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FINAL REPORT

DEVELOPMENT AND VALIDATION OF METHODS FOR MAN-MACHINE INTERFACE EVALUATION

Contract NASW-2747

Prepared for:

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1.0 INTRODUCTION

This section of the report will describe the background and rationale for the study, and will discuss the implications of the study results for space shuttle man-machine interface evaluation. The succeeding sections of the report will then describe the study procedures and materials, test results, and conclusions and recommendations based on an interpretation of the results.

1.1 Background

In June 1974 the Essex Corporation published a document entitled "Human Engineering Data Guide for Evaluation" (HEDGE), for the U. S. Army Test and Evaluation Command. The rationale behind the HEDGE was that the most effective procedure for evaluating the man-machine interface of a system entails an assessment of tasks and task sequences as well as physical characteristics of the interface elements. In planning the study which produced the HEDGE, it had been recognized that the alternate methods of conducting a man-machine interface evaluation can be classified into two general categories: static and dynamic. The static approach entails evaluation of each element of the interface (e.g. controls or displays) independently of the sequence of tasks associated with the operations to be used. The dynamic evaluation incorporates an assessment of the interface in terms of the characteristics of each element and in terms of the operational sequence. The HEDGE then represents a dynamic evaluation tool which provides for a determination of the effectiveness of the man-machine interface in terms of the sequence of operations with the interface and in terms of the physical characteristics of the interface.

1.2 Statement of the Problem

During the development of the space shuttle and shuttle payloads such as spacelab and flight experiments, a number of man-machine interface evaluations will be required. For any one interface (e.g. crew station), a number of evaluations will also be required corresponding to different development stages.

The two basic requirements for conducting a man-machine interface evaluation are:

1. Availability of criteria serving as specifications against which man-machine interface characteristics are compared
2. Availability of a methodology for acquiring data on the characteristics of the interface

NASA has been giving increasing attention to man-machine interface specifications over recent years, with the publication of the JSC Crew Station Specifications in October 1972, and the MSFC Standard 512, "Man/Systems Design Criteria for Manned Orbiting Payloads." These documents present in considerable detail recommended and required design criteria for specific elements of the man-machine interface.

While NASA has available the criteria for assessing the effectiveness of the man-machine interface, there is no accepted standard methodology available for acquiring data on the man-machine interface under evaluation. The evaluations conducted to date usually involve a static assessment of the physical characteristics of elements of the interface. The authors have personally participated in a number of formal and informal crew station reviews and man-machine interface evaluations conducted by NASA and NASA contractors for several space systems at different stages of system development (Apollo lunar module, Apollo lunar surface experiment package, manned orbiting laboratory mission control center, Skylab Apollo Telescope Mount, Skylab film retrieval system, and Life Sciences earth orbital teleoperator systems). The distinguishing elements of these evaluations were that:

1. They were static, usually comprising checklists of interface characteristics on which the design of elements of the interface were judged to be acceptable or unacceptable.
2. They were not standardized but rather were developed specifically for the individual evaluation.

A program was proposed to develop a standard methodology for conducting dynamic man-machine interface evaluations. The initial step in this program is to determine the degree to which a dynamic evaluation approach is more effective than a static procedure. Such a comparison of alternate evaluation methods has never been formally conducted. The present study represents the results of a controlled comparison of a dynamic evaluation approach with a static procedure. If the dynamic approach is judged to be significantly superior to the static method, a recommendation will be formulated that the program continue through development of dynamic evaluation materials and methods.

1.3 Study Output

The output of the program to develop man-machine interface evaluation methods will be the materials, procedures and data required for a dynamic evaluation provided that it can be demonstrated that the dynamic approach is significantly superior to static assessment techniques. The output of this first phase of the program will comprise the results of a comparison of dynamic and static methodologies. The comparison of methods was conducted using the shuttle payload specialist station as the baseline station to be evaluated. An ancillary output of the study is therefore an evaluation of the current PSS design concept from a man-machine interface orientation.

