NASA CR 185678 1 of 3

514825

NASA Contractor Report 185678

Payload and General Support Computer (PGSC) Detailed Test Objective (DTO) #795 Postflight Report -- STS-41

Jurine A. Adolf, Benjamin J. Beberness, and Kritina L. Holden

October 25, 1991

CONTRACT NAS9-17900

JSC-25459

LESC-29081

NASA

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ACRONYMS AND ABBREVIATIONS

CDR	Commander
DTO	Detailed Test Objective
EL	Electroluminescent
EMI	Electromagnetic Interference
FC	Foot Candle
GRiD	Graphical Retrieval and Information Display
HCIL	Human-Computer Interaction Laboratory
KSC	Kennedy Space Center
LCD	Liquid Crystal Display
LOS	Line of Sight
MS	Mission Specialist
PGSC	Payload General Support Computer
PLT	Pilot
SPoC	Shuttle Portable Computer
STS	Space Transportation System

ACKNOWLEDGEMENTS

The authors of this document wish to thank Patty Bergquist and Dan Murphy of GRiD Systems Corporation and Pat Wilson of Instrumentation and Processor Applications Branch of Flight Data Systems Division at Johnson Space Center for providing detailed technical information regarding the PGSC display types. The lighting measurements performed by Jennifer Toole are also greatly appreciated.

A special thanks is given to the STS-41 crewmembers: Richard N. Richards (CDR), Robert D. Cabana (PLT), Bruce E. Melnick (MS1), William M Shepherd (MS2), and Thomas D. Akers (MS3). The data received as a result of the crew's effort during the mission will be very important in shaping the future of the PGSC.

Payload and General Support Computer (PGSC) Detailed Test Objective (DTO) #795 Postflight Report--STS-41

ABSTRACT

Since 1983, the Space Transportation System (STS) had routinely flown the GRiD 1139 (80286) laptop computer as a portable onboard computing resource. In the Spring of 1988, the GRiD 1530, an 80386-based machine, was chosen to replace the GRiD 1139. Three display types were available for the GRiD 1530 including: gas plasma, transmissive Liquid Crystal Display (LCD), and transflective LCD. A Human Factors ground evaluation examined the readability of those displays under different lighting conditions and various angle deviations. Although the gas plasma display was found to be superior, it was unable to fly due to qualification problems related to heat dissipation and Electromagnetic Interference (EMI). Due to a lack of these problems as well as lower power consumption, the transmissive LCD display was chosen. Detailed Test Objectives (DTO) for STS-29 and STS-30 examined the usability of the LCD display for the Shuttle environment. Crewmembers conducted a structured in-flight evaluation and filled out a detailed questionnaire. The transmissive LCD proved to be unsuitable during conditions of direct sunlight, large angular deviations from line of sight, and dark adaptation. In 1990, an Electroluminescent (EL) display for the GRiD 1530 became flight qualified and another DTO was undertaken to examine this display on-orbit. Under conditions of indirect sunlight and low ambient light, the readability of the text and graphics was only limited by the observer's distance from the display. Although a problem of direct sunlight viewing still existed, there were no problems with large angular deviations nor dark adaptation. No further evaluations were deemed necessary. The GRiD 1530 with the EL display was accepted by the STS program as the new standard for the PGSC.

1.0 INTRODUCTION

The GRiD model 1139 portable computer (Figure 1), referred to as the SPoC (Shuttle Portable Computer), has been used on the shuttle as the carry-on laptop computer since Space Transportation System (STS) mission number 9 (STS-9), launched in November, 1983. The primary purpose of the portable is to run the SPoC World Map software and other mission-related software. It is deployed early in the mission and stowed 20 minutes before entry. In the Spring of 1988, the GRiD 1530 was selected to replace the SPoC as the Payload General Support Computer (PGSC). Its superior computing power and speed (80386) allowed it to run the traditional SPoC software as well as many new software functions. The PGSC also provided a standard hardware interface for the control of payloads. The World Map program currently displays trajectory status, provides auditory cues for earth observation times, and provides emergency information such as landing opportunities, de-orbit targets, and center of gravity management procedures. In the past, the GRiD has been limited to the display of information, such as the World Map, although, in the future, its usage will expand to meet many other onboard needs.

In addition to technological considerations, such as speed, memory, and storage, one of the most important hardware features to the user is a high quality screen display. The readability of the screen in various lighting conditions and angles is an important consideration in the selection of a display technology.

The GRiD 1139 was equipped with an LCD display. The GRiD 1530 was initially available with a gas plasma, a transmissive LCD, and a transflective LCD. The purpose of the present report is to document evaluations that have been performed on the gas plasma, transmissive Liquid Crystal Display (LCD), transflective LCD, and Electroluminescent (EL) display technologies.

2.0 DISPLAY CHARACTERISTICS

The display characteristics for the gas plasma, transmissive LCD, transflective LCD, and EL display technologies are shown in Table 1.

2.1 Gas Plasma

Gas plasma displays are constructed with an insulating layer over a cathode and anode which are charged each half cycle of the driving waveform

(Bylander, 1979). The gas plasma display shown in Figure 2 appears red/orange on a black background. Each activated pixel is a light source that appears red/orange when activated and black when inactive. Since the pixels are light emitting, the characters formed by the activated pixels appear to be continuous. The ratio of the intensity from the lightest area to the darkest area defines the brightness contrast ratio. It is recommended that the visual field should not have a relative brightness contrast of more than 3:1 (Helander, 1987). The brightness contrast ratio of 20:1 given by the manufacturers for the gas plasma was possibly measured on a single pixel without the protective layers (e.g., glare control, glass) over the pixel. The 2.9:1 ratio measured by human factors personnel is closer to the perceived brightness contrast ratio since it takes into account the effect of these layers on the light that reaches the eye.

