(NASA-CR-150877) DEVELOPMENT OF USER GUIDELINES FOR ECAS DISPLAY DESIGN, VOLUME 1 Final Report (Essex Corp., Huntsville, Ala.) 29 p HC A03/MF A01 CSCL 09B

N79-15675

Unclas
G3/61 42217

ESSEX

ESSEX CORPORATION • 201 North Fairfax Street, Alexandria, Virginia 22314

ESSEX

FOREWORD

This report describes the results of a six month study performed by the Essex Corporation to develop user guidelines for Spacelab Experiment Computer Application Software (ECAS) display design and command usage.

The final report is submitted in two parts: Volume I describes the activities associated with the development of the Spacelab ECAS Display Design and Command Usage Guidelines Document; and Volume II discusses the tasks associated with the development of Spacelab capability descriptions and the development of written matter relevant to specific science fields. Technical direction for the effort was provided by Mr. Paul T. Artis (EL15), Mr. Ronald Schlagheck (EL12), Mr. Leon B. Weaver (JA71), and Dr. Richard Chappell (ES53).

ACKNOWLEDGEMENTS

The authors with to thank Messrs. Paul Artis, Ronald Schlagheck, and Mr. Harry Watters for their guidance and direction during this effort. The authors also wish to thank Mr. Bob Bell of the University of Alabama in Huntsville for his efforts in conducting the initial literature survey and to Messrs. David Robinson and Steve Jefferies of Computer Sciences Corporation for their efforts in developing the software for the basic research evaluations on the Data Display System (DDS) simulator. A special thanks is extended to the test subjects who participated in the basic research and to the many people who reviewed the guidelines document and offered valuable suggestions concerning the content of the final document.

ESSEX

TABLE OF CONTENTS

ESSEX

LIST OF FIGURES

LIST OF TABLES

ESSEX

ACRONYMS

COR	Contracting Officer's Representative
CRT	Cathode Ray Tube
DEP	Dedicated Experiment Processor
DDS	Data Display System
DDU	Data Display Unit
ECAS	Experiment Computer Application Software
ECOS	Experiment Computer Operating System
ERD	Experiment Requirements Document
IIA	Instrument Interface Agreements

1.0 INTRODUCTION

During Spacelab flights, control and monitoring of experiment operations and scientific data gathering will be augmented by the use of an onboard Spacelab experiment computer. The payload crew's interface with this computer and/or dedicated experiment processors (DEP) for experiments which require active control and monitoring will be accommodated by a special data display system (DDS). This data display system will consist of an interactive keyboard and data display unit (DDU) including a CRT display monitor.

1.1 BACKGROUND

The information presented in the Spacelab Experiment Requirements Document (ERD) and the Instrument Interface Agreements (IIA) indicated that Spacelab experimenters were developing Experiment Computer Application Software (ECAS) displays and command scenarios without being fully aware of all the DDS capabilities and services provided by the Expriment Computer Operating System (ECOS). The existing documentation on the DDS and ECOS was prepared from a specifications and requirements standpoint that did not present an approach for the utilization of those capabilities from a man/systems interface point-of-view. The man/systems interface was largely being ignored in the initial development of ECAS displays. Without some commonality concerning the utilization of the ECOS services and DDS capabilities among different experiments, training and flight operations could develop into a problem.

1.2 SCOPE

The purpose of this effort was to develop ECAS display design and command usage guidelines which if followed by Spacelab experimenters would standardize the crew/experiment interface among different payloads by providing standard methods and techniques for data presentation and commanding via ECAS. These guidelines would provide some commonality among experiments which would enhance crew training and flight operations.

The guidelines developed during this effort are applicable to all onboard experiment displays, whether allocated by ECAS or a DEP. The ECAS Display Design and Command Usage Guidelines document includes a brief description of the Spacelab DDS characteristics and of the services provided by the ECOS. Guidelines concerning data presentation and layout of alphanumeric and graphic information are presented along with guidelines concerning keyboard commanding and command feedback.

ESSEX

2.0 DEVELOPMENT OF ECAS DISPLAY DESIGN AND COMMAND USAGE GUIDELINES

The primary objective of this effort was the development of a guidelines document which could be used by Spacelab experimenters and display designers to standardize the crew/experiment interface among different payloads. Spacelab Experiment Computer Application Software (ECAS) Display Design and Command Usage Guidelines, MSFC-PROC-711, was prepared and delivered to the COR for distribution. The guidelines presented in this document were developed using such methods as survey of existing literature, empirical studies on the DDS simulator, the personal experience of the authors on the DDS simulator, extensive review of the guidelines by crew systems/flight operations personnel, and validation of the guidelines using a typical Spacelab I experiment. The following paragraphs discuss the major activities concerning the development of the guidelines.

2.1 REVIEW OF SPACELAB DDS CAPABILITIES

The Spacelab Data Display System Equipment Specification, MATRA ESPACE document EQ-MA-0010, was reviewed to determine the characteristics of the DDS. Although the intent of the guidelines document was to present guidelines and not a description of the system capabilities, it was necessary to include some description of the system capabilities so that the document user would fully understand the meaning of the guidelines. Table 2-1 presents the DDS characteristics that were initially condensed from the DDS specification. These characteristic were then examined to determine which were appropriate to describe in the guidelines document (i.e., those relating to the display of information to the crew) and those that required the development of guidelines concerning their usage. Only those characteristics that were important to the crew/DDS interface were included in the final guidelines document.

2.2 ECOS DISPLAY SERVICES

Since the display of information on the DDU is controlled by the ECOS, it was important to include a brief explanation of the display services provided by ECOS. The intent of including this type of information in the guidelines document was not to provide a complete description of all ECOS services but just to provide a general description of the ECOS services as they related to the display of information on the DDU. More detailed information could be found in the ECOS Requirements Document and the Software Users Guide.