2.0 PROCEDURES AND MATERIALS

2.1 Checklists

Prior to preparing the static and dynamic evaluation methods to be compared in this study, it was necessary to clearly define the two techniques and how they differ each from the other. For purposes of this study, the static evaluation technique represents a checklist of the factors to be evaluated for each control and display within the payload specialist station (PSS) panel concept. Factors evaluated for controls include:

- handle type
- handle length and width
- separation from other controls
- provision of barriers
- separation of barriers
- force required to activate
- direction of activation
- control displacement
- nomenclature and location
- legend size (height and width)
- lighting
- brightness contrast
- reach distance (functional)
- viewing angle
- viewing distance
- arrangement of control positions

Display factors included in the evaluation techniques include:

- type of display
- size

- target size
- display update action
- update rate - data rate
- slew rate
- viewing angle
- viewing distance
- duration of view
- display orientation
- adjustments
- range of adjustments
- brightness contrast
- lighting - glare
- labelling size (height-width)
- display color
- display scaling
- nomenclature
- location

The static technique entailed acquisition of available data on each of these factors for each control and display of the PSS. After the data acquisition, the data on each factor were compared to applicable criteria from the JSC crew station specification and from Mil-Standard 1472. At this point problems were identified as situations where measured design factors were outside tolerances prescribed by the specifications.

The dynamic approach consisted of a checklist based on the operational sequence to be followed in the use of the PSS for a specified mission. For this study the selected mission was payload servicing using the free flying teleoperator system (FFTS). The dynamic checklist consisted of one column for tasks associated with this mission, a second column identifying controls and displays to be used in the performance of each task, and four other columns wherein each control and display was evaluated for each task, and within the task sequence, along four dimensions:

- location (including arrangement and layout)
- operation (including method of control activation)
- coding (labelling and nomenclature, shape coding, place coding, color coding)
- design (sizes and shapes of controls and displays)

The dynamic checklist was differentiated from the static in that, for the dynamic, the evaluation of a particular control or display considered the tasks requiring use of the control or display as well as the sequence of tasks. The static checklist was concerned with evaluating each control and display separately.

2.2 Test Subjects and Procedures

Subsequent to the development of the checklists, each was used to evaluate a PSS panel arrangement developed for the FFTS mission.

The panel concept was the configuration developed for mission 8 by MSFC. A full scale paper representation of the panel concept was mounted in a cardboard mockup of the shuttle aft cabin and the evaluations were conducted using this mockup. Four subjects used the dynamic checklist. All were employees of Essex. Two were Ph.D's in Experimental Psychology, and the other two had masters degrees, one in Industrial Psychology and the other in Administrative Sciences. The human factors experience of this group of subjects had not seen the checklist prior to the evaluation exercise.

The static checklist was used by only one subject. Additional subjects were not used since completion of the checklist was a straightforward measurement and recording process. For this reason it was assured that little variation would be expected among different evaluations conducted by different subjects.

The evaluation procedures used with the static checklist were as follows:

- identify panel containing control or display to be evaluated
- identify control or display
- consult individual checklist items concerning required data for the control or display
- measure sizes, distances, separations, etc.
- record measurements on appropriate space
- continue obtaining data as required for each control and display
- complete the checklist for all controls and displays
- consult crew station specifications for standard measurements of sizes, separations, distances, etc.
- compare obtained measurements with standards
- identify situations where obtained measurements exceed standard values
- list these situations as human factors problems

The evaluation procedures followed for the dynamic checklist were:

- review required procedures and sequences

- simulate the required operation at each step of the sequence (e.g. perform switch activation motions, read displays, etc.)
- identify problems in conducting simulated operations, in terms of:
    - control or display location (including spatial arrangement)
    - control or display operation (direction of motion, type of operation)
    - control or display coding (labelling, shape code, color code)
    - control or display design (size, shape, type)
- record problem areas in space provided
- complete the checklist

3.0 RESULTS

Prior to the conduct of the panel evaluations a number of assumptions were made concerning the expected performance of the two types of checklists. These assumptions were as follows:

1. The static checklist would require significantly more time to develop, administer and perform data analysis, as compared to the dynamic checklist.
2. The static checklist should be more comprehensive in terms of the number of problems identified.
3. The dynamic checklist will identify more critical problems.
4. The dynamic checklist will identify more different types of problems.

The results of the comparisons of checklists can be structured in terms of these assumptions.

3.1 Time to Develop and Use

The static checklist included an average of nine factors to be evaluated for each of 168 controls and displays. The checklist comprised 50 pages with an average of three controls or displays to a page.

The dynamic checklist included the same 168 controls and displays within 139 tasks in a baseline mission (Free Flying Teleoperator Servicing Mission). The checklist was seven pages long.

Development Time

The time to prepare the static checklist was 18 hours. This included time for identifying controls and displays and selecting factors to be considered for each. The time to prepare the dynamic checklist was 12 hours which included time to develop a task sequence for a representative mission which required use of each control and display on at least one task each.

Data Recording Time

The static checklist required three hours to administer. The dynamic checklist required 2.65 hours for the group of four subjects (approximately 40 minutes each).

Data Reduction Time

The reduction of data for the static checklist required 20 hours. This activity entailed comparing each value recorded for each factor on each control and display with standard limits contained in the JSC Crew Station Specification, the MSFC Standard 512, or the Military Standard 1472B.

The reduction of dynamic checklist data was completed in four hours.

Total Time

The total times required for each checklist are presented in Table 1.

TABLE 1. TOTAL TIMES FOR EACH CHECKLIST (IN MAN HOURS)

	Static	Dynamic
Development Time	18	12
Data Recording Time	3	2.65
Data Reduction Time	20	4
TOTAL TIME	41	18.65

As indicated in this table the total time required for the static checklist was more than twice that for the dynamic checklist even though the two were closely comparable in terms of data recording time.

3.2 Number of Problems

It had been assumed that more problems would be identified with the static checklist due to its level of detail in treating control/display characteristics to be evaluated. This assumption was borne out when the results of the checklist comparisons were limited to any one and only one user of the dynamic checklist. These were a total of 146 man-machine problems identified with the static checklist. For each of the four subjects using the dynamic checklist the total number of problems was: 40, 49, 64 and 95. The checklist evaluation had been structured to compare the results for one subject on the static checklist with the results of however many other subjects who could complete the dynamic checklist in about the same time as required for the static checklist. Thus, the number of problems identified per checklist should include the results of the four dynamic checklist subjects. When the checklists were compared using this approach, the dynamic list resulted in 184 different problems, or 1.25 times more problems than were identified with the static list. A total of 65% of all problems identified by either list were identified with the dynamic checklist, while 52% were identified with the static list. Only 17% of all problems were identified by both lists.

3.3 Problem Criticality

The man-machine problems identified in the panel concept evaluations were classified according to the following criteria:

- critical problems - those which will degrade operator performance and which are important at the panel stage of development
- non-critical problems - those which are not expected to degrade operator performance or which are not considered important at the panel stage of development

The PSS panels under evaluation in this study were conceptual designs and, as such, were not to be considered outputs of a detailed design effort. For that reason the class of problems concerned with control and display location and arrangement was the only set of problems designated as critical. The problems associated with labelling, coding, control-display design, or operation were not considered critical since the intent of the panel concept development had not been to finalize a panel design.

A total of 186 of the 281 PSS man-machine interface problems identified in this study were classified as critical. This represents about two-thirds of all of the problems. Of the 186 critical problems, 159 or 86% were identified using the dynamic checklist. The static checklist identified 69 or 37% of the critical problems, and both checklists identified 42 or 23% of the critical problems.

The dynamic checklist not only identified more critical problems than did the static checklist, the dynamic checklist was also more sensitive to critical problems. A good majority (again 86%) of the problems identified by the dynamic checklist were critical. With the static checklist almost half (47%) of the identified problems were classified as critical.

3.4 Type of Problems

Probably the most important measure of the effectiveness of an evaluation procedure is the range of problems that it is sensitive to. As indicated in Table 2 there were 21 different types of problems identified in this study. Of these, 14 or 67% were classified as critical. Of the 14 critical problem types the dynamic checklist identified 13 while the static checklist identified eight. Both checklists identified problems of six types.

The significant differences between checklists, in terms of types of problems identified, include the following:

- The dynamic checklist alone is sensitive to adequacy of the panel arrangement, in terms of the sequence of operations and the location and layout of panels to support these operations.
- The dynamic checklist alone is sensitive to requirements to relocate controls and displays based on the frequency of use.
- The dynamic checklist alone is sensitive to non-standardized arrangements of components on different panels.
- The dynamic checklist alone is sensitive to limitations in workspace and situations where the control or display interferes with its operation.
- The dynamic checklist is more sensitive than the static checklist to problems of insufficient separation of controls and displays, likelihood of inadvertent activation, situations of obstructed reach, and requirements to move controls or displays to more effective locations.

- The static checklist was more sensitive than the dynamic on only one factor, excessive reach. On this factor the dynamic checklist identified 29 problems, 26 of which were also identified by the static checklist. The static list on the other hand identified 13 reach problem situations not cited by the dynamic checklist.
- The static checklist was much more sensitive than the dynamic to non-critical problems, such as label size, control element size, and viewing distance.

TABLE 2. FREQUENCY OF TYPE OF PROBLEM FOR TWO TYPES OF CHECKLISTS

Critical Problems	Static Checklist	Dynamic Checklist	Both
Poor panel arrangement	0	15	0
Infrequently used C/D in prime space	0	10	0
Related C/D too far apart	0	2	0
C/D too close together	17	33	11
Controls outside of operator's reach	39	29	26
Controls can be inadvertently activated	3	9	0
Reach to control obstructed	1	20	1
C/D location interferes with operations	0	4	0
C/D could be moved to more effective location	5	17	2
Poor viewing angle	1	3	1
Limited workspace	0	6	0
Too much control rotation required	1	2	1
High likelihood of control confusion	2	0	0
Layout not standard for all panels	0	9	0
TOTAL CRITICAL	69	159	42
Non-Critical Problems			
Labelling ambiguous	7	14	7
Label size too small	52	0	0
Insufficient display states	2	0	0
Control element too small	9	6	0
View distance too large	6	0	0
Control on wrong side of display	1	4	0
No directional code	0	1	0
TOTAL NON-CRITICAL	77	25	7

4.0 CONCLUSIONS AND RECOMMENDATIONS

The outputs of this study were to include three separate items:

- a selection of a man-machine evaluation approach with a justification for the selection
- a description of the approach as it is to be applied to man-machine interface evaluations for shuttle and shuttle payloads
- an evaluation of the man-machine interface currently being considered for the shuttle aft cabin Payload Specialist Station (PSS).

The conclusions and recommendations associated with each of these areas include the following:

4.1 Evaluation Technique Selection

Based on the results of this study the dynamic checklist approach is recommended for shuttle and shuttle payload man-machine interface evaluations. This recommendation is based on:

- Time to prepare, administer and reduce data. These times were twice as long for the static approach as compared with the dynamic.
- Number and criticality of problems. The dynamic checklist is more sensitive to problems which are expected to significantly impact operator performance and which are important for the stage of panel development. The static checklist is more sensitive to non-critical problems.
- Type of problem identified. The dynamic checklist is sensitive to significantly more (13 of 14) types of critical problems than

is the static approach which identified problems in only 8 of 14 critical categories.

Both checklists performed effectively in identifying human factors problems for individual controls and displays. The dynamic checklist excelled over the static primarily in identification of problems which were related to the sequence of operations, where the concern was not only with individual controls and displays but also with the relationships among different controls and displays. The dynamic checklist alone was sensitive to problems stemming from the arrangement of controls and displays on panels, and the arrangement of panels themselves. The dynamic approach also was the only technique which identified problems of non-standardization of control and display arrangements across different panels. It alone also identified problems with workspace provided the operator.

The implications of these results are important for spacecraft man-machine interface evaluation. If the evaluation approach continues to follow the lines of a static technique, then a significant number of important problems of different types will not be identified. It is only through the application of a dynamic evaluation scheme that the integration of man-machine interface elements can be effectively evaluated. Early in the design and development process (as at the present time in the shuttle aft cabin development) an evaluation of component integration and arrangement is more important than a full evaluation of station man-systems design.

4.2 Dynamic Checklist Specification

The dynamic evaluation approach considered in this investigation represents an application of a technique developed by Essex for the U. S. Army Test and Evaluation Command. The essential characteristics of the technique are as follows:

- It is not actually a checklist as such but rather supports and facilitates the identification of what aspects of an item must be evaluated. As such it can serve as the basis for a specific checklist developed by the evaluator.
- It is oriented toward evaluation of what the user must do with an item and under what conditions. Therefore, it enables the evaluator to consider user requirements in a dynamic situation, rather than providing checkpoints in a static format.
- It is operationally oriented rather than simply equipment oriented. It emphasizes operational interfaces rather than only physical interfaces.
- It provides the evaluator with a basis for conceptualizing what the user must do with the item, enabling him to approach the test and evaluation of the item as a trained human factors engineer would. Therefore, it provides him with more than a simple list of what to look at and look for.
- It enables the evaluator to follow the operational orientation even to the point of adding additional operations and test item components not specifically covered in the document data bank.

Therefore, it has applicability to a wide range of man-machine interface elements, even beyond those identified in the data bank.

- It makes most effective use of evaluator time and effort by limiting his attention to man-machine data specified for items by class of item and purpose of testing.

The approach provides the evaluator with a classification of systems and, for each class, a set of standard operations man-machine interfaces associated with operations. Examples of man-machine interfaces would involve the following:

- controls/displays
- consoles
- workspace
- habitability
- documentation
- communication
- data management
- pointing control
- procedures and operations
- stowage
- restraints
- mobility aids
- timelines and work/rest cycles
- design for operability
- design for maintainability
- design for safety
- handles, handholds
- lighting
- clearances
- visual system
- workload
- skills and knowledges

The dynamic technique would then include:

- a classification of systems (e.g. experiment control console, EVA translation aids, work station restraints, etc.)
- standard operations for each system class, at three levels of specificity (function, sub-function and task)
- a list of man-machine interfaces associated with each task
- a list of man-machine interface evaluation criteria areas, such as:
    - visibility
    - location/arrangement
    - size, shape
    - forces, resistance
    - condition of use
    - safety
    - coding/identification
- man-machine interface evaluation criteria or specification data classified by criterion areas and interfaces, for tasks by system classes

The technique will be used by a man-machine interface evaluation to construct a dynamic checklist specifically tailored for the system to be evaluated. The technique will then indicate what should be evaluated and would also comprise the criteria derived from the JSC Workstation Specifications and/or MSFC Man-Machine Interface Standard 512. Evaluators would develop a dynamic checklist based on the technique, and would apply the checklist by simulating the operations to be performed with a mockup of the interface. Based on the stage of development, the mockup can range from an engineering drawing to a high fidelity full scale mockup.

4.3 Evaluation of the PSS for the Life Science FFTS Servicing Mission

The PSS configuration evaluated in this study is presented in Figure 1. The results of the evaluation, as they relate to the PSS man-machine interface, include the following conclusions and recommendations:

1. The significant problem inherent in the PSS concept evaluated was the same problem which plagued the Skylab Apollo Telescope Mount Console - that of establishing a design approach which states that a station might be a one or two man station. It is important to understand that the differences between one and two man stations extend beyond the size difference. Controls and displays must be integrated and arranged for a one man console in a manner different than for a two man station. Reliance on an approach which attempts to accommodate either manning level must result in a concept which has serious problems for either approach. The PSS evaluated in this study could not be operated by a single operator. One sequence of activities required 18 sequential shifts between the aft panel area (A-4) and the forward most side console (L-12). An operator stationed at L-12 simply cannot reach A-4, and similarly, a crew member stationed at A-4 cannot reach L-12. The actual control of free flying teleoperator systems requires operational sequences utilizing

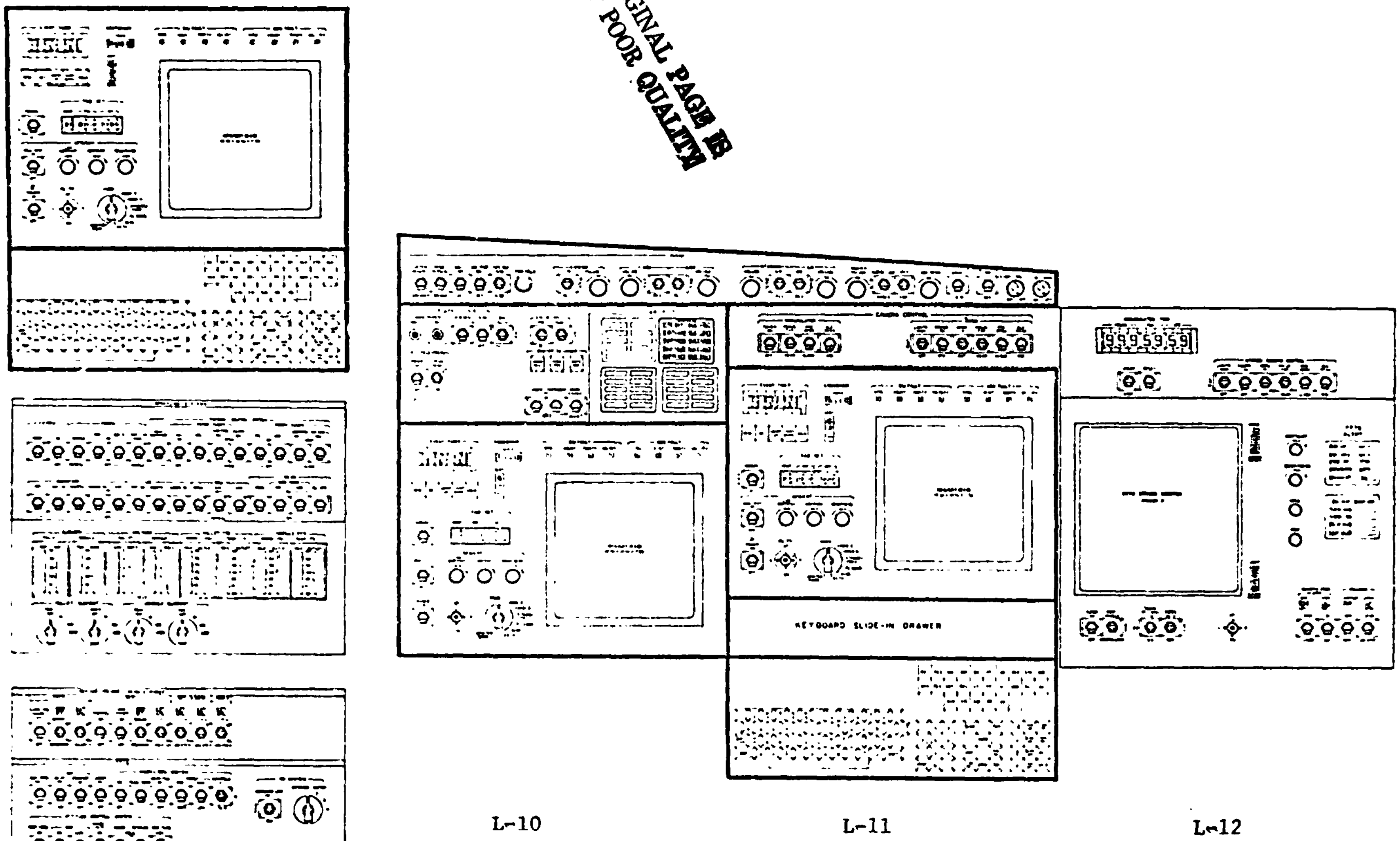

FIGURE 1. FFTS CONTROL PANEL EVALUATED IN THE MSFC AFT CABIN MOCKUP

components located on both panels which is impossible. The approach of using the station as a two-man console is also unacceptable due to the small space provided and the required coordination of functions located on different consoles.

2. The console arrangement is poor in terms of reach envelope, even if the problems identified in item 1 above are resolved. A crewmember standing at the central side console (L-11) can reach controls located on the aft most side console (L-10) only with difficulty, due to the distance involved and the location of obstructions.
3. The mission specific panel (L-12) was not designed using the same guidelines and criteria as the standard panels (L-10, L-11).
4. Hand controllers are too low for a standing operation. The centerline of the controller panel is 30 inches from the floor and controls are 16 inches apart.
5. Controls which are located on the panel should be on the hand controllers (clutch, grip open/close).
6. There is not enough head room for a six foot operator to reach all controls from a standing position.

APPENDIX A

DYNAMIC CHECKLIST

TASK	C/D	PNL	C/D FUNCTION
1. Activate FFTO (Checkout in Cargo Bay	Power Distribution	L-10	PRI or SEC CRT BKR Turn on: Sym Gen. Sivc Diu Auto Status Lights: PRI Enable P/L TV Power On Focus as Reqd. Select Orb. Recorder Enable Voice Video Hardcopy Monitor c/w & alert
	CRT PNL	L-10	Power on Select Disp. mode P/L CDMS Adj. line contrast Adj. contrast Adj. Brightness Adj. Camera pointing Reset Event Timer Event Timer Controls as reqd.
	AFT Bulkhead	A-4	Umbilical Power On Connect Latch
	Keyboard	L-11	Input Commands Per Sequence
	CRT PNL	L-10	Monitor FFTO Checkout Status

TASK	C/D	PNL	C/D FUNCTION
	Keyboard	L-11	Set FFTO Systems to Standby
2. Deploy FFTO (Activate and Verify FFTO Systems Attached to RMS)	FFTS	A-4	Battery . Bus feed-on . Select-PRI . Charger-Off
	Aft Bulkhead	A-4	Umbilical Power-On Disconnect Unlatch
	Keyboard	L-11	Input Commands to Activate FFTO System
		L-10	Monitor CRT Adjust as Necessary
	Stereo Monitor PNL	L-12	Cont.-Vehicle Move Auto Trans. Rate - 1.6 FPS
	Propulsion System	A-4	System on Blow down as required Manipulator/Isol - as required Thrust-Enable/Safe Thrust-High Manifold-Select as required
	Attitude Control System	A-4	Rate Gyro-On CMG-On CMG-Release Rate/Change-On Range-Translate