Table 1 Characteristics of the Gas Plasma, Transmissive LCD, Transflective LCD, and EL Displays for the GRiD 1530

	Gas Plasma	Transmissive LCD	Transflective LCD	EL
No. of Pixels	640 x 400	640 x 400	640 x 400	640 x 400
Pixel Size (mm)	.19 x .21	.29 x .29	.29 x .29	.22 x .22
Interpixel Dist.	.15 mm	.03 mm	.03 mm	.08 mm
Pixel Pitch (mm)	.34 x .36	.32 x .32	.32 x .32	.30 x .30
Active Area (mm)	217.26x143.85	204.76x127.96	204.76x127.96	191.9x119.9
Contrast Ratio	20:1(2.9:1 M)	1.5:1 (M)	.35:1 (M)	5:1
Wavelength (nm)	595 peak	485 (E)	575 (E)	580 (E)
Display Surface	non-glare	non-glare	non-glare	non-glare
Brightness (fL)	5.5-9.3 (2.9 max.M)	.5-2 (M)	.75-1.1 (M)	11.8 (see text)

Note: Measured (M) or Estimated (E) display characteristics were provided by the authors. All other characteristics were provided by the display manufacturers.

2.2 Liquid Crystal Display (LCD)

The next display type, LCD, consists of transflective and transmissive types shown in Figures 3 and 4, respectively. Typically the LCD displays are comprised of liquid crystals aligned in a parallel axis contained between two electrodes. One electrode must be transparent if a display is viewed by reflected light and both electrodes must be transparent if a display is viewed by transmitted light.

The color of the characters on the transmissive LCDs appear blue since the blue background shows through clear pixels. When the pixel array is inactive, the pixels are not transparent, but rather silver. The transflective LCD has a yellow background that ordinarily shows through the transparent pixel array when inactive. Images are formed by activated LCD pixels which appear silver on the yellow background.

Throughout the range from low light conditions (low enough for dark adaptation to occur) to nominal light conditions (artificial light and/or indirect sunlight), images on the blue LCD appear sharper than images on the yellow LCD. The clear areas between the silver pixels on the yellow LCD show yellow through the letters formed by the silver pixels. Consequently, the letters on the yellow LCD screen have fine vertical and horizontal yellow lines through them. On the other hand, both the pixels, and the spaces between the pixels, are clear for images on the blue LCD screen. The blue background that is transmitted to form the characters is continuous and without the fine lines.

The yellow LCD has a very low brightness contrast ratio of 0.35:1. An observer is able to perceive the foreground from the background on the yellow LCD because of an effect known as "cone contrast". The cone receptors in the retina are particularly sensitive to yellow and very low levels of yellow light will appear brighter than a different color at the same energy level. For example, the blue LCD has a brightness contrast ratio of 1.5:1, but the border area of the blue LCD display does not appear to be brighter than the yellow border.

2.3 Electroluminescent (EL)

The EL display technology is composed of light emitted from a semiconductor material under the direct stimulation of an electric field (Luxenberg, 1967). With an EL display, shown in Figure 5, the foreground appears yellow with a black background. The pixels appear yellow when active and black when inactive.

The pixel dimensions of the gas plasma display are considerably different than the LCDs and EL displays. These differences could have a significant effect on the perceived resolutions of the screens. Although the gas plasma pixels are smaller, the light emitted by an individual gas plasma pixel is diffused at the screen causing the large interpixel distances to be imperceptible. All of the GRiD screens have 10-inch diagonals with equivalent bezels. The EL, as well as the LCDs, has a larger active display area than the gas plasma display.

3.0 PREVIOUS EVALUATIONS

In mid-1988, human factors engineers from the Human-Computer Interaction Laboratory (HCIL) in the Man-Systems Division were tasked with performing a ground evaluation of the three existing display types for the GRiD 1530. Criteria for evaluation were readability under different lighting conditions, various angle deviations from Line of Sight (LOS), and blinking rates of graphical objects. A flight evaluation took place in March of 1989 on STS-29 and was repeated in May of the same year on STS-30 to assess the usability of the transmissive LCD to meet qualifications. A summary of the results and recommendations follows.

3.1 Human Factors Ground Evaluation The first evaluation was conducted on three display types: gas plasma, transflective LCD, and transmissive LCD. Displays were compared on their readability as defined by the maximum distance and angular displacement at which text could be read and graphics identified. A summary of the DTO follows. A more detailed discussion can be found in Jensen and McKay, 1988.

3.1.1 Procedure

To obtain the maximum reading distance, measurements were taken first with the screen perpendicular or normal to the Line of Sight (LOS). Measurements were then taken with the observer positioned such that the horizontal angle between the normal LOS and the observer was increased until the text could no longer be read. In addition to distance and angle, tilt is also important to crew as a result of weightlessness. Therefore, the screen was then tilted in the vertical plane by ten degree increments until the text could not be read. The maximum readability measures were then obtained for the entire set of horizontal increments. Measurements were also taken for two different text sizes, SPoC and character generator sizes, 7 x 5 pixel letters and 14 x 7 pixel letters, respectively. All measurements were completed under low light, normal, and direct sunlight conditions.

3.1.2 Results

3.1.2.1 Low and Normal Light

Under low and normal light conditions, the gas plasma display was the easiest to read for both text and graphics. In fact, the gas plasma could be read at 1.5 times the distance of the LCDs over the visual envelope of the horizontal plane. Readability of the text and graphics on the LCDs decreased as the angle from LOS increased. The gas plasma display was still readable at angles of 65° compared to 30° for both LCDs.

Starting at a 60° vertical angular displacement from LOS, the images on the LCDs appeared to become reversed (light areas became dark and vice versa). Although the displays were still readable, this anomaly was considered to be an unacceptable side effect. At one point in the reversal transition, the images were perceived to disappear altogether.

After becoming dark adapted for 20 minutes, observers looked at one of the displays for two minutes and then looked away towards a dimly lit scene. The gas plasma display did not interfere with the process of dark adaptation. The wavelength emitted from this display does not affect the functioning of the night-vision rods as much as the LCDs. The LCDs caused the dimly lit scene to appear black.

3.1.2.2 High/Direct Light

Under conditions of direct sunlight, high levels of light in the user's LOS or high levels of diffuse ambient light, the gas plasma was unreadable. The readability of the LCDs was good, with the transflective superior to the transmissive display. Those same results occurred when reflections on the screen were present.

3.1.2.3 Blinking

The effect of blinking is achieved by activating and deactivating pixels. The rate of blinking contributes to the speed with which one can locate and identify a flashing image on the screen. The blinking of graphics on the LCDs appears to become active gradually and decay gradually, making it more difficult to locate than on the gas plasma display which appeared to rapidly switch between active and inactive states. The difficulty in locating a blinking icon on the LCDs also increased with increases in the ambient light.

3.1.3 Conclusions

Based on the ground evaluation, it was the recommendation of the HCIL that the gas plasma display be used on all STS flights due to its readability at greater distances and wider range of angles. To make the LCDs acceptable for Shuttle use, modifications to several parameters would be necessary. For instance, the text and graphics would have to be enlarged and simplified due to small contrast levels throughout the range of readability of the LCDs. Enlarging the blinking screen areas for distinctive icons would also be required.

3.2 PGSC LCD Detailed Test Objective (DTO) -- STS-29

Although the gas plasma was not flight qualified due to heat dissipation and Electromagnetic Interference (EMI) problems, it was desirable to evaluate one of the 80386-based computers in-flight. For STS-29, the transmissive LCD was chosen due to a lack of these problems as well as lower power consumption. A Detailed Test Objective (DTO) was performed to study the LCD's suitability for use in zero gravity. A summary of those results follows. However, a more detailed discussion can be found in Hooten & Sanders, 1989.

3.2.1 Procedure

A questionnaire was developed to collect subjective crew input on the LCD. The questionnaire was developed based on concerns identified in the one-g human factors evaluation: (1) limited readability distance, (2) difficulty in identification of graphical details, (3) reverse image effect at larger angular deviations, (4) dark adaptation problems, and (5) difficulty in location of blinking objects. Readability measurements were taken based on three lighting conditions: indirect, direct, and low/no ambient, covering all possible on-orbit situations. General comments and an overall impression of the LCD were also examined.

3.2.2 Results

Five crewmembers provided the subjective measures as follows.

3.2.2.1 Indirect Light

Crew first examined the LCD PGSC under indirect light conditions. When positioned directly in front of the display in the optimal viewing position, the crew reported no problems in the readability of text and graphics including the ground tracks and continental outlines of the World Map display. Some indicated on the questionnaire that blinking was identifiable while others had trouble with the Space Shuttle icon.

When not positioned directly in the LOS, the crew noted an inability to read the text and graphics, or identify the blinking graphical areas. Translating was necessary to improve performance. This required the astronaut to leave the flight deck station located on panel F-3, which is totally unsatisfactory for flight deck operations.

Crew also reported experiencing the "reverse image" effect at large angular deviations. The day and night areas of the Earth on the display were reversed, which was considered distracting and potentially misleading. Translation was also required to correct this problem.

3.2.2.2 Direct Light

The second lighting condition tested by the crew was direct sunlight on the PGSC screen. The highest brightness level in the orbiter is between 8,000 and 10,000 foot candles (fc). The astronauts again assumed various positions around the PGSC. Contrary to the ground evaluation, the display was reported as difficult to read with direct sunlight. The brightness condition used in the one-g evaluation was only 5,000 to 7,000 fc, accounting for the differences found.

3.2.2.3 Low/No Ambient Light

In agreement with the ground evaluation, the transmissive LCD interfered with dark adaptation. The evaluation required the crew to view the World Map for three minutes and then look away. It was not possible to clearly see around the cabin.

3.2.2.4 Comments

The crew noted on the questionnaire that the display was "absolutely unsatisfactory." While the GRiD "may possess more power, it can't communicate and display."

3.2.2.5 Debriefing

In order to rate the overall performance of the LCD, crew members were given a subjective scale from one (poor) to ten (excellent). For the SPoC applications, the crew extended the scale to zero and marked zero as their response. For other applications (e.g., orbital operations checklist), the display ranked a three, but only if it was positioned directly in front of them. The crew was quoted as saying "The display is worthless... ." Its major failure was communication. Other comments ranged from "worthless" to "unacceptable." The narrow viewing angle and image reversal were cited as specific problems.

3.2.3 Conclusions

The results of this DTO supported the human factors ground evaluation which found the transmissive LCD unsuitable for flight operations. The major advantage of the LCD cited in the ground evaluation, the acceptable performance under direct sunlight, proved to be invalid with the intensity of the sunlight on-orbit. The LCD screen washed out except for a small visual envelope.

Although some tasks could be completed, the PGSC must provide readability with casual glances at unpredictable distances and angles. The requirement for crew repositioning has an operational impact and is unacceptable. Without an improved screen, the GRiD is "unsuitable for flight," as quoted by a crewmember.

3.3 PGSC LCD DTO -- STS-30

Since the same hardware was flown on STS-30, a repeat of the above study was done. STS-30 was launched in May of 1989 aboard Atlantis. Results confirmed the inadequacy of the transmissive LCD in all similar aspects of the earlier study.

4.0 PGSC EL DTO -- STS-41

4.1 Purpose

Until 1988, an electroluminescent (EL) display was the standard for the portable GRiD 1139 computers display. The newer 386 GRiD computer was not initially available with an EL display. As the flight qualified EL display became available for the GRiD 1530, it was desirable to repeat the display evaluations performed on STS-29 and STS-30. The following describes the evaluation of the EL during DTO #795 on STS-41 launched aboard the Space Shuttle Discovery on October 6, 1990 from Kennedy Space Center (KSC).

4.2 Procedure

The same type of questionnaire used for the DTOs on STS-29 and STS-30 was chosen for this evaluation (see Appendix A). Astronauts were directed to position the GRiD EL display in various locations. Lighting was varied from direct sunlight, indirect sunlight, and no light. For each of the lighting conditions, the crew was asked to view the World Map display directly and assume various station positions on the flight deck as well. For the conditions of direct and indirect sunlight, the crew was asked about their ability to read the text and graphics and readily identify blinking objects. They were also asked if and how they translated to see the display. Under the dark adaptation condition, the questionnaire queried the crew about the effects of viewing the screen and the necessity of remaining adapted to the dark. The questionnaire ended with general questions about the overall performance of the PGSC.

4.3 Results

The crewmembers provided the subjective measures as follows.

4.3.1 Indirect Light

When indirect light was available, the crew was asked to place the PGSC on panel F-3. When positioned directly in front of the screen, all reported they were able to read the information. It was also possible to readily identify the blinking Shuttle picture on the World Map.

When asked to assume the various station positions on the flight deck, crew had no trouble seeing the graphics, but had some trouble with text. The AFT station was reported as a location where reading text was difficult. A comment was also made that the SPoC FSTOP could be seen easily from all stations. The FSTOP, located in the lower center portion of the World Map, is a large number, perhaps four times that of the other text.

If the crew translated to make the display more readable, it was to get closer to the screen. The angle of sight did not pose any problem for the astronauts. The blinking Shuttle picture on the World Map was identifiable from each station tested.

4.3.2 Direct Light

The crew was directed to place the PGSC in direct sunlight, preferably at panel F-3. They were not able to read text or graphics or identify the blinking Shuttle icon. The display was then repositioned around the flight deck, but it was still impossible to read the screen without translating. This is consistent with all other evaluations of displays which have been placed in direct sunlight on the orbiter. Problems of readability for particular stations depended on the sun's angle to the screen. In order to make the display readable, the astronauts had to move closer and change their angle with respect to the screen. The same was true for identification of the blinking icon.

4.3.3 Low/No Ambient Light

For the dark viewing condition, the PGSC was placed on the mid-deck. The crewmembers were directed to keep their eyes on the World Map for approximately three minutes, then look away to another area of the cabin. They were still able to clearly see around the cabin after viewing the screen for that length of time. It was also reported that light provided by the screen aided performance of other tasks within the cabin.

4.3.4 General Comments

The crew reported that the PGSC EL's overall performance was excellent. They compared the quality of the display to the older SPoC 1139 EL displays which have been very acceptable for onboard use. The crew agreed that no more evaluations were required. In fact, one crewmember reported that after the first day, the SPoC 1139 was stowed and the PGSC 1530 was used exclusively.

4.4 Conclusions

The readability of the text and graphics of the EL display under conditions of indirect sunlight and low or no ambient light was only limited by the observer's distance from the display. There were no problems with large angular deviations, nor dark adaptation, as was the case with the LCDs. However, under direct sunlight, it was impossible to read the display without changing the sun's angle to the screen. This has been the case with all previous display technologies tested. In general, the EL display's quality was excellent.

5.0 CONCLUSION

Previous formal human factors evaluations have been performed on the gas plasma, transflective LCD, and transmissive LCD display technologies. Problems with these technologies have been identified. The EL display for the 80386-based GRiD 1530 was examined during shuttle mission, STS-41, under conditions of direct sunlight, indirect sunlight, and low or no ambient light conditions. Refer to Table 2 for a summary of display characteristics for all display types. The performance of the EL technology proved superior or equal to that of all other display types previously tested. No further evaluations are necessary. The current recommendation for the PGSC screen is the EL display technology.

Table 2 Summary of Results Across Display Characteristics for Gas Plasma, Transflective LCD, Transmission LCD, and EL displays.

	Gas Plasma	Transmissive LCD	Transflective LCD	EL
Nominal Ambient Light				
Text	±65° & 1.5 Distance	±30° & 1 Distance	±30° & 1 Distance	±65° & 1.75 Distance*
Graphics	Easily Read	Difficult to Read	Difficult to Read	Easily Read
Blinking	Easily Detected	Difficult to Detect	Difficult to Detect	–
Direct Light	Images Lost	Easily Read	Clearest	Difficult
Indirect Light	Dark	Dark	Better	Best
Low/No Ambient	Vision Retention	Vision Loss	Vision Loss	Vision Retention

* Although the exact procedure could not be replicated, similar measurements for the EL were compared to those measurements reported in Jensen and McKay (1988).

REFERENCES

Bylander, E. G. (1979). Electronic Displays. New York: McGraw Hill.

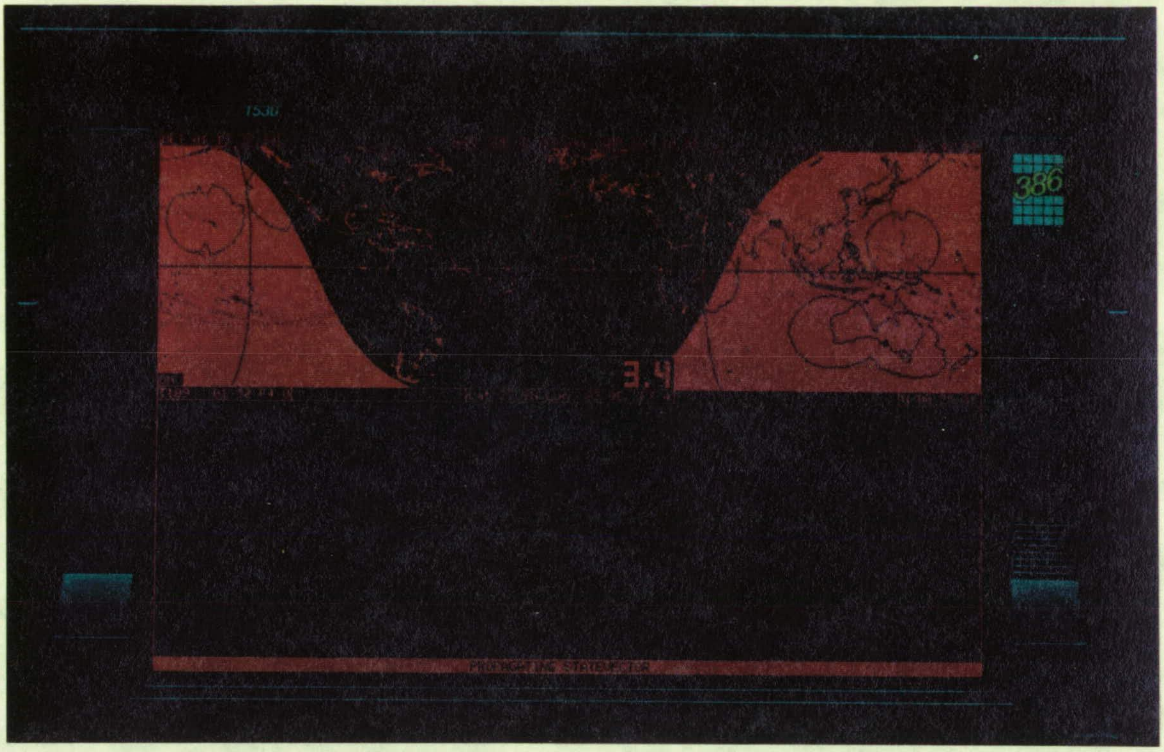
Helander, M. G. (1987). Design of Visual Displays. In G. Salvendy (Ed.), Handbook of Human Factors (pp. 507-548). New York: John Wiley & Sons.

Hooten, D. & Sanders, P. (1989). Payload and General Support Computer (PGSC) Detailed Test Objective (DTO) #789 postflight report -- STS-29. (NASA Report No. 24027). Houston, TX: Johnson Space Center.

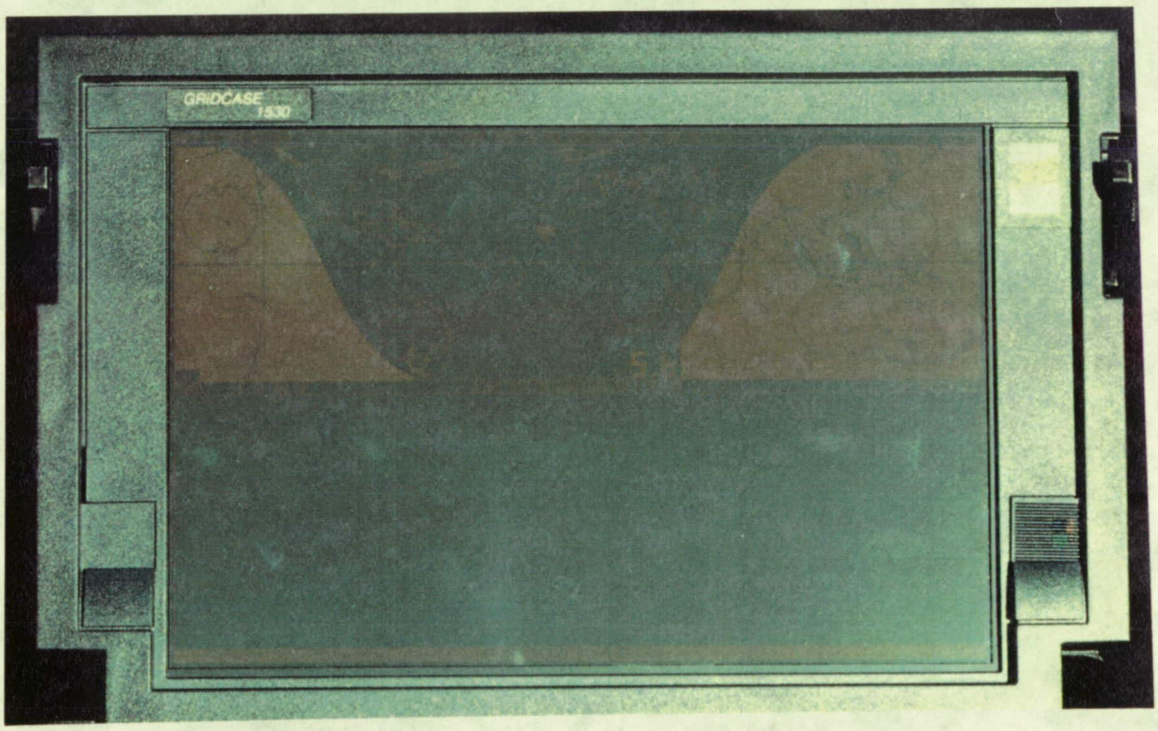
Jensen, D. & McKay, T. (1988). The human factors evaluation of the gas plasma, transmissive LCD, and transflective LCD displays for the GRiD shuttle portable computer. (NASA Report No. 23104). Houston, TX: Johnson Space Center.

Luxenberg, H. R. (1967). Display Systems Engineering. In R. L. Kuehn (Ed.), Inter University Electronic Series (Vol. 5). New York: McGraw-Hill.

Figure 1. GRiD 1530 Laptop Computer

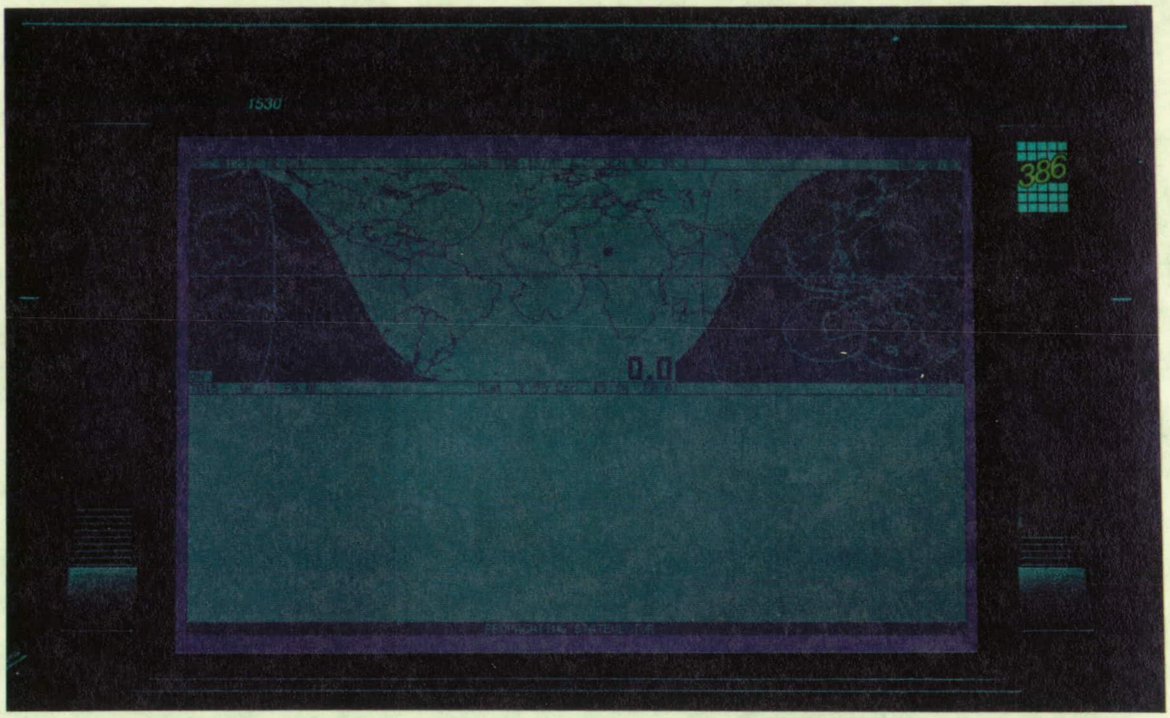


Gas Plasma Display in Nominal Light (20 Footcandles).

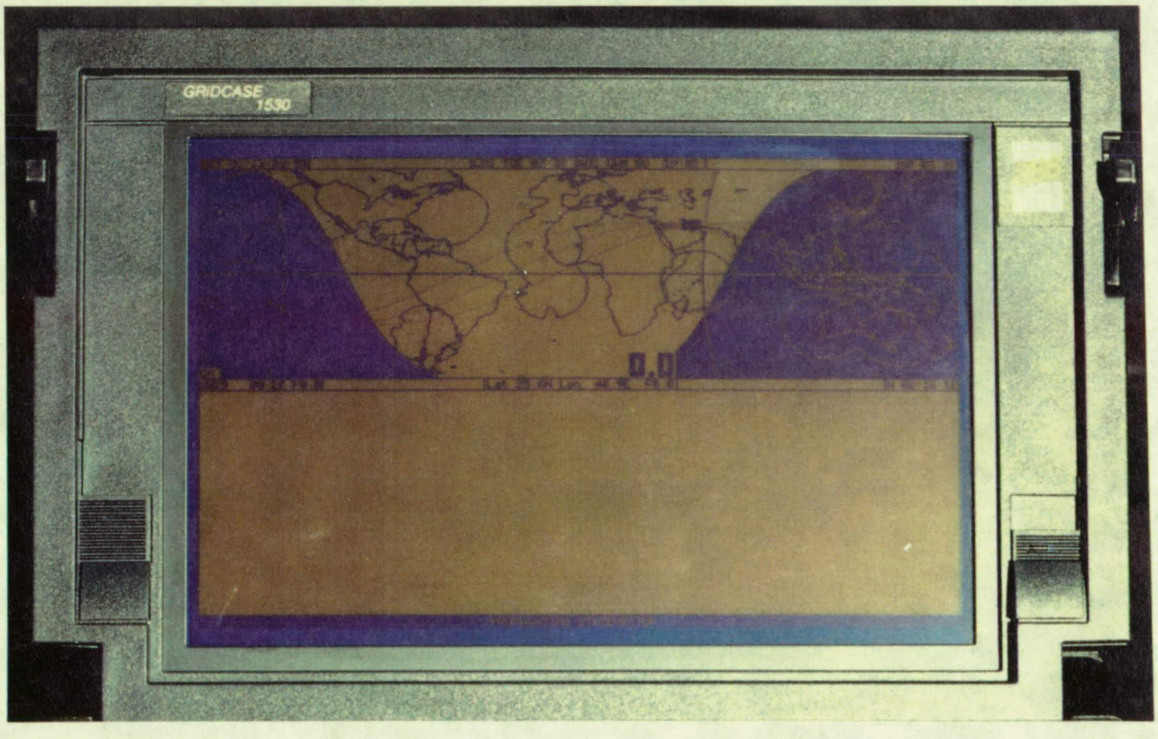


Gas Plasma Display in Direct Floodlight (5000 Footcandles).

Figure 2. Gas Plasma Display in Nominal/High Ambient Light.

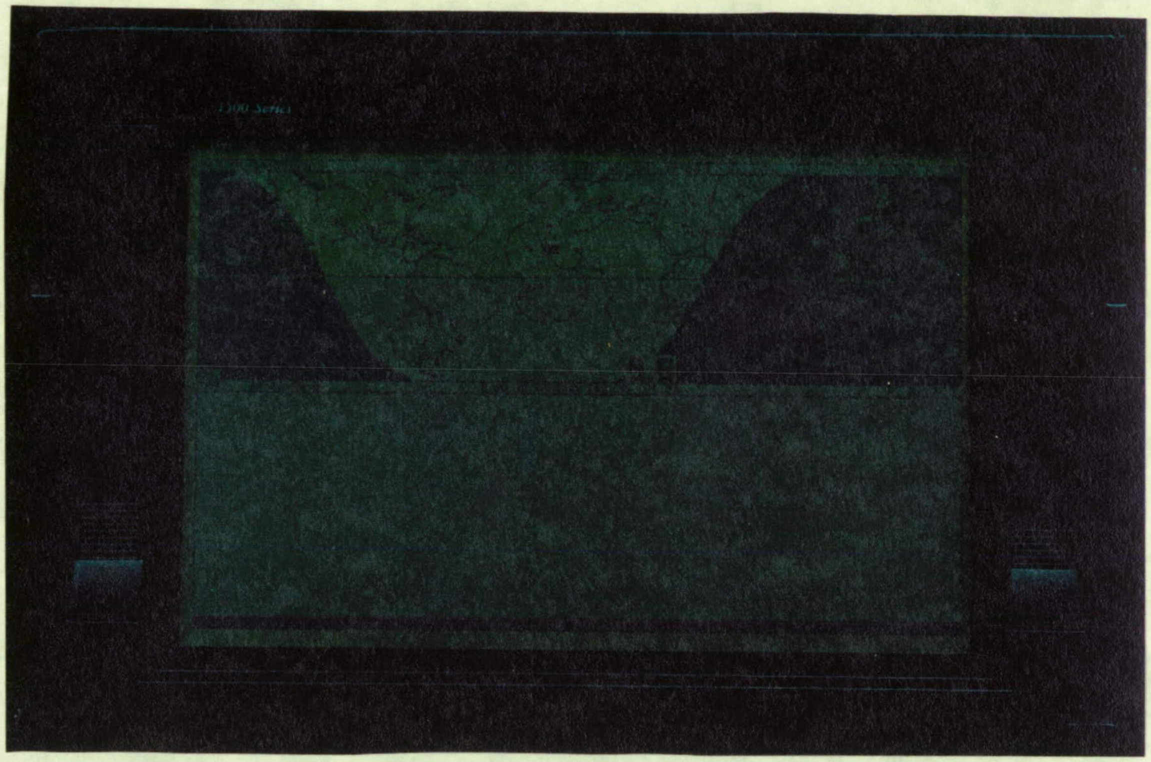


Transmissive LCD Display in Nominal Light (20 Footcandles).

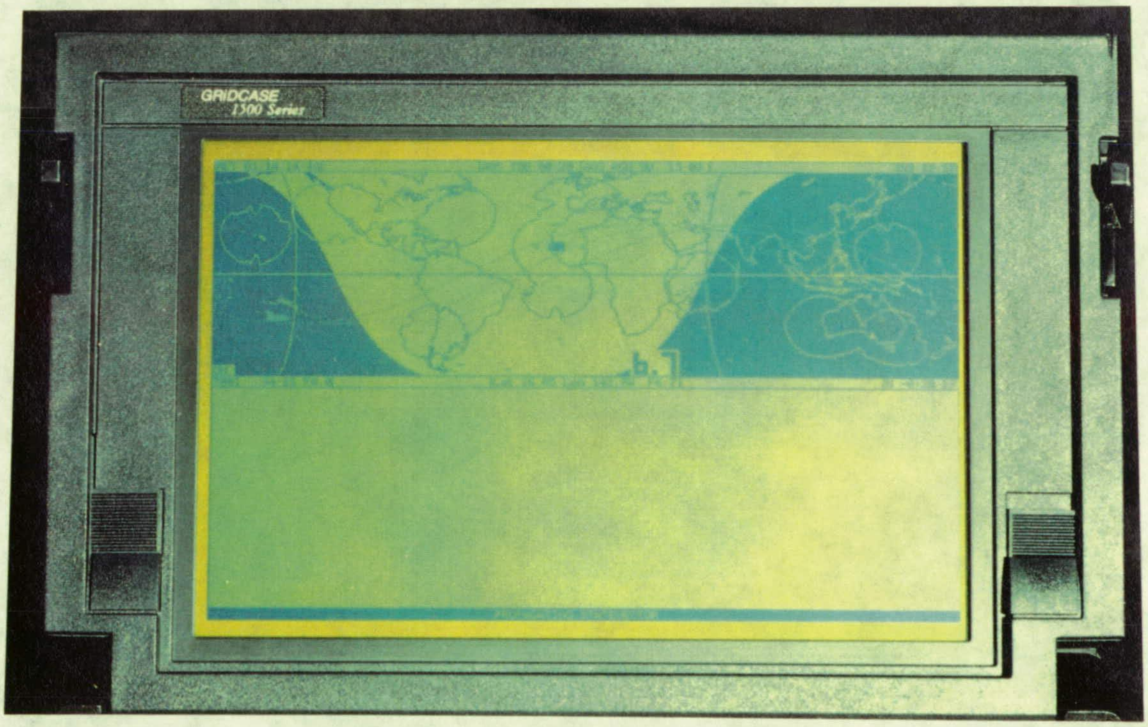


Transmissive LCD Display in Direct Floodlight (5000 Footcandles).

Figure 3. Transmissive LCD Display in Nominal/High Ambient Light.



Transflective LCD Display in Nominal Light (20 Footcandles).



Transflective LCD Display in Direct Floodlight (5000 Footcandles).

Figure 4. Transflective LCD Display in Nominal/High Ambient Light.

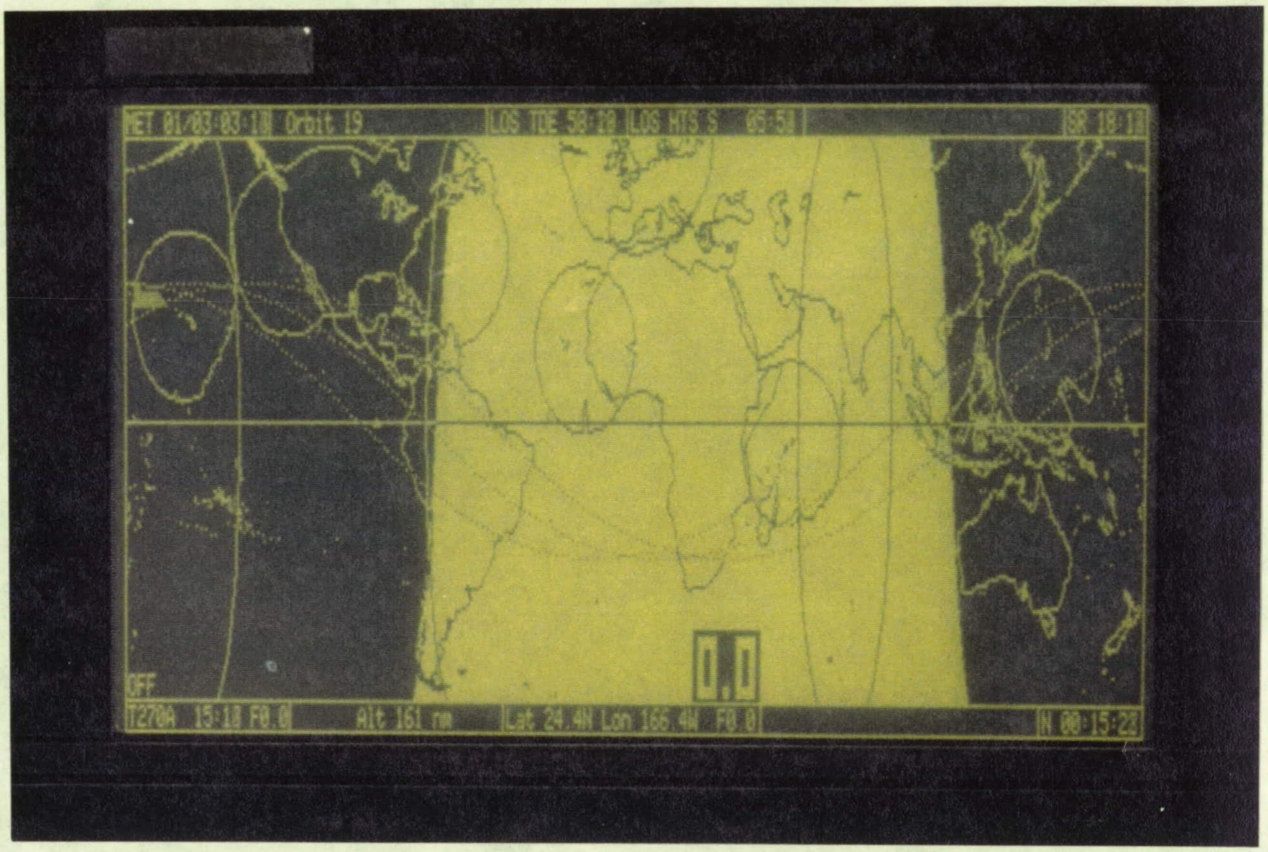


Figure 5. EL Display

APPENDIX A
DTO #795 Questionnaire

PGSC EL DISPLAY EVAL (DTO 795)

Instructions: When there is indirect light, place PGSC on panel F-3. Initial your responses.

Answer following questions when you are directly in front of screen.

1. Are you able to read text and graphics?
   - Text: YES NO
   - Graphics: YES NO

2. Are you able to readily identify blinking Shuttle picture on World Map?
   - YES NO

Assume various station positions on flight deck and look at display and answer following questions.

3. Can you read text and graphics from each station without translating?
   - Text: YES NO
   - Graphics: YES NO

4. If no, from which station(s) is it difficult to read display?

   Station(s) ____ ____ ____

5. If you translate to make display more readable, is it to get closer or to change your angle with respect to screen, or both?

   CLOSER ANGLE BOTH

6. Are you able to readily identify blinking Shuttle picture on World Map from each station?
   - YES NO

If no, from which station(s) is it difficult to identify Shuttle picture?

Station(s) ____ ____ ____

Instructions: Place screen in direct sunlight on flight deck (preferably at panel F-3). Initial your responses.

Answer the following questions when you are directly in front of screen.

1. Are you able to read text and graphics?

   Text: YES NO

   Graphics: YES NO

2. Are you able to readily identify blinking Shuttle picture on World Map?

   YES NO

Assume various station positions on flight deck and look at display and answer following questions.

3. Can you read text and graphics from each station without translating?

   Text: YES NO

   Graphics: YES NO

4. If no, from which station(s) is it difficult to read display?

   Station(s) ____ ____ ____

5. If you translate to make display more readable, is it to get closer or to change your angle with respect to screen, or both?

   CLOSER ANGLE BOTH

6. Are you able to readily identify blinking Shuttle picture on World Map from each station?

   YES NO

If no, from which station(s) is it difficult to identify Shuttle picture?
Station(s) ____ ____ ____

Instructions: When it is dark, place PGSC on middeck. Bring up World Map. Initial your responses.

Keep your eyes on World Map for approximately three minutes, then look away to another area of cabin, then answer following questions.

1. Can you clearly see around cabin?

   YES NO

2. After looking at PGSC screen, is it important that you keep your eyes adjusted to the dark to perform other operations?

   MOST OF THE TIME SOMETIMES NEVER

----

1. Given typical crew operative environment, PGSC is most readable under which lighting condition?

   INDIRECT SUNLIGHT DIRECT SUNLIGHT DARK

2. Do you have any additional comments about readability of PGSC EL?

3. How would you rate overall performance of this monitor?

4. How does PGSC EL monitor compare with previously used EL monitors (SPOC)?

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	25 October 1991	Contractor Report - final

4. TITLE AND SUBTITLE

PAYLOAD AND GENERAL SUPPORT COMPUTER (PGSC) DETAILED TEST OBJECTIVE (DTO) #795 POSTFLIGHT REPORT -- STS-41

5. FUNDING NUMBERS

NAS 9-17900

6. AUTHOR(S)

J. A. Adolf (LESC), B. J. Beberness (LESC), K. L. Holden (LESC)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Lockheed Engineering and Sciences Company
2400 NASA Road One, C95
Houston, TX 77058

8. PERFORMING ORGANIZATION REPORT NUMBER

LESC 29081

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Human-Computer Interaction Laboratory
Lyndon B. Johnson Space Center
Houston, TX 77058

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

CR 185678
JSC 25459

11. SUPPLEMENTARY NOTES

Technical Monitor - M. Rudisill/SP34

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Unlimited/Unclassified

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Since 1983, the Space Transportation System (STS) had routinely flown the GRiD 1139 (80286) laptop computer as a portable onboard computing resource. In the Spring of 1988, the GRiD 1530, an 80386-based machine, was chosen to replace the GRiD 1139. Human factors ground evaluations and detailed test objectives (DTO) examined the usability of the available display types under different lighting conditions and various angle deviations. All proved unsuitable due to either flight qualification of usability problems. In 1990, an Electro-luminescent (EL) display for the GRiD 1530 became flight qualified and another DTO was undertaken to examine this display on-orbit. Under conditions of indirect sunlight and low ambient light, the readability of the text and graphics was only limited by the observer's distance from the display. Although a problem of direct sunlight viewing still existed, there were no problems with large angular deviations nor dark adaptation. No further evaluations were deemed necessary. The GRiD 1530 with the EL display was accepted by the STS program as the new standard for the PGSC.

14. SUBJECT TERMS

ELECTROLUMINESCENT (EL) DISPLAY, LIQUID CRYSTAL DISPLAY (LCD), GAS PLASMA, PAYLOAD AND GENERAL SUPPORT COMPUTER (PGSC)

15. NUMBER OF PAGES

27

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL