Nil

GPO PRICE $ ______

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Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

FACILITY FORM 602

N68-26022 (ACCESSION NUMBER)
(THRU) 1
66 (PAGES)
(CODE)
CR 61814 (NASA CR OR TMX OR AD NUMBER)
31 (CATEGORY)

Lockheed

MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

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HUNTSVILLE RESEARCH & ENGINEERING CENTER
HUNTSVILLE RESEARCH PARK
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CONTROL AND DISPLAY PANEL DESIGN AUGMENTATION TASK NO. 27

LMSC/HREC A784656

5 September 1967

Prepared Under Contract No. NAS8-21003 by

Lockheed Missiles & Space Company
A Group Division of Lockheed Aircraft Corporation
Sunnyvale, California

for

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama

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for R. I. Schneyer
AAP Program Manager

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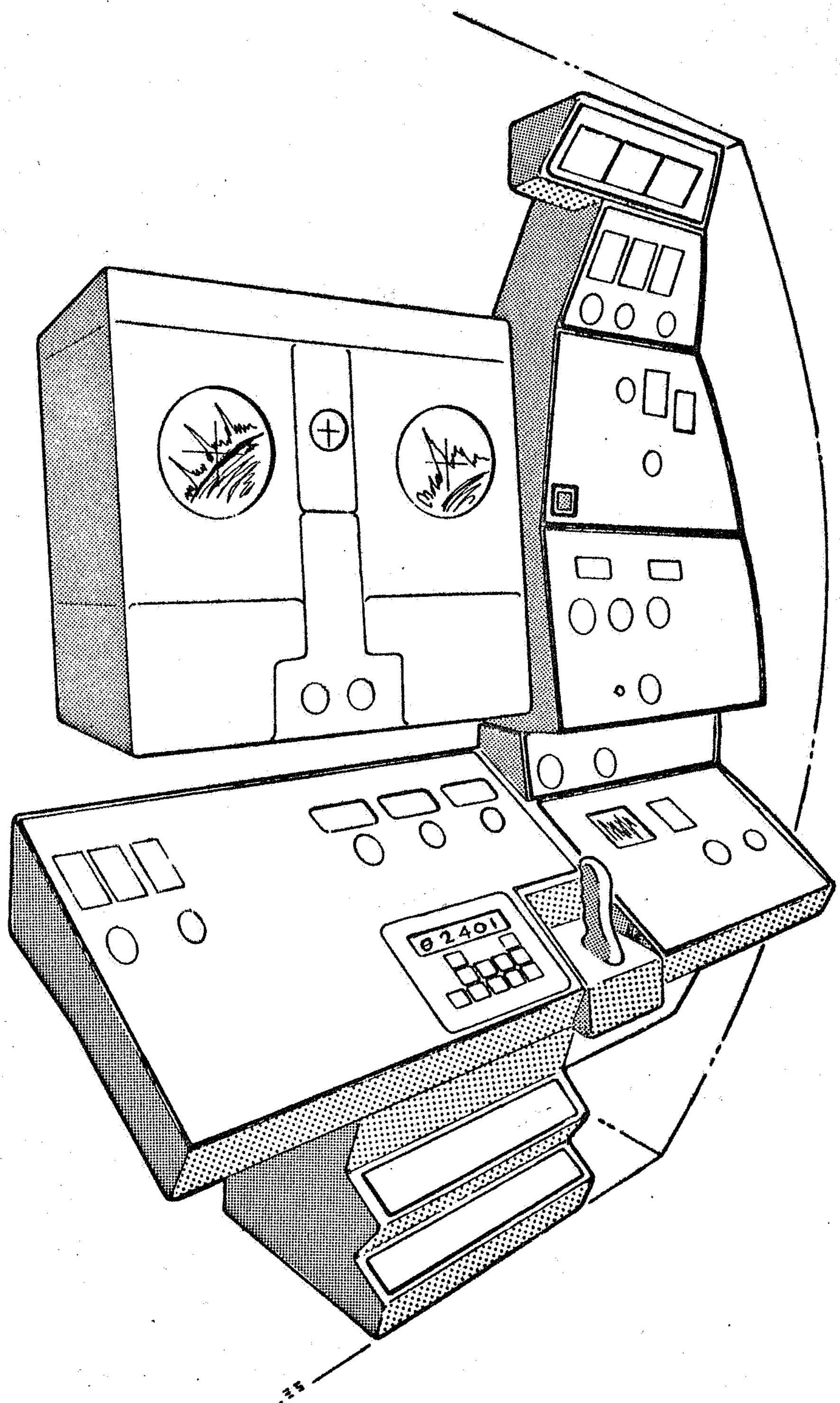