Since many of the man/systems interface requirements of ECOS were being reviewed and updated during the conduct of this effort, the existing ECOS documentation did not reflect the latest status of ECOS man/systems interfaces. In order to insure that the guidelines document reflected the latest information available concerning the status of ECOS, it was necessary to stay cognizant of ECOS man/systems design changes as they occurred. This was accomplished by

ESSEX

Table 2-1: DDS Characteristics

Display Screen Size, diagonal measure	305mm
Display Aspect Ratio	4:3
Display Useful Area	16mm x 212mm
Symbols Capacity per Display	1024
Symbols Available	128
Symbol Size, Standard	4.8 x 3.2mm
Symbol Size, Enlarged	7.7 x 5.1mm
Symbols Per Line, Capacity	47
Lines Per Display, Total	22
Lines Per Display, User Available	17
Separation of Symbols	
Standard Between Characters	1.1mm
Between Lines	1.6mm
Enlarged Between Characters	1.7mm
Between Lines	2.6mm
Colors Available	3: Red Yellow Green
Intensity Levels of Green	2: High Low
Flash Rates	1 Hz (.5 on/.5 off)
Dashing Duty Cycle	2mm on/off
Vector Points Addressable	256 (Y) x 512 (X)
Matrix Size	820 x 620
Refresh Rate	60 Hz
Memory Size of Buffer	1024 words @ 16 bits
Illumination, ambient	30 Lumens/M^2
Brightness Uniformity	$\pm$20%
Contrast	2.5 to 1 $\pm$ 25%
Resolution Line Width	.50 Red .35 Green

attendance at and participation in ECOS preliminary design review board meetings and ESA/MSFC/JSC flight operations reviews. ECOS design changes were reflected in the guidelines document as they were approved.

2.3 LITERATURE SURVEY

The initial effort in developing guidelines for display design was directed at performing a survey of existing literature to determine if information obtained during previous CRT information display studies could be applied to the development of guidelines for the use of the Spacelab DDS. Mr. Bob Bell of the University of Alabama, Huntsville consulted with Essex in the performance of this literature survey. His familiarity with existing literature through graduate thesis work concerning the display of information on a CRT made his assistance desirable. Mr. Bell's literature survey indicated that most previous studies had dealt with systems design characteristics that were already established by the DDS specification and were therefore beyond the scope of this effort. Copies of the literature survey may be obtained from the COR or from Essex' Huntsville office.

2.4 EMPIRICAL STUDIES ON THE DDS SIMULATOR

In addition to the information obtained from the literature survey, personal experience on the DDS simulator, and review comments by crew system/flight operation personnel, empirical studies on the DDS simulator were used to develop valid guidelines for display design and command usage. Such display parameters as information location, display density, data organization, status presentation, and dynamic update effects were evaluated during research studies on the DDS simulator. The following paragraphs describe the objectives and results of the empirical studies conducted during this effort.

2.4.1 Information Location and Display Density

The first study conducted during this effort dealt with the optimum location of information on the display and the effect of display density on operator performance time and error rates regarding status recognition. During this evaluation 20 test runs (five subjects - four replications each) consisting of 150 questions each were conducted.

In this evaluation, the parameter dealing with information location had five levels corresponding to the four quadrants of the available display area and a fifth "quadrant" being defined as the physical center of the available display with an area equal to the size of a quadrant. This enabled evaluation of peripheral and central locations for data display. Three data densities, corresponding to 30%, 50%, and 70% of available characters were investigated with 0% being a blank screen and 100% being every user available character space filled. Data densities were uniform within the "quadrants" such that density in any one "quadrant" did not vary from the tested density ($\pm 1\%$).

Figures 2-1, 2-2, and 2-3 present the three displays used during this evaluation. During a test run, the test subjects responded to questions

```
AEPI COMMANDS                        70 PERCENT DSPLY
1 EMERGENCY PARK=YES/NO       6 START=YES/NO
2 MOUNT CHECK=YES/NO          7 EDIT=YES/NO
3 SW CHECK=YES/NO             8 SELF DUMP=YES/NO
4 RUN=YES/NO        43:4      9 SW RELOAD=YES/NO
5 HALT=YES/NO                10 CALIBRATE=YES/NO
                  126:26:48      XRAY=ON
FO SEQUENCE 11 1A-774:12:36      15 2C-445:35:43
            12 1B-785:48:50      16 03-451:19:42
63 XLG2     13 2A-930:15:28      17 04-287:23:51
            14 2B-300:56:41      18 05-515:21:20
08-288:28:26      432:48:56 DELAYED
19 FW0=73     23 FOCUS=15       27 TRACK=YES/NO
20 FW1=83     24 CAM HV=2       28 RAY=90
21 FW2=61     25 PCA HV=9       29 MPD DELAY 88
22 FOV=14     26 EXP TIME=1     30 RESET=703



WHAT IS THE TIME VALUE OF 1A >
```

Figure 2-1: Seventy Percent (70%) Density Display

```
CMDS
1  FAULT CK=YES/NO                    6  SRT=YES/NO
2  VAL CK=YES/NO                      7  FC=YES/NO
3  START=YES/NO                       8  TEST SELF=YES/NO
4  CAL=YES/NO                         9  RESTART 1=YES/NO
5  STOP=YES/NO                       10  POWER=YES/NO

FO SEQ        11  1A-870:16:14       14  2B-801:41:48
              12  1B-411:21:23       15  2C-958:46:50
              13  2A-582:49:10       16  03-391:35:21
08 675:48:58
19 PAO=28         23 AMPER=12        27  SIGNL=YES/NO
20 PBO=40         24 HI VLT=2        28  FOV=7
21 PCO=26         25 LO VLT=4        29  MSG RELAY=61
                  26 HOLD OFF=1      30




WHAT IS THE VALUE OF ITEM 23 >
```

Figure 2-2: Fifty Percent (50%) Density Display

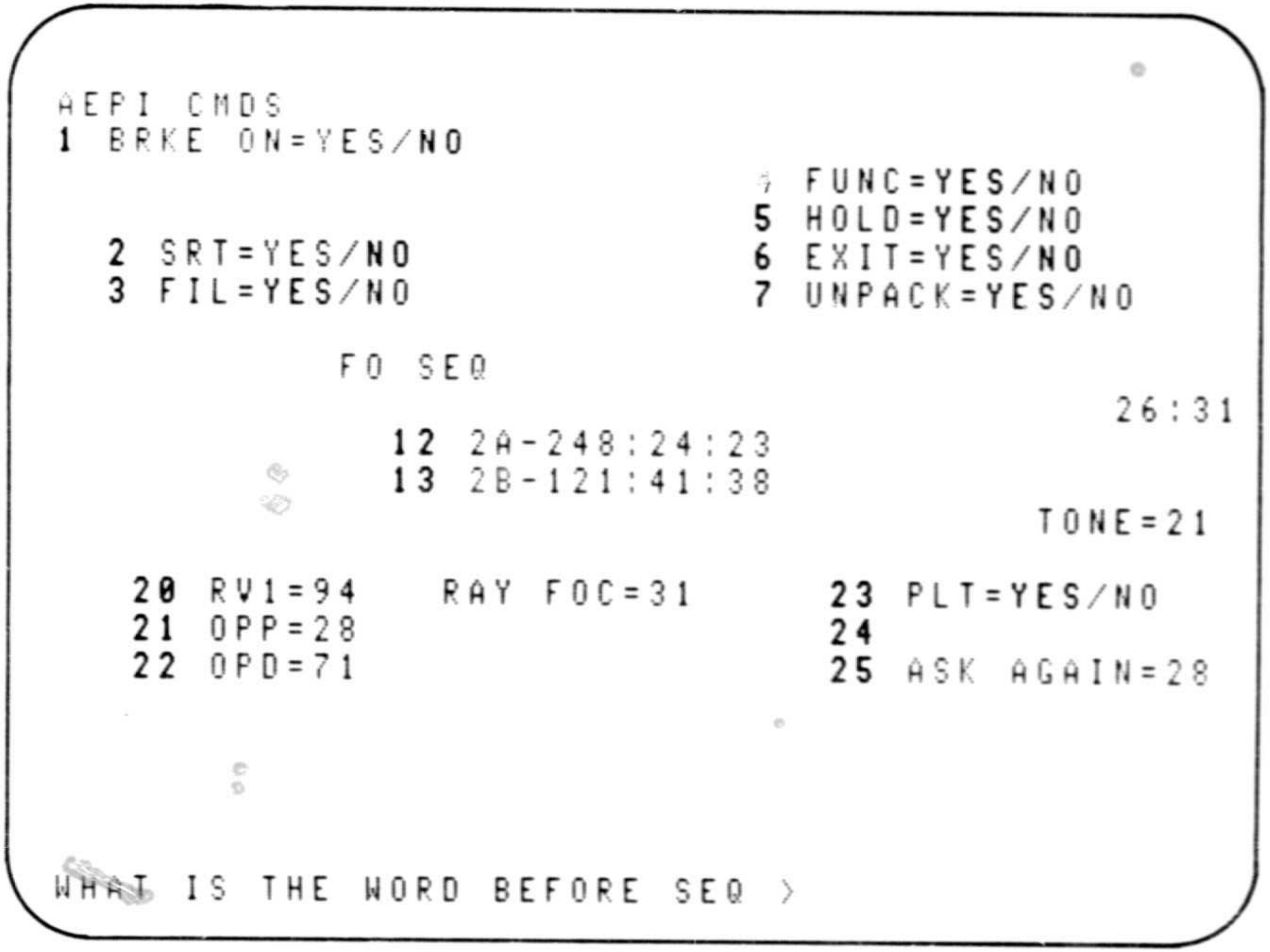

Figure 2-3: Thirty Percent (30%) Density Display

presented on the message line (i.e., last line of the display) by first hitting the keyboard space bar and then typing in the appropriate response. Hitting the keyboard "enter" key completed the input and brought up the next question. Responses to the questions were contained within the data presented on the display. Subjects were instructed to search the display for the correct response prior to initiating their keyboard input. A total of 150 questions were presented during a test run with the display updating (i.e., density changing) after every tenth question. Although each run contained the same 150 questions, the questions and display densities were presented on a strictly random basis during each test run.

Figure 2-4 presents the effects of display density on the response time to locate and identify responses to a block of ten questions. As can be seen from this figure, response time as a function of display density is an exponential function with times rapidly increasing as display density exceeds 60%.

In terms of error rates and information location on the display, no significant results or trends could be determined from the evaluations. Status recognition errors were minimal and appeared to be random in nature without regard to display density or information location. In terms of information location, data presented in the lower right quadrant had slightly lower response times than the other quadrants. However, this was attributed to the location of the question presentation, rather than any other difference among the quadrants.

2.4.2 Data Organization, Status Presentation, and Dynamic Density

A second study was conducted on the DDS simulator which dealt with display parameters concerning data organization, status presentation, and dynamic density (i.e., per cent of display parameters actively updating). This study was structured similarly to the first test with five subjects repeating four replications for a total of 20 test runs. Each test run consisted of 90 questions.

During this test, two displays consisting of three columns each were used. These displays are shown in Figures 2-5 and 2-6. The display parameters in Figure 2-5 were functionally organized by instrument while those presented on Figure 2-6 had no functional arrangement. The six columns on the displays corresponded to four discrete status presentation methods and two arrangements of numerical information. In Column 1 the present discrete status was indicated by an asterisk. Overbright green indicated the state in Column 2. Column 3 values were arranged without regard to decimal location. In Column 4 the parameter identifier was displayed in overbright green to indicate "active" states. Only the current states were presented in Column 5 with "active" states displayed in overbright green and "passive" states in normal green. Column 6 values were displayed with only two significant digits to the right of the decimal.

Dynamic density was another variable that was investigated during this evaluation. The percentage of the parameters on the displays that were being actively updated was varied at 15%, 50%, and 85% to determine the effects of dynamic density on response times and error rates. Upon presentation of a

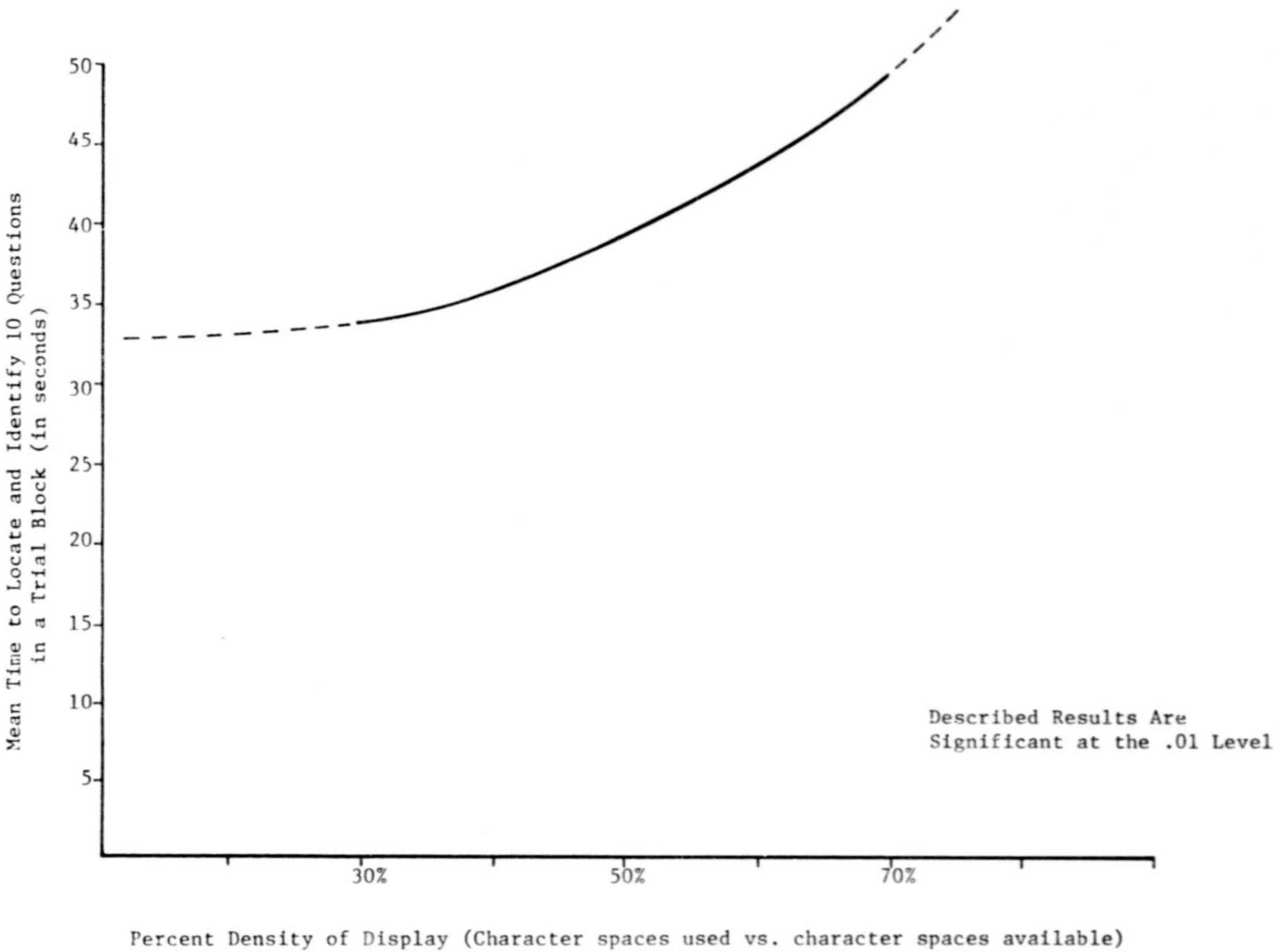

Figure 2-4: Mean Response Time to Locate Answers to Ten Questions As A Function of Display Density

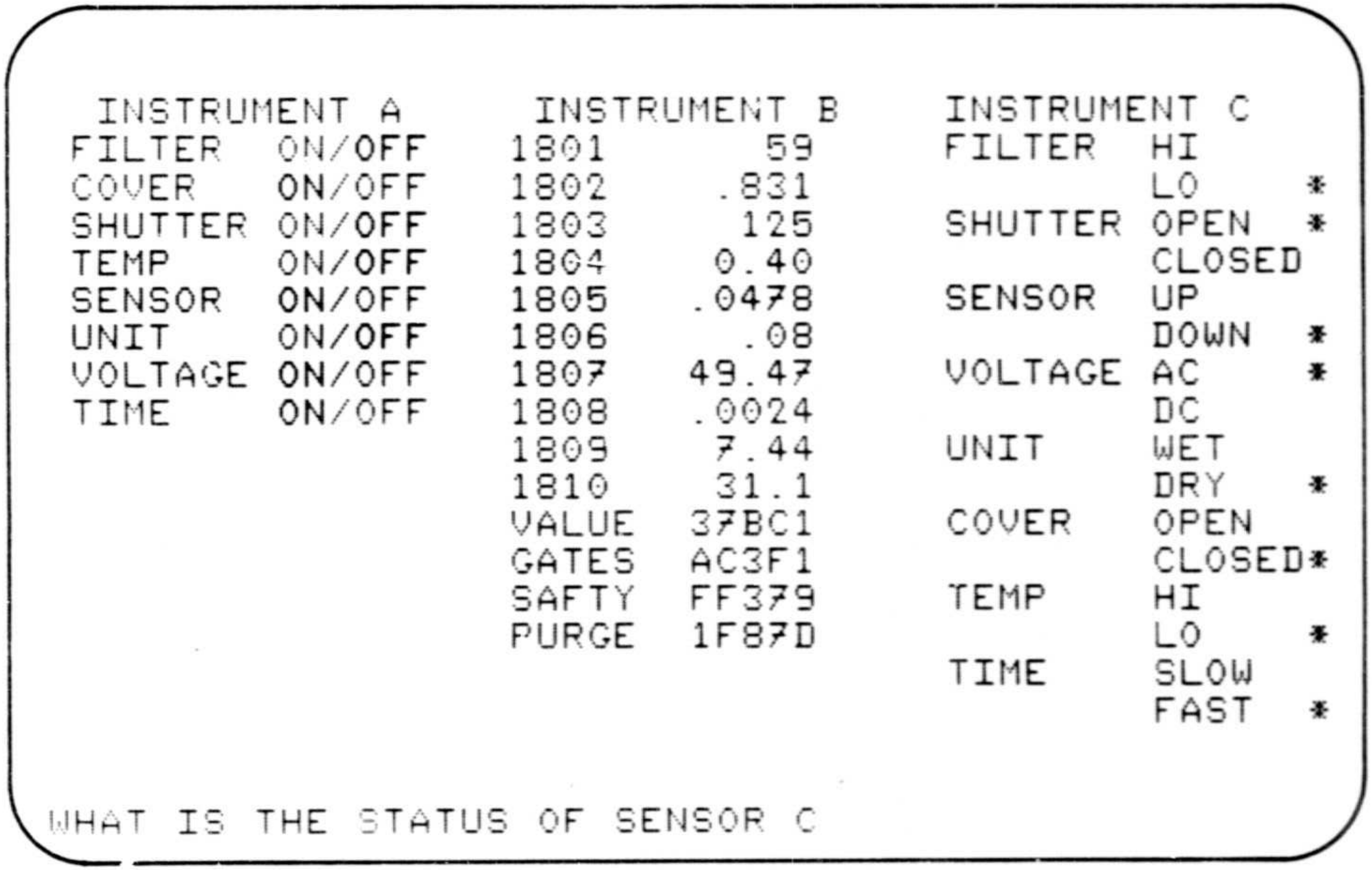

Figure 2-5: Display Functionally Organized By Instrument

SYSTEM	STATE	SYSTEM	STATE	SYSTEM	STATE
IRIS	OPEN	FILTER	A	UPR LM	6.38
SHUTTR	OPEN	SENSOR	A	LWR LM	1.75
COVER	CLOSED	HI VLT		TOLER	.33
MANUAL	ON	OP VLT		TEMP A	29.16
X-AXIS	WET	FILTER	B	TEMP B	29.66
Y-AXIS	WET	SENSOR	B	0301	C1A46
Z-AXIS	WET	INSTMT		0302	F001B
TAPE	OFF	RECORD		0303	FA7C5
TRNSMT	TRUE	PRI		0304	883FE
RCV	FALSE	SEC		TIME	48:34

WHAT IS THE STATUS OF FILTER B

Figure 2-6: Non-Functionally Organized Display question, the appropriate number of display parameters continued to update until the subject had located the response and hit the space bar to initiate a keyboard input. Six questions were presented before the display and update density were changed. The arrangement of the columns on the displays was also changed each time a new display was presented. Again questions, displays, and dynamic densities were presented to each subject in a random order.

As can be seen in Figure 2-7, the mean response times for parameters located in Columns 1, 2, and 3 (i.e., columns that were functionally arranged according to equipment) were lower than the response times for Columns 4, 5, and 6 (i.e., columns that had no functional arrangement). The peak in mean response time indicated for Column 4 can probably be attributed to the fact that parameters presented in this column did not have a state code displayed with the parameter. Subjects had to translate the color of the parameter identifier into a state code (i.e., parameters presented in overbright green were considered on, and parameters presented in normal green were considered off). Figure 2-8 presents the effects of dynamic display parameters on response times. Virtually no difference in response times was detected dependent upon the percentage of display parameters that were actively updating. This can be explained by the fact that the parameter identifiers remained static regardless of whether the state changed.

As in the first test, no conclusions could be drawn from the error rate data. Errors were minimal and appeared to be random in nature without regard to any of the independent measures being evaluated.

2.5 GUIDELINES VALIDATION

Before final publication of the display design and command usage guidelines, the guidelines were applied to the design of a typical Spacelab I display to determine their validity. Experiment 1NS003, Atmospheric Emissions Photometric Imaging (AEPI) was selected for this validation because its requirements included both information display and command inputs and because of the availability of information on the AEPI display requirements. Working with flight operations personnel and the experiment principal investigator, recommendations were formulated for an AEPI display which applied the guidelines developed during this effort. The recommended AEPI display (Figure 2-9) and command input recommendations were accepted by the experiment principal investigator without comment. The recommendations were also reviewed by the Spacelab I Mission Specialists and accepted without change. The AEPI display and command input recommendations are presented in Appendix A.

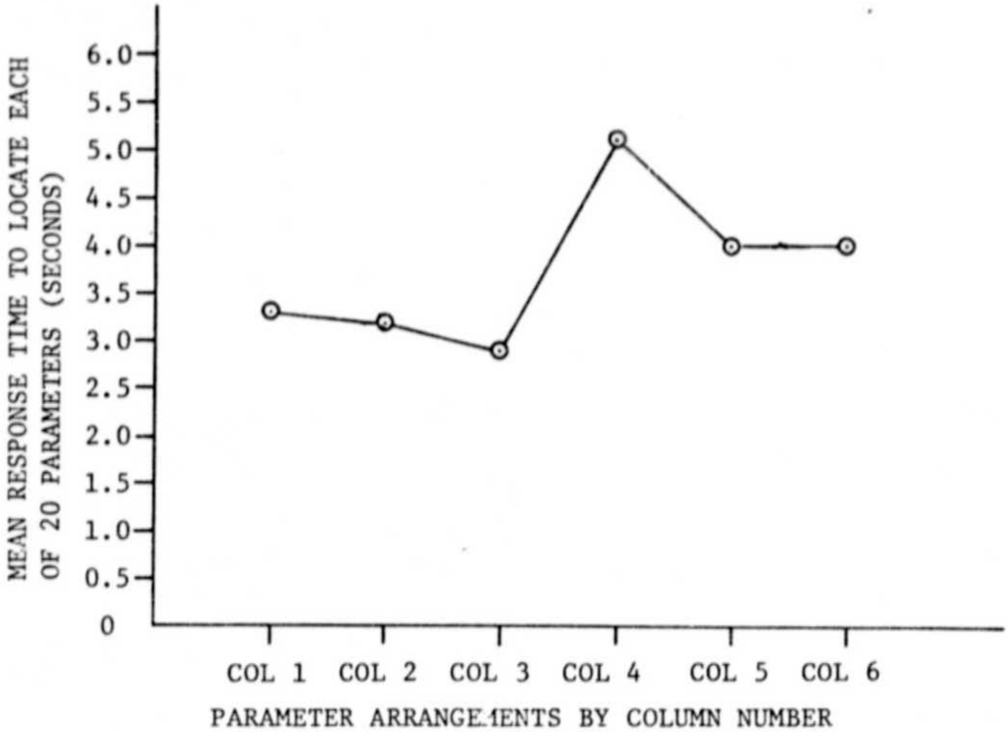

Figure 2-7: Mean Response Time as a Function of Parameter Organization and Presentation of Status

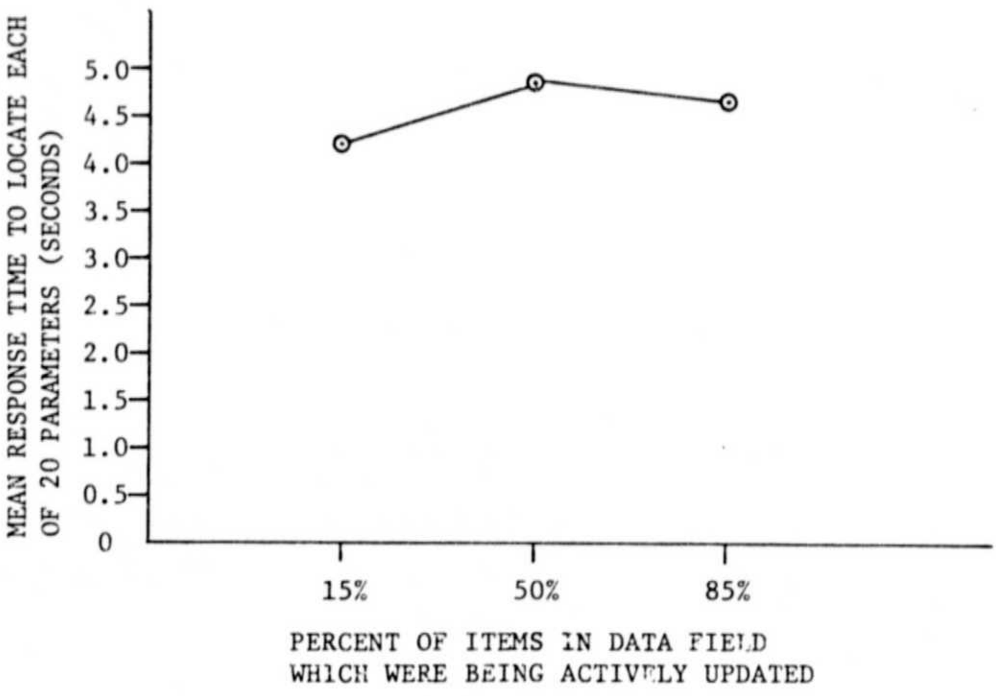

Figure 2-8: Effects of Dynamic Display Parameters on Mean Response Times

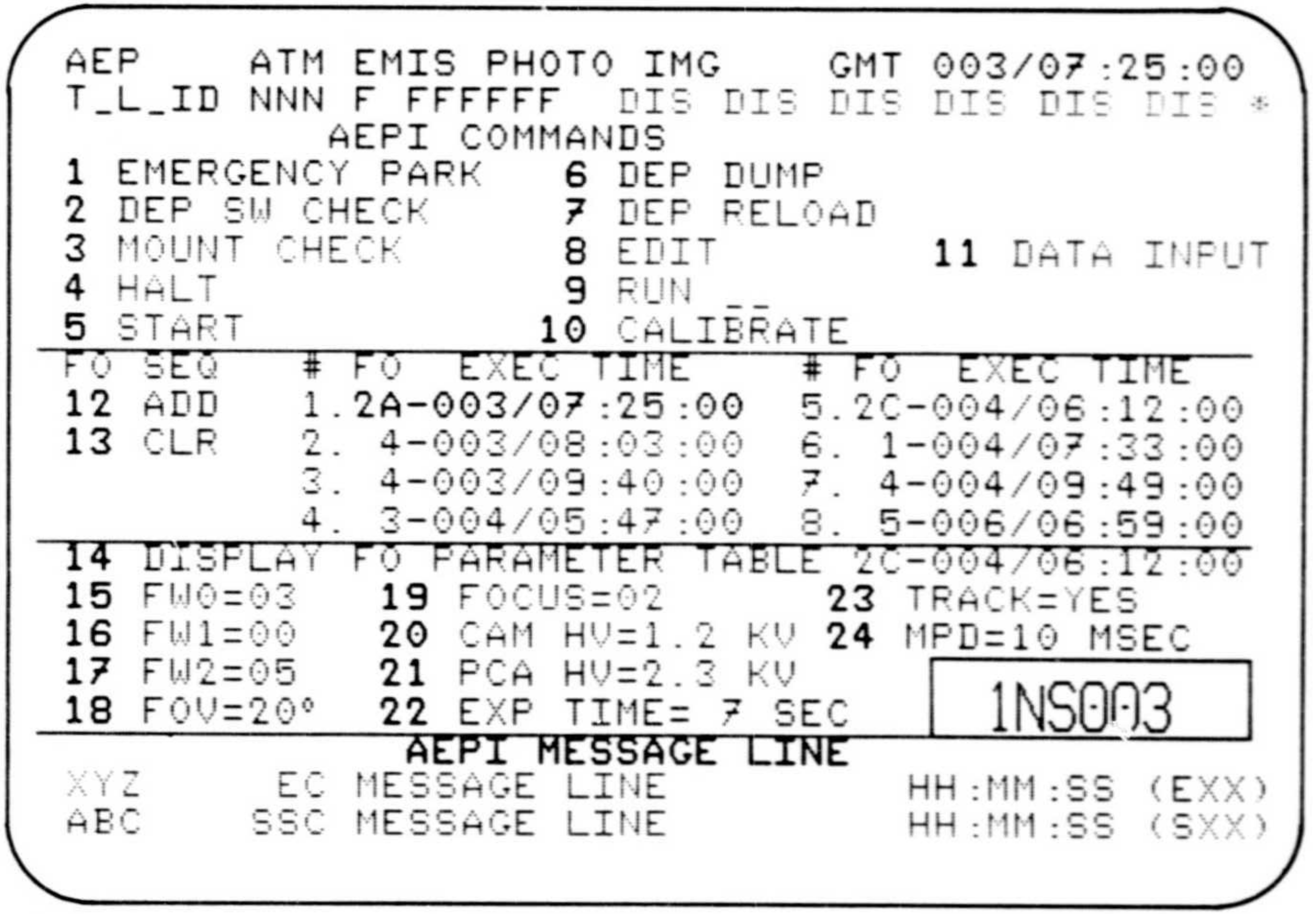

Figure 2-9: AEPI Experiment Display As Developed From Guidelines

3.0 SUMMARY

The primary output of this effort was the development and publication of the Spacelab Experiment Computer Application Software (ECAS) Display Design and Command Usage Guidelines document, MSFC-PROC-711. The guidelines presented in this document, while not given as strict requirements, explained recommended methods and techniques for presenting data from the ECAS programs via the DDS to the payload crew. The document primarily deals with man/system interface guidelines. No attempt was made to analyze the impact of these man/system interface guidelines on other considerations such as memory conservation, etc. In some cases the display designer may be forced to make tradeoffs between memory management considerations and man/system interfaces. Although an attempt was made to present guidelines for all foreseeable display data presentation situations, it is expected that individual experiments may have unique situations for which no specific guidance was offered. In such cases, ECAS designers are urged to keep in mind the crew interface point-of-view rather than the programmer's.

ESSEX

APPENDIX A

AEPI DISPLAY AND COMMAND INPUT RECOMMENDATIONS

Display mnemonic: AEP

Display title: ATM EMIS PHOTO IMG

Display initializes with the next eight scheduled FO's and their execution time in GMT displayed in the FO SEQ table. The FO's are temporally ordered 1 thru 8 according to execution time.

The AEPI display is divided into three sections (Command Input, FO Sequence Table, and FO Parameter Table). Display areas are divided by solid normal intensity green vectors. The display is used primarily for preparation prior to an experiment operation sequence. During this preparation time software and mount checks will be performed and the FO sequence and FO parameters will be modified for the next eight scheduled FO's.

The following describe the syntax and function for each of the ITEM # command inputs from the AEPI display.

1. ITEM 1 EMERGENCY PARK

   Syntax: ITEM 1 ENTER

   Function: Executes the Emergency Park routine in the DEP software. This routine safes the instrument in a stowed and locked position.

   Command Feedback Messages: IN PROGRESS while emergency park routine is executing. Upon completion of routine, message should change to COMPLETE.

   Note: Messages are output on the AEPI Message Line (line 19 of the user defined area). All messages will be output in yellow.

2. ITEM 2 DEP SW CHECK

   Syntax: ITEM 2 ENTER

   Function: Executes software check routine in DEP to verify DEP software.

Command Feedback Messages: If software check is not satisfactory error messages (TBD) will be output on AEPI message line. If software check is satisfactory, COMPLETE message will be output on AEPI message line.

3. ITEM 3 MT CHECK

Syntax: ITEM 3 ENTER

Function: Executes Mount Check routine in DEP software to verify operation of mount.

Command Feedback Messages: IN PROGRESS while routine is executing and COMPLETE after mount check routine is completed.

4. ITEM 4 HALT

Syntax: ITEM 4 ENTER

Function: Halts execution of currently executing program in the DEP. Program is placed into a loop cycle.

Command Feedback Messages: HALTED

5. ITEM 5 START

Syntax: ITEM 5 ENTER

Function: Continues execution of halted DEP software program.

Command Feedback Messages: STARTED

6. ITEM 6 DEP DUMP

Syntax: ITEM 6 ENTER

Function: Dumps the entire DEP memory to the HRM for downlink. Note: This is not a normal ECOS DEP dump but a direct link from the DEP to the HRM.

Command Feedback Messages: IN PROGRESS while dump is in progress, changing to COMPLETE when dump is completed.

Note: This command might be executed if the software check was not satisfactory. Memory would be dumped to ground for analysis.

7. ITEM 7 DEP RELOAD

Syntax: ITEM 7 ENTER

Function: Reloads the DEP software from the MMU.

Command Feedback Messages: IN PROGRESS while load is taking place, changing to LOADED when load is complete.

8. ITEM 8 EDIT

Syntax: ITEM 8 ENTER

Function: Executes tutorial edit program to edit the DEP software. Tutorial messages/questions will be output on the AEPI message line. The crewman will respond to these messages via ITEM 11, DATA INPUT. Typical inputs might include a memory address, change in memory, etc., or edit complete.

Command Feedback Messages: Messages will consist of tutorial messages/questions output on AEPI message line.

9. ITEM 9 RUN

Syntax: ITEM 9_ Run # ENTER, where Run # is a two digit number 1 thru 99 which will select a predefined program to execute in the DEP. These will also be tutorial programs in which the crewman will input data in response to messages via ITEM 11, DATA INPUT.

Function: Selects and executes the indicated program in the DEP. These programs will be tutorial with data input by the crewman using ITEM 11. A typical program will be one to input the ephemeris.

Command Feedback Messages: The indicated Run # will be displayed immediately following ITEM 9 RUN while the program is executing. Tutorial messages/questions will be output on the AEPI message line. The Run # will be removed from the display when the program execution is completed.

10. ITEM 10 CALIBRATE

Syntax: ITEM 10 ENTER

Function: Executes the Calibration routine in the DEP software.

Command Feedback Messages: If input is accepted next tutorial message in program will appear. Syntax error messages will be output if input is not valid.

The following describe the command inputs associated with the FO SEQ table. The FO's and their Execution Times in CMT will be displayed in normal intensity green. If one of the FO's should execute while the display is up on the DDU, that FO and its Execution Time will be displayed in overbright green. Note that this is not likely to occur since this display will normally only be displayed on the DDU during a preparatory cycle and not during actual experiment operations.

12. ITEM 12 ADD

Syntax: ITEM 12_FO#_ Exec Time ENTER, where FO# is the FO you wish to add to the eight currently scheduled FO's and Exec Time is the GMT time this FO will execute.

Function: Adds the indicated FO and Exec time to the FO SEQ table. The table will be searched and the new FO will be added in temporal order. The FO that was listed 8th in the table will be cleared to make room for the new FO.

Command Feedback Messages: FO SEQ table will be reordered to indicate change.

13. ITEM 13 CLR

Syntax: ITEM 13_ Ent # ENTER, where Ent # is the entry number (1 thru 8) corresponding to the FO and Exec Time you wish to clear from the FO SEQ table.

Function: Clears the indicated FO from the FO SEQ table. The indicated FO will be removed from the table and the table will be reordered with the next scheduled FO moving into entry 8 from the master table in the DEP.

Command Feedback Messages: FO SEQ table will be reordered to indicate change.

The following describe the command inputs and display format of the FO Parameter Table.

14. ITEM 14 DISPLAY FO PARAMETER TABLE

Syntax: ITEM 14_ Ent # ENTER, where Ent # is the entry number in the FO SEQ table of the FO that you wish to display the associated parameters.

Function: Displays the parameters associated with the indicated FO in the FO Parameter Table. The displayed parameters may then be modified using ITEMs 15 thru 24.

Command Feedback Messages: Indicated FO and its Exec Time will be displayed immediately following DISPLAY FO PARAMETER TABLE. Associated parameters (either default parameters or last loaded parameters) will be displayed in ITEMs 15 thru 24.

15. - 24. ITEMs 15 thru 24

Syntax: ITEM #_ New Parameter Value ENTER

Function: Change values in the FO Parameter Table. Changed parameters should be displayed in overbright green. Initially all parameters will be displayed in normal intensity green. Parameters should be displayed in engineering units (degrees, volts, seconds, etc) if possible rather than binary numbers.

Command Feedback Messages: New parameters will be displayed in the table as they are changed. Changed parameters will be displayed in overbright green.

Units should be displayed after the parameter value if it is not clear what the units are (i.e., V or KV, etc.)

Note: It will be incumbent upon the receiving ECAS software to verify the validity of the command inputs. If an input is invalid, syntax error messages or numbers must be output on the AEPI message line. If syntax error numbers are used they should correspond to the ECOS syntax error numbers if possible.

Additional Recommendations:

- The experiment number (1NS003) should be displayed in the lower right corner of the display. It should be displayed in large size characters, overbright green and should be outlined (boxed in) by overbright green vectors.

- The ITEM PARAMETER (RUN, EDIT, CALIBRATE, etc.) of the selected Item # command input should be displayed in overbright green. This indicates to the crewman which command he just input. For example, if the crewman just executed the DEP SW CHECK command, it would be displayed in overbright green.