TASK	C/D	PNL	C/D FUNCTION
			Attitude-Hold Disc. Rate-High
	Aft Bulkhead	A-4	Rf System . as required . antenna sector as reqd.
	Stereo Monitor PNL	L-12	Camera Control . lights - as required . power-on . zoom-as required . focus-as required . Iris-as required . ALC-as required
	Translation/Attitude Cont.	L-12	Actuate as required
4. Coast to P/L	Stereo Monitor PNL	L-12	Propulsion System . Thrust-low . Manifold Select as reqd.
			Camera Controls as required
			Trans. Rate - 0.6 FPS
5. Decelerate to P/L	Stereo Mon. PNL	L-12	Propulsion System . Thrust-Safe . Manifold Select as reqd. . Camera Control as reqd. . Transl. Rate - 0.2 FPS
6. Stabilize/Stand-off	Stereo Mon. PNL	L-12	Propulsion Power System . Manifold Select as reqd.

TASK	C/D	PNL	C/D FUNCTION
Stabilize/Stand-Off, Cont'd.			Attitude Control System . Range-Hold
			Camera Control System . Adjust as required
		L-10	Cross Hair . Set Horizontal . Set Vertical
7. Acquire Target Docking Interface	Stereo Mon. PNL	L-12	Translation Control. Attitude Controller as Required Camera Controls as Required
8. Dock	Stereo Mon. PNL	L-12	Propulsion System . Thrust-Enable . Manifold-as required
			Adjust Translation & Attitude Controls as required
			Attitude Control System Range Translate
			Camera Controls as required
			Manipulator Despin . Grip-Open . Cluth-In

TASK	C/D	PNL	C/D FUNCTION
8. Dock, Contd.			Observe Status Lights Docking . Arm . Latch Observe Status Lights Deactivate Propulsion System
9. Activate Manipulator System	Stereo Mon. PNL	L-12	Control . Manipulator Manipulator-On Camera Control as required Actuate translation and attitude conts. as necessary
10. Service Payload	Stereo Mon. PNL	L-12	Camera Control as required (including camera pointing system) Translation and attitude controllers as required
11. Checkout Servicing	CRT PNL	L-11	Activate CRT . Power on . Reset Event Timer . Event Timer Controls as required Select Mode . P.L. Coms

TASK	C/D	PNL	C/D FUNCTION
11. Checkout Servicing, Contd.			Adjust Brightness, Contrast, Line Contrast, as required Input commands to P/L to Checkout Servicing
12. De-Activate Manipulator	Stereo Mon. PNL	L-12	Manipulator Despin . Grip-open . Clutch-as required Attitude Controllers translation controllers as reqd. to retract manipulator Camera Controls as required Control-Vehicle FFTS PNL-Manipulator off
13. Undock	Stereo Mon. PNL	L-12	Contact-Safe Latch-Unlatch Propulsion System . on . thrust . thrust-enable . thrust-low . manifold-select as reqd. Attitude Cont. System Range/Rate-on Range-translate Attitude-hold Disc. Rate-High

TASK	C/D	PNL	C/D FUNCTION
13. Undock, Contd.			Attitude & Translation Controllers as required
14. Translate FFTO to Orbiter	Stereo Mon. PNL	L-12	Propulsion System . thrust-high . Manifold-as required Translation-1.6 PFS Mode-Auto Actuate translation and attitude controllers as reqd.
15. Stabilize & Standoff	Stereo Mon. PNL	L-12	Transl. Rate-0.2 FPS Propulsion System . Thrust-low . Manifold select as reqd. Attitude control . Range-hold . Attitude-hold Actuate translation and attitude controllers as required
16. Post Capture by RMS	Stereo Mon. PNL	L-12	Propulsion System . off Attitude Control System . off
	Keyboard	L-11	Command FFTO Systems to Standby

TASK	C/D	PNL	C/D FUNCTION
17. Deactivate FFTO in Cargo Bay and Stowage	Aft Bulkhead	A-4	Umbilical Connect Umbilical Power-on Latch
	Stereo Mon. PNL	L-12	Battery Bus Feed-off Charger-on
	Keyboard	L-11	Command FFTO Systems-off