ATM CONTROL AND DISPLAY CONSOLE

FOREWORD

This report was prepared by Lockheed's Huntsville Research & Engineering Center for Marshall Space Flight Center under Contract NAS8-21003, Augmentation Task No. 27. Work accomplished from 8 July through 5 September 1967 is presented.

Principal contributors to this report were Z. V. Adams, M. L. Blackledge, A. M. Ellison, G. O. Floyd, J. H. Lane and E. L. Saenger.

CONTENTS

Section 1
INTRODUCTION

Located within the Apollo Telescope Mount (ATM) Lunar Module (LM) is a large console which provides the control and display functions necessary for the astronauts to conduct ATM experiments. The design of this console system is the responsibility of the Airborne Electrical System Section of the Marshall Space Flight Center's Astrionics Laboratory. Lockheed Missiles & Space Company (LMSC) provided engineering design and documentation of the console system under Task 27 of a broad ATM contract, extending from 8 July through 5 September 1967 (Period IV). This work was a continuation of similar work previously performed in the following areas:

- Conceptual and detailed mechanical and electrical design of the control and display console subsystem.
- Documentation support in the preparation of finished drawings, specifications and interface control documents.
- Formulation and documentation of design guidelines.

In addition, during this period a full scale mock-up of the panel layout and television monitor console, fold-down mechanism was made.

Section 2
ATM CONTROL AND DISPLAY CONSOLE DESIGN

Task 27 of the contract specifies, among other things, the following:

- Continue design of ATM console
- Revise and up-date drawings, specifications, interface control documentation and parts lists.

This effort is to incorporate requirement changes resulting from revised experiment and operating definition, including but not limited to:

- Revision of panel specifications
- Updating of Console/Rack and Console/LM interface control documentation
- Updating of panel detail design documentation
- Satisfying and improving human engineering aspects.

This section of the report was prepared to document the effort to fulfill this portion of the task.

The design of the ATM Control and Display Consoles was initially based on the original design guidelines (Reference 1). These guidelines were progressively modified as requirements changed. The final configuration meets the design guidelines formalized in Reference 2. The effects of these changes are presented in the following discussion.

Since the previously recommended configuration of 3 July 1967, the panel layouts and console configuration have changed considerably, however, the basic shape and location have remained.

2.1 FINAL CONFIGURATION

The final console configuration is shown in Figure 2-1. To facilitate installation in the LM, the ATM console is divided into three major sub-consoles:

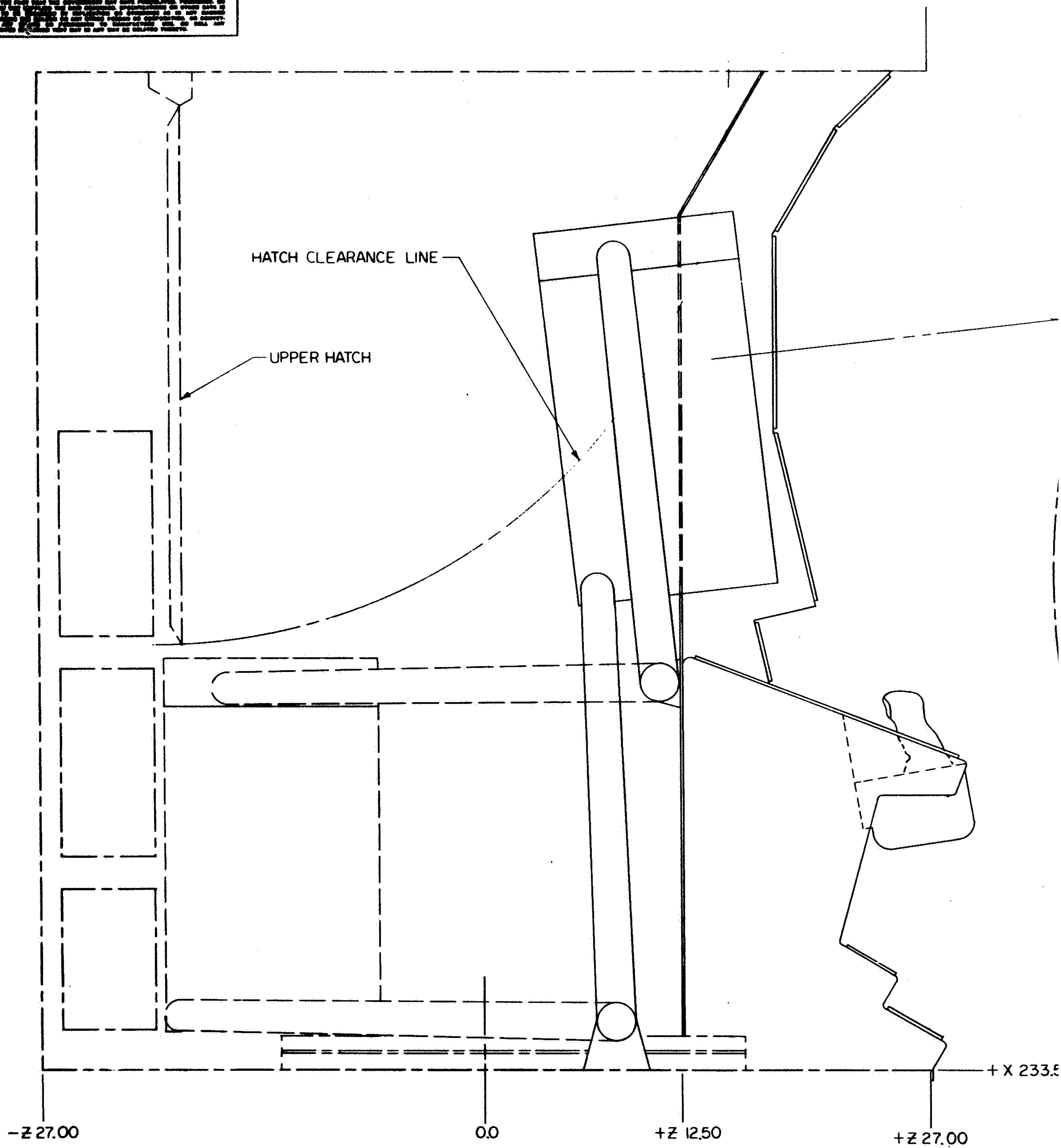
- The Lower Console, which contains the pointing control, ATM power, HCO power, lighting and solar array and the GSFC experiment and distribution box.
- The Center Console, with the two TV monitors, the associated TV controls and the NRL experiment panel.
- The Side Console, which contains the caution and warning array, the power monitor meters, HAO, HCO and AS&E experiment panels.

To present a comprehensive report of the various revisions of the panels and console, it is necessary to begin with the 3 July 1967 configuration and proceed chronologically to describe the changes as they occurred.

2.2 CONFIGURATION OF 3 JULY 1967

Figure 2-2 illustrates the 3 July 1967 configuration. At this point, the panel design was based upon data received by HREC on or before 29 May 1967. The total panel area was 1522 square inches.

The basic configuration consisted of two fixed consