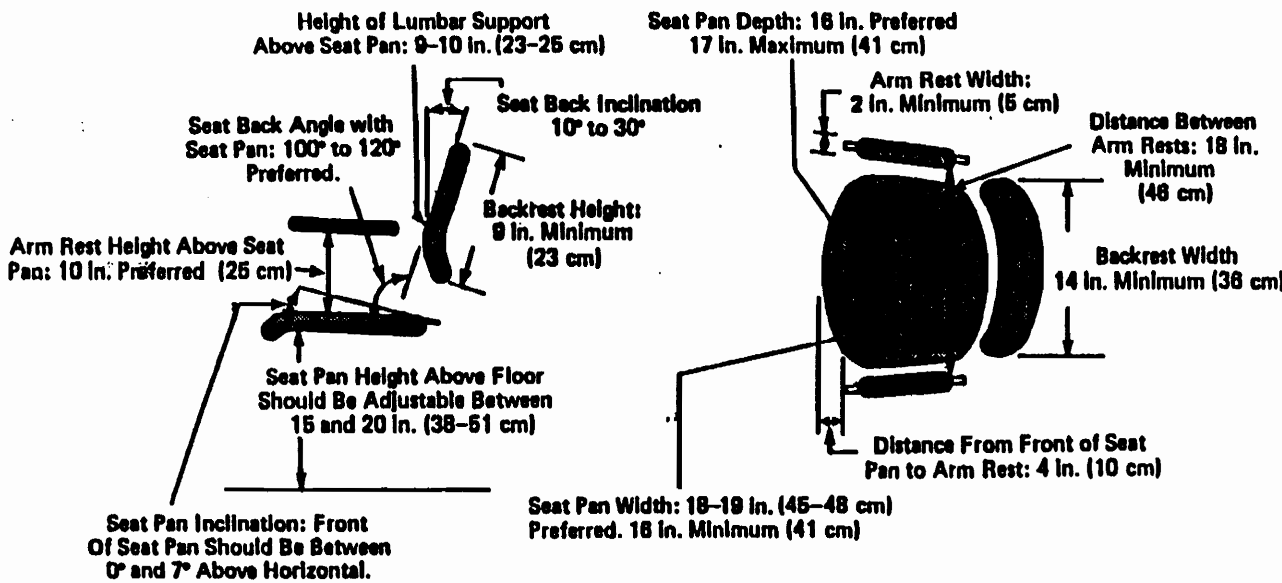


Figure 21. Recommended Chair Design Dimensions.

AT&T Bell Laboratories, Video Display Terminals, Short Hills, NJ, 1983.

3.3 Data Entry

Data can be entered into computers in a variety of ways. Users might designate position or direction by pointing at a display. Users might enter numbers, letters, or more extended textual material by keyed inputs, or in some application by spoken inputs. Data might be keyed into displayed forms or tables, into constrained message formats, or as free text. In graphic interaction, the user might draw pictures or manipulate displayed graphic elements. These different types of data entry all merit consideration for FAST.

The computer also plays a role in the data entry process, guiding users who need help, checking data entries to detect errors, and providing other kinds of data processing aids. Design objectives include minimal entry actions by the user, minimal memory load on the user, on-line help capability, exit from any screen, compatibility of data entry and data display, and flexibility for user control of data entry.

3.3.1 Data Entry Guidelines

The following list details guidelines for data entry: [8]

a. The user should not have to enter any particular data element more than once.

b. Primary data should appear on the main part of the screen.

c. Keyed entries should be displayed stroke by stroke.

d. Delays in displayed feedback should not exceed 0.2 seconds.

e. Delete and insert actions should enable changes in previous entries to be made.

f. The user should take an explicit ENTER action to initiate processing of entered data, not as a result of some other action.

g. All functions should be properly labeled for clear identification.

h. All changes should be flagged with a WARNING to indicate that these changes will be saved.

i. Data entry items should not exceed 5-7 characters.

j. Prompting should precede a request for data entry.

k. Upper and lower case entries when selecting a menu choice should be treated as equal.

l. Single and multiple blanks should be treated as equivalent.

m. The cursor should maintain a stable position unless an explicit action is taken to move the cursor position.

n. Position designation controlled by the cursor should also be handled by the keyboard.

o. Function keys such as "HOME" should be enabled to assist in quick retrieval and identification of data.

p. The display capacity should be adequate to support efficient performance of text entry/editing tasks.

q. The display should allow more than one file to be opened simultaneously.

r. DELETE actions should have a second confirmation.

3.3.2 Keyboard Layout

Because of hardware constraints (the system must operate on previously procured IBM hardware), data entry into FAST must be accomplished through a keyboard. Therefore, standardization of the keyboard layout is an important HCI concern.

The speed and accuracy of entering alphanumeric information through a keyboard is dependent on the quality of the data presented to the operator. Greater clarity and legibility of data increases the speed and accuracy of the data entry. Speed and accuracy will be greater if the operator is familiar with the format of information, upper and lower-case characters are used, and long strings of characters are separated into chunks.

Most keyboards are sequential, meaning that the individual characters are entered in a specific sequence, as opposed to chord keyboards which require simultaneous activation of two or more keys. ANSI recognizes two acceptable layouts for the sequential keyboard- the QWERTY and the Dvorak Simplified Keyboard. [6]

The QWERTY is the older and more common of the two keyboards. The most commonly used keys are delegated to the weakest and slowest fingers. It was intentionally designed this way to slow down the rate of keying because operators were entering information faster than the machine could handle. With computer processing time improvements, rate of data entry is no longer a concern. Therefore, the Dvorak Simplified Keyboard was created. [6]

The main difference is that the most frequently used keys are activated by the strongest fingers. The arrangement of the keyboard may improve data entry speed by 10-20%, with less hand and finger fatigue. [6] However, since the existing computers owned and operated by the Facilities Branch already have a QWERTY keyboard, this layout will be adopted for FAST. The advantages of replacing the QWERTY keyboards with the Dvorak Simplified Keyboards do not outweigh the costs required to purchase the new hardware and retrain the users. Figure 22 displays the two accepted keyboard formats.

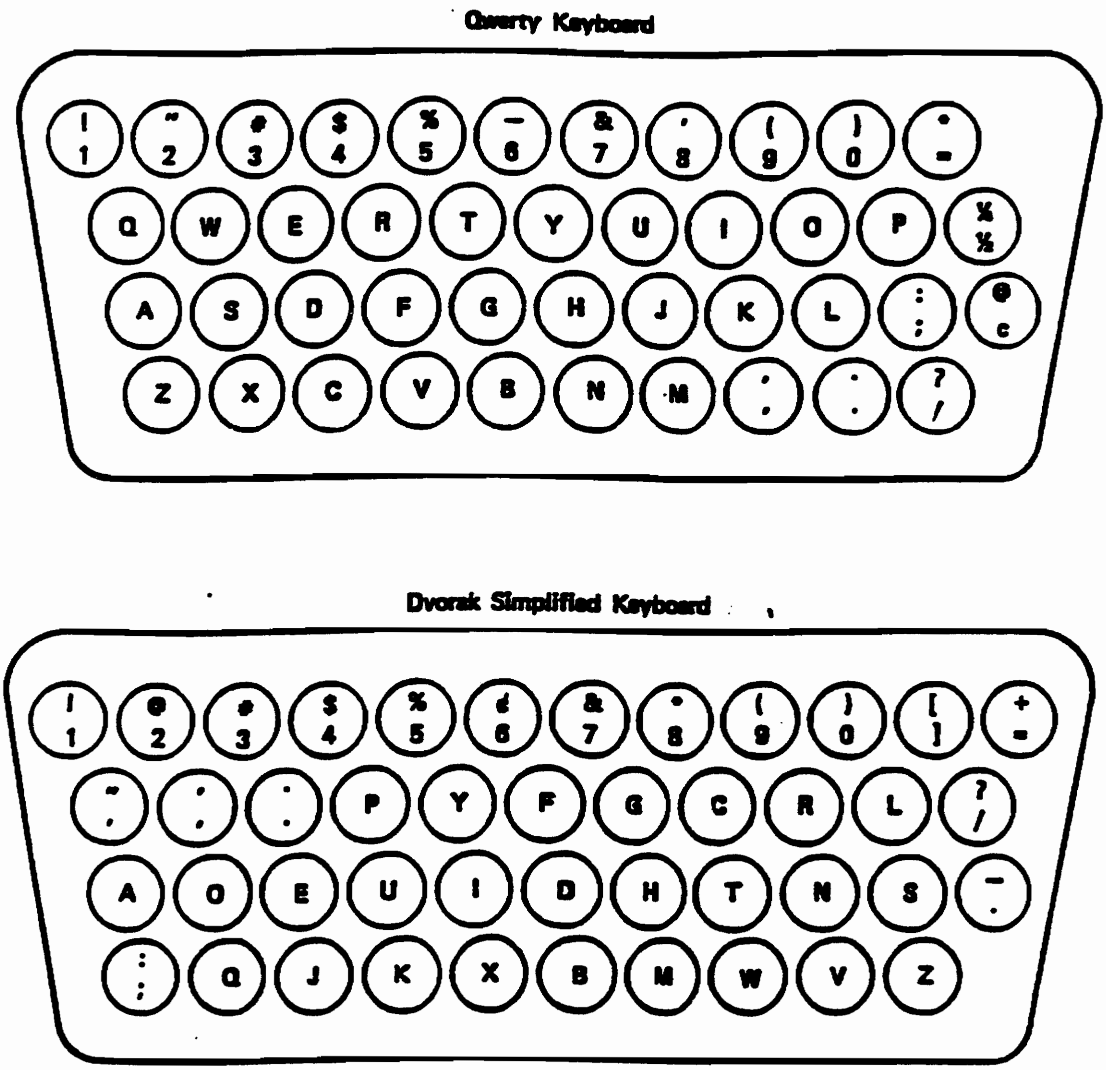


Figure 22. QWERTY and Dvorak Simplified Keyboard Layouts.

Sanders, M.S., and McCormick, E.J., Human Factors in Engineering and Design, McGraw-Hill, New York, NY, 1987.

Another data entry human factors concern is the "feel" of the keyboard and how quickly it responds to user activation. Keyboard "feel" is a function of key travel, resistance characteristics, and hysteresis. Hysteresis refers to the tendency of the key switch to remain in the closed position even after a partial release of the downward pressure. [6] Not only are these issues a concern for the keyboard pads, but for the mouse button as well. Too little hysteresis can produce key bounce and cause inadvertent insertions of extra characters, while too much hysteresis can interfere with high-speed typing. Key response can be adjusted by the control panel of the FAST system to allow for the greatest user comfort and productivity in data entry.

3.4 Display Design

Display design refers to the manner in which information is presented to the operator, including selection of information to be displayed, organization and formatting of information, and the location of the information on the screen. The quality of the display's design determines the ease with which the operator can locate, access, interpret, and respond to the required information. The operator's ability to access and use information, in turn, contributes to the overall effectiveness of the system.

From a human factors perspective, the most critical aspects of display design are logic and consistency. Logic implies that the information displayed to the operator is necessary and sufficient for the operator to perform his/her assigned functions. Consistency implies that the information is consistent in both content, format and layout, such that the operator can anticipate and predict system response. To the extent that display design is illogical or inconsistent, operator performance will be degraded!

3.4.1 Display Windows

FAST displays provide the Facilities Specialists with a method for inputting, updating, statusing, and deleting RFCs in the overall modification plan. The following capabilities are provided:

a. The capability to monitor in real-time the modification schedule, and any changes to that schedule.

b. The capability to generate on-line help from any screen.

c. The capability to backup all data.

d. The capability to modify any or all important milestones associated with any particular modification.

e. The capability to modify the critical path that determines the impact of one modification on another.

f. The capability to remove any modification from the "open" file and convert it to a history file.

g. The capability to produce hardcopy screen dumps of any portion of the workstation screen as specified by the operator.

h. The capability to request report generation in support of specific operator tasks.

i. The capability to exit from any part of the scheduling program. while automatically saving the data.

The ultimate goal of display design is the accomplishment of consistency and meaningful organization. Displays are designed consisting of graphics, color. alphanumeric data, tables, etc., as necessary, to provide an effective presentation of information. All information which enters the workstation is displayed functionally in pop-up windows which are selected by the user and provide the greatest flexiblity and organization for the operator. The primary window resides in front, and the windows can be moved to the front or back with the keyboard or mouse if desired. The window display concept is presented in Figure 23.

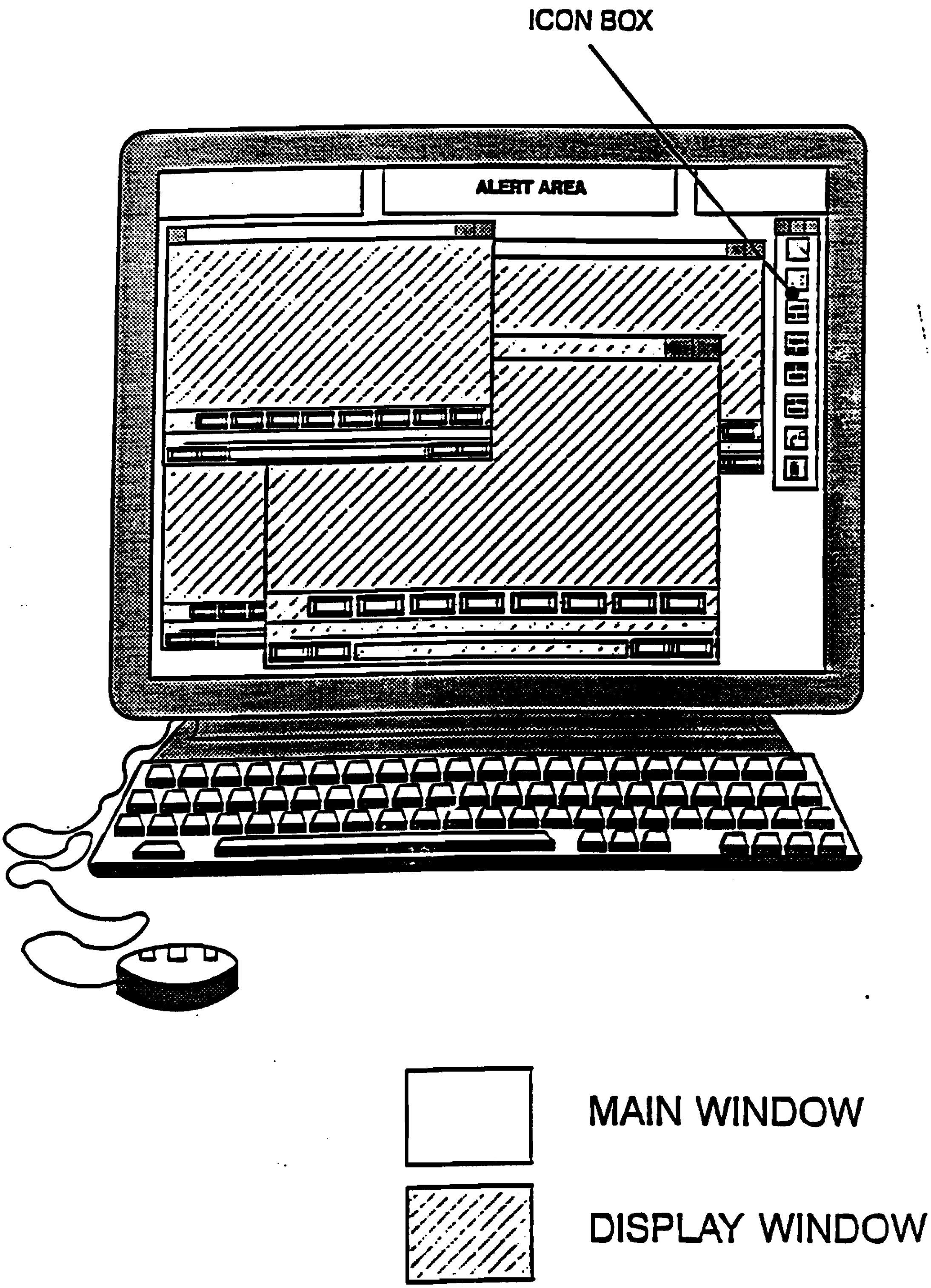


Figure 23. Screen Display Area.
"Second TDRSS Ground Terminal Human Factors Design Review". GE Aerospace. General Electric Company. Valley Forge. PA. 1990.

Based on ANSI standards, the command buttons appear at the bottom of each of the windows. PREV, MENU, and the arrow buttons appear on all the screen displays which allow the operator to refer to the previous command, display the main menu, page forward, or page backward. Other soft buttons are also located at the base of each window on the screen. A soft button is an object on the screen which performs some single, distinct function when selected. [1] The soft button commands are discussed in the next section (Section 3.4.2. FAST Main Menu Selections). The main display window layout is presented in Figure 24.

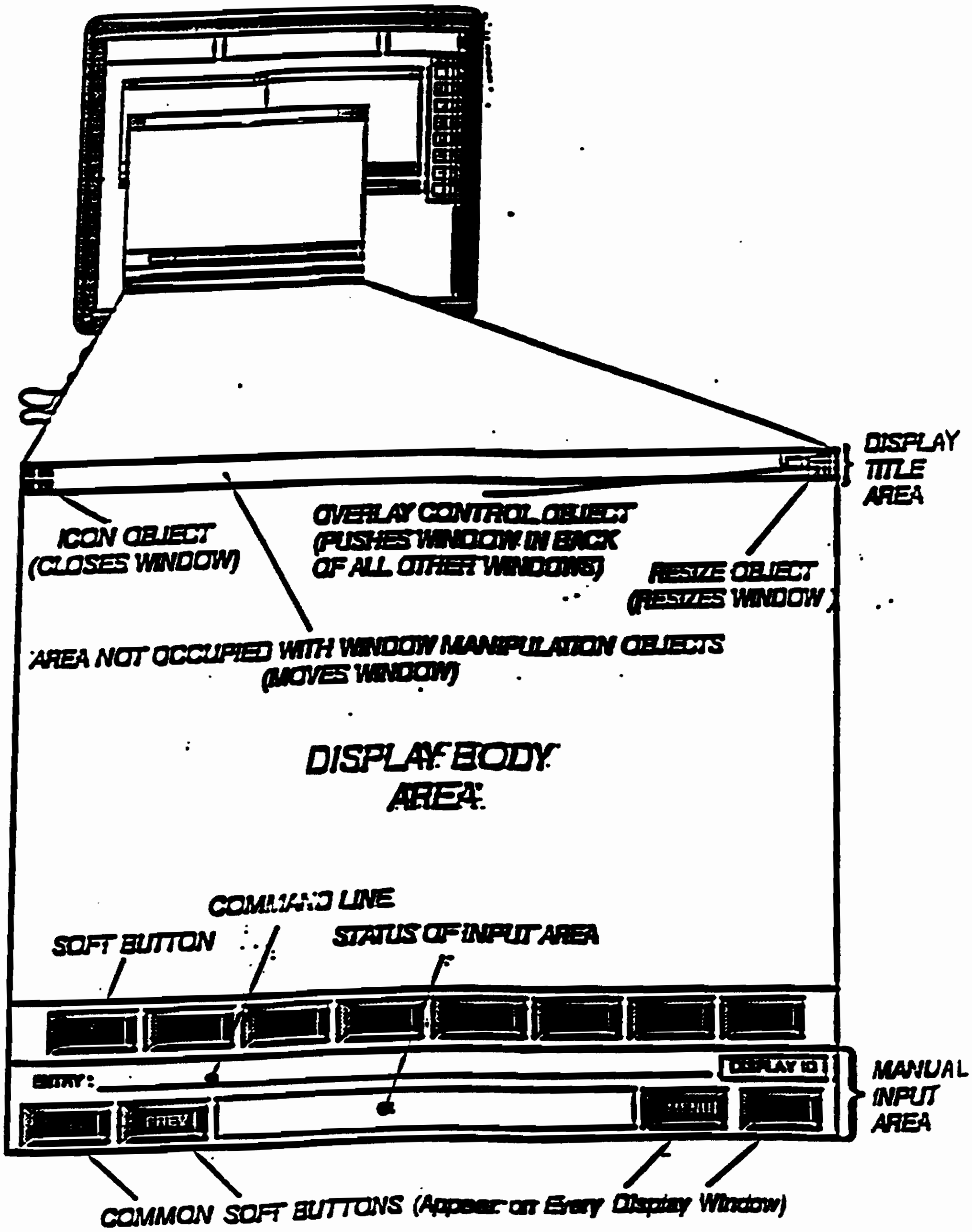


Figure 24. Main Display Window.

"Second TDRSS Ground Terminal Human Factors Design Review", GE Aerospace, General Electric Company, Valley Forge, PA, 1990.

3.4.2 FAST Main Menu Selections

A menu is available to the operator to assist in locating a particular display. The top-level menu is a graphical display which is called up via a soft button selection (the MENU soft button appears on every window display in the lower right corner of the window). A particular soft button can be selected by either pressing a keyboard function key or clicking on the soft button with the mouse.

Soft buttons are the standard method for selecting a function because they provide the greatest ease in system operation. An infrequent computer user will operate the system much more quickly and efficiently if functions can be selected with the touch of one button or the click of the mouse. The top level menu is hierarchically organized to allow the operator access to any set of related displays in the system.

Automatically following logon, the FAST program main menu appears as the main display window on the screen as shown in Figure 25.

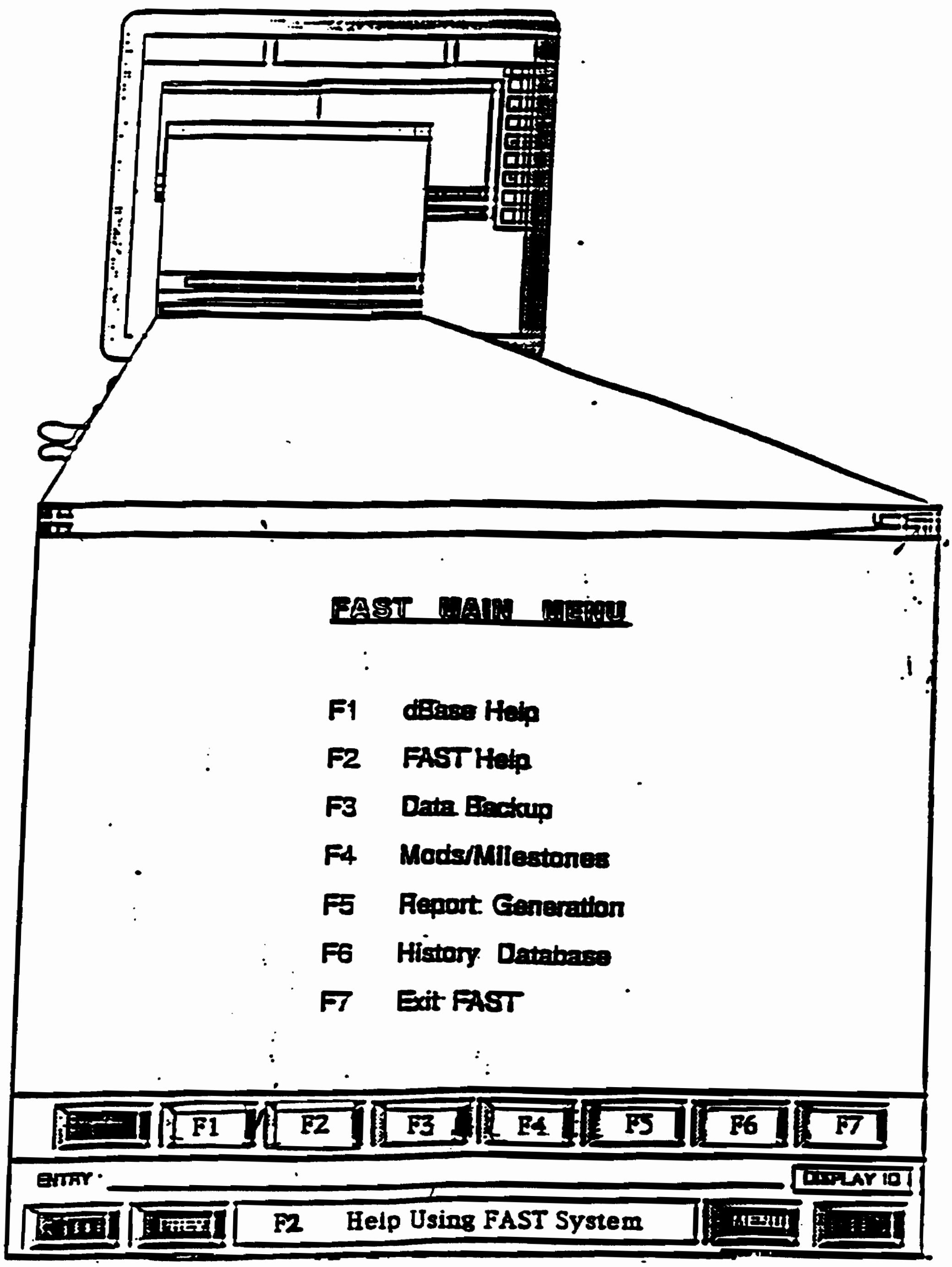


Figure 25. FAST Program Main Menu.

Once the operator has selected a display set, a lower level set of function keys replaces the top level menu. These function keys or soft buttons associated with each window display allow the operator to move forwards, backwards, search, add, delete, and update different RFC's. An exit button is always provided.

The proposed functions of the seven main menu options are briefly discussed here. Options F1 and F2 of the main menu provide on-line help to the user either for database manipulation in dBase or FAST application specific questions, respectively. Selection F3 runs a backup routine of all the data in the database. Another element of the backup routine is the automatic capability. If the user logs into the program and has not backed-up the data in seven days, the data will be automatically backed-up as if the F3 function were selected.

When the F4 function is selected, several statistics are reported. The date of the last update is given, the operator who last modified the data is provided and the RFC number being referenced is displayed. Following these statistics, a data screen is displayed which includes the most important dates associated with each RFC.

The F5 function allows the modification schedule to be presented in bar chart format, or other specific reports to be selected for distribution and review. The RFCs can be sorted by name, begin date, or end date. Each of the projects has a color coding depending on whether that RFC remained the same as in the previous month's schedule, slipped, was added, or was deleted from the database. A comment field is also provided to allow for operator events or remarks to be recorded.

F6 allows a RFC to be closed and archived into the history database. F7 allows the operator to exit FAST and terminate this modification statusing session. A confirmation that the operator wants to exit is required as in Figure 26.

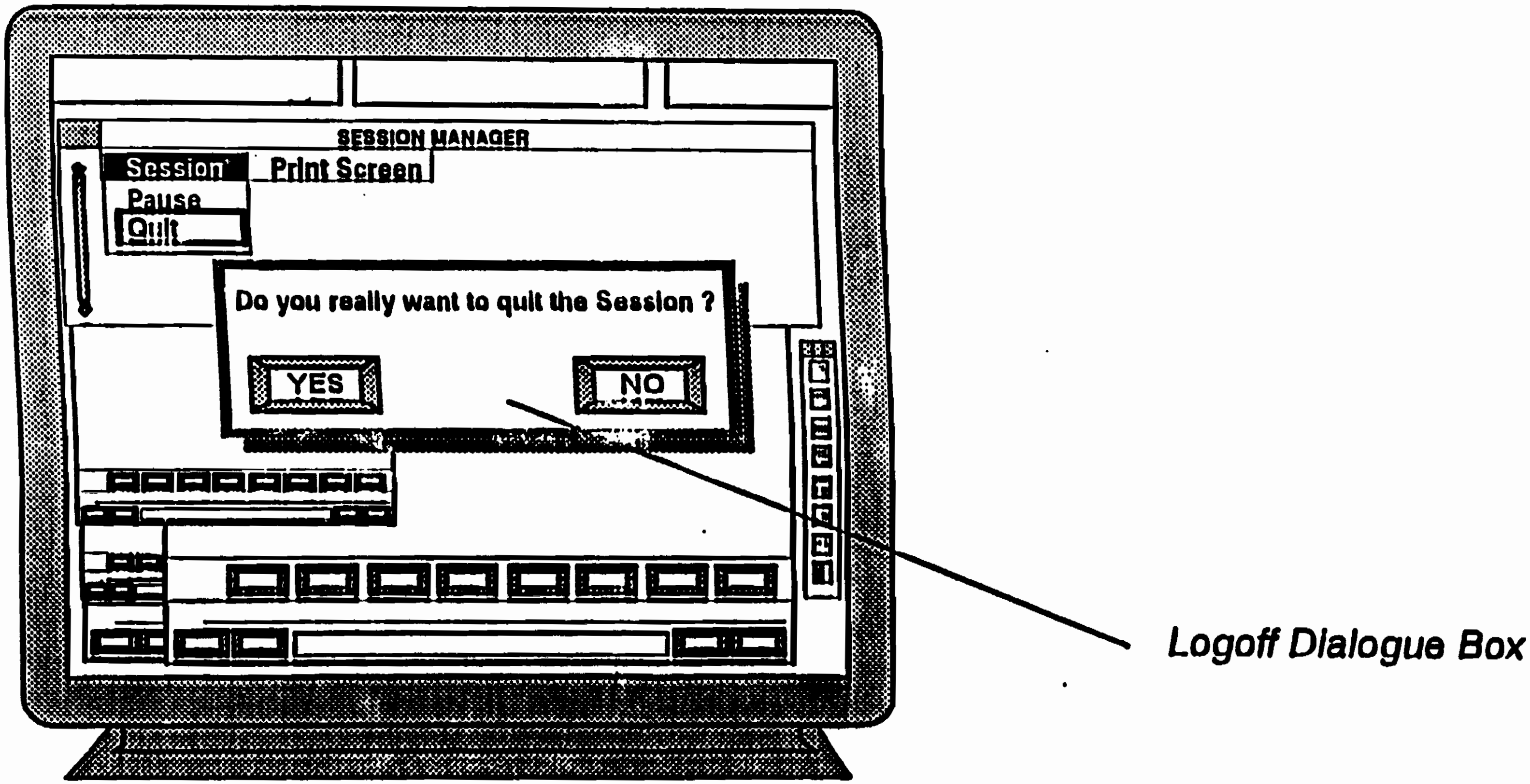


Figure 26. Confirmation to Exit Screen.
"Second TDRSS Ground Terminal Human Factors Design Review", GE Aerospace, General Electric Company, Valley Forge, PA, 1990.

3.4.3 Visual Display Characteristics

The FAST Program presents scheduling data through the use of neatly organized visual displays. The effectiveness of these displays depends largely on the viewing capability of the operator. The human eyes must be able to differentiate the fine print on a computer screen. defined as visual acuity. [6] Letters and geometric forms on the screen can be varied in size, width, height, and contrast to provide the operator with optimal visual acuity.

Visual acuity is usually measured in terms of the reciprocal of the visual angle. The visual angle is measured in minutes of arc (a circle is divided into 60 minutes of arc). The reciprocal of a visual angle of one minute of arc is used as the standard. [6] Poorer or better levels of acuity are compared to this standard.

Operators of a computer system must have the ability to discriminate between different objects on the screen. Because each individual is different. the display controls must be adaptable to meet the needs of each operator. thereby producing optimal working conditions which result in increased performance. Luminance contrast is one display control which refers to the difference in luminance of the features of the object being viewed. in particular. discriminating an object from its background.

Luminance contrast is expressed by

$$\text{Contrast} = (B1 - B2)/B1 * 100, \qquad \text{(Eq. 1)}$$

where B1 is the percent of reflectance of the brighter of two contrasting areas and B2 is the percent of reflectance of the darker of two contrasting areas. [6] For instance, the contrast between the text in this report and the background is approximately 88%, because the reflectance of the paper is 80% and the print is 10%. If the print were lighter (closer reflectance to the paper), then the luminance contract would be significantly less. An 80% luminance contrast is optimal for most purposes involving alphanumeric data.

When the contrast between an object and its background is high, the object can be small and still distinguishable. However, when the contrast between an object and its background is low, the object must be larger in order to be equally as discernable. For example, two sets of parallel bars with different visual angles and luminance contrasts must also have different heights in order to be equally discernable. The set of bars with a visual angle of one minute, a luminance contrast of 45%, and a height of 1/4 inch is equally discriminated to the set of bars with a visual angle of four minutes, a luminance contrast of 5%, and a height of 1 inch. [6]

Most of the information in FAST is critical scheduling information which must be thoroughly examined by the operator.

The longer the viewing time, the more comprehensible the information becomes. Therefore, the viewing time between screens is controlled manually by the operator. The operator has the capability to move between the different pages in the schedule, and the different screens in the program as necessary.

3.4.4 Alphanumeric Displays

In dealing with alphanumeric displays, the displays must be seen clearly, but also must be displayed to help the operator correctly perceive the meaning of the information. Displaying the words in any fashion will confuse the operator and lower performance. Three important criteria of alphanumeric displays are visibility, legibility, and readability. [6] Visibility refers to the quality of a character to make it clearly visible from its background. Legibility enables the operator to identify one character from another, which depends on stroke width, form of characters, contrast, and illumination. Readability allows recognition of the information content of the text when it is placed in meaningful groupings.

Typography refers to the various features of alphanumeric characters, individually and collectively. [6] Most variations in typography fulfill the human factors criteria, but in certain circumstances when viewing is poor, specific variations in typography can be applied to facilitate viewing.

Stroke width is expressed as the ratio of the thickness of the stroke to the height of the character as shown in Table 2.

Table 2. Stroke Width-Height Ratio.

Stroke-width to height ratio	Black on white	White on black
1:5	A B C 4 5 6	A B C 4 5 6
1:6	A B C 4 5 6	A B C 4 5 6
1:8	A B C 4 5 6	A B C 4 5 6
1:10	A B C 4 5 6	A B C 4 5 6
1:12	A B C 4 5 6	A B C 4 5 6

Because of irradiation which causes white features on a black background to appear to "spread" into adjacent dark areas, black-on-white letters should be thicker than white-on-black ones. Reasonably good viewing ratios are 1:7 for black on white, and 1:9 for white on black. The width-height ratio represents the relationship between the width and the height of a character. A 3:5 width-height ratio is satisfactory for most purposes. [6]

Many type styles or fonts exist for the text, such as Roman, Sans Serif, Geneva, Helvetica, and Times, which are the fonts enabled by the IBM printer. Some are more legible than others. Roman, and Helvetica are suitable for most purposes, while the other fonts are reserved for special instances, to highlight a special field on the display. The styles can be further enhanced by selecting such styles as *italics*, **bold**, or shadowing. These features allow further highlighting and can be used for alarms or special warnings to the operator. A warning signal in flashing, **large, bold** text is used to signal to the user when logging in that a change was made during the last session. Therefore, a double check on the changed elements can be conducted to ensure that system tampering and incorrect data manipulation did not occur.

The size of the print is another critical factor in providing the operator with clear and distinguishable text, which is measured in points. The most common type size is 12-point which is the size of this text. This sentence is written in 10-point which is also frequently used. The existing IBM equipment allows 9-point to 24-point to be printed. The large bold font on the previous page is 18-point. The data fields in the FAST system are displayed in size 12-point.

The density of alphanumeric characters refers to the compactness of the characters or the spacing between lines as shown in Table 3.

Table 3. Regular vs. High Density Text.

Regular spacing of text type (regular density)

> The ESS Performance Series is both a choice and a statement. The choice is to continue ESS's long tradition of excellence by trimming costs without

Close-set text type (high density)

> The ESS Performance Series is both a choice and a statement. The choice is to continue ESS's long tradition of excellence by trimming costs without sacrificing performance and by omitting

While legibility depends primarily on stroke width, font size, character type, and luminance contrast, readability refers to the recognition, understanding, and retention of information. Reading densely packed characters requires less cognitive work than reading less densely packed characters. Furthermore, chunking long strings of characters into pieces such as a social security number provides better recognition. [6] The data strings in FAST are required to be less than 20 characters in length in order to be accepted. 80 characters per line of prose is allowed for word processing.

All of these human factors concepts must be considered when designing the FAST displays. The recommended size, density, thickness, etc., presented in this report will create the optimal viewing effect for the operator. Scrolling, paging, and menus are other important screen effects that are incorporated into the screen design to provide the greatest flexibility and ease of use for the operator.

3.5 Environmental Recommendations

Along with the characteristics of alphanumeric display, the environment is an important human factors concern.

3.5.1 Lighting

The amount of light striking a surface is called illumination, measured in terms of luminous flux per unit area. Furthermore, the amount of light per unit area leaving a surface is called luminance. Reflectance, therefore, is the ratio of the amount of luminance to the amount of illuminance. A reflectance of 1.0 refers to a perfect reflecting surface. [6]

Lamps or luminaires can be classified into five different categories: direct, simidirect, general diffuse, semi-indirect, and indirect. [6] Each emits a different amount of light above and below the horizontal. Depending on the task at hand and the visibility of the operator, any one of the luminaires can be selected to produce the proper reflectance on an object.

Glare is produced by brightness within the field of vision that is sufficiently greater than the luminance to which the eyes are adapted, causing loss of visual performance. Glare is classified as direct glare or reflected glare and can result in discomfort glare, disability glare, or blinding glare. Discomfort glare will cause annoyance or pain, but still enable the operator to work, disability glare reduces the ability of the operator to continue work, and blinding glare is so intense that it often eliminates the object from view. All glare should be eliminated in order to provide maximum comfort.

Glare from luminaires, from windows, and reflected glare can be reduced by taking certain precautions. Glare from luminaires can be reduced by using several low luminaires instead of a few bright ones and by using light shields, hoods, diffusing lenses, or filters. Glare from windows is reduced primarily by using blinds and shades. Reflected glare is reduced by providing a good level of general illumination so that the contrast is minimal, using diffused light or indirect light, and positioning the light source so that the reflected light is not directed toward the eyes. [6]

Lighting, itself can not produce work output, but lighting is so critical to operator performance that it can increase work throughput. With the proper lighting, details are easier to see and objects and text more distinguishable without producing discomfort or distraction. A recommended lighting scheme consists of using a diffused overhead light with another semidirect desk lamp. The *diffused* overhead light provides the general light in the room with minimal glare. The desk light provides added light for reading, but because it is semidirect, it reduces reflected glare. Therefore, operators will be less irritated by poor viewing conditions, resulting in greater work efficiency!

3.5.2 Comfort Level

The basic heat exchange process is influenced by the insulating effects of clothing, measured by the clo unit. The clo unit is a measure of the thermal insulation necessary to *comfortably* maintain a sitting, resting subject in a normally ventilated room at 70° F and 50% relative humidity. Comfort can be influenced by the work being performed , the clothing worn, and the season of the year.

Temperature control has a significant impact on performance. The Occupational Safety and Health Administration (OSHA) has set temperature limits for various levels of work. In the case of operator control (cognitive work), 86° F is the upper limit, with a normal condition of comfort being 76° F.

4.0 CONCLUSIONS

For the design of FAST, human factors engineering is the most critical element in the system engineering process because of the continuous human element in the system. During the early stages of the system life-cycle, particularly during the requirements definition and preliminary design phases, human factors analysis is critical to produce the optimal system for the users.

Once the need of the customer is properly identified, human factors analyses must be conducted. The human-computer interface requirements must be formed early in the life cycle process so that as research, trade-offs, and feasibility studies are performed, the design of the system can be modified to satisfy the needs of the operators of FAST. HCI system specifications can then be established to produce the most effective and efficient system possible.

However, it is important to remember that a proposed design which optimizes the human-computer interface for everyone is impossible. Therefore, compromises must be made to satisfy the greatest number of users. Everything from chair width to room temperature is examined to determine the combination of factors that will comply with the requirements of the system and create the most effective system.

Therefore, in designing the system for the Facilities Branch and meeting the requirements dictated by the ABC Company, a flexible, open architecture with evolvable software is designed that will adapt to human capabilities, differences, and limitations. The design of FAST will influence the operator's behavior and well-being which in turn will increase performance.

After analyzing the anthropometric ranges. and psychological and physiological conditions of the human beings. the recommendation is to design the FAST system using the ANSI and MIL-STD-1472D standards described in detail in this report. The seat pan height should be adjustable from 15-20", the seat back angle should be adjustable from 10-30 degrees from the vertical, arm and wrist rests are critical for comfort during long hours of operation. The table height should be 30" to allow both men and women to use the system. [6] A summary of the optimal ranges for work space design is provided in Figure 27.

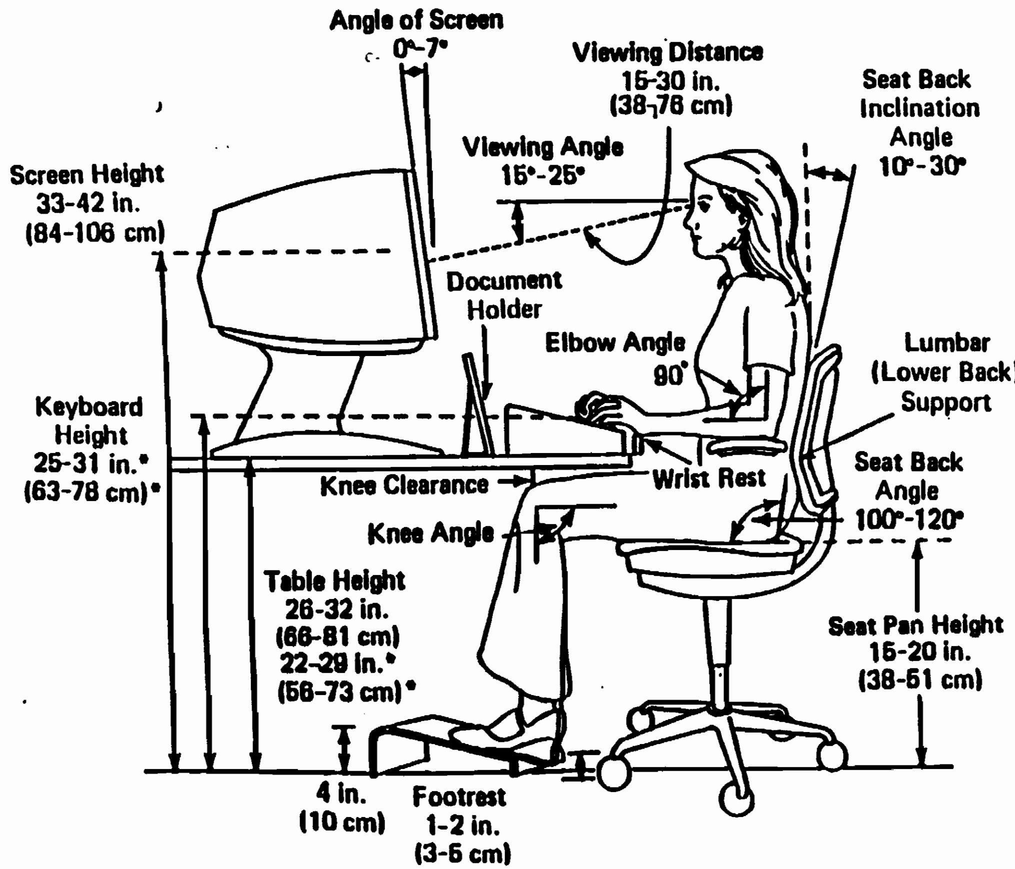


Figure 27. Summary of Ranges for Work Station Design.

Sanders, M.S., and McCormick, E.J., Human Factors in Engineering and Design, McGraw-Hill, New York, NY, 1987.

The horizontal wrap-around console with three 3-foot long panels is highly recommended which provides the operator with optimal flexibility for workstation configuration. Peripheral equipment can be placed within reach of the operator without obstructing data entry.

Not only are the physical dimensions of the work space critical. but as addressed in this report, the screen layouts are equally as important for efficient data entry, updating, and deleting. The system is a menu driven system for easy function identification. The main menu and exit keys are accessible from every screen. Functions are selected by pressing one key or clicking with the mouse.

The most critical information is always located in the center of the screen and changes are indicated with a warning signal so the operator can be sure that all the required actions for the day have been completed and nothing is overlooked. RFCs will not be lost or forgotten, softcopy archived files will replace 80% of the file cabinets. and hundreds of paper files will no longer be needed. New project entry can be performed in 15 minutes, instead of the three weeks required by the manual system. The Facilities Specialists will be able to work more efficiently, resulting in more time for other important tasks, greater job satisfaction, higher performance, and ultimately, more profit for the company.

While much of the screen display is adjustable to meet the specific needs of the user, character field lengths are set at twenty characters and font size is set at 12-point in most instances. Screen lighting and contrast is slightly adjustable with a control knob, but the recommended default values are set at 80% illuminance contrast, 1:7 stroke width for black on white characters, and 3:5 width-height ratio.

It must be remembered that human factors is not just applying a checklist, guidelines, or common sense. Human factors is a science! Knowing how large to make letters on a display or selecting a chair backrest angle that provides the most comfort for the longest periods of time are not trivial questions. They are important elements in satisfying the needs of the customer. Only after human factors considerations are studied, and solutions proposed to meet the HCI needs of the system, can the system engineers propose a technical design to will fully satisfy and comply with the customer demands!

As a recommendation for a future project, this report uses a system life-cycle approach to *design* the FAST system. A follow-on project could further develop the FAST system by progressing through the test and evaluation, production, operation, and maintenance of FAST. In essence, someone could take the design and finish the life-cycle analysis concentrating on human factors or some other element of design that was initiated in this report.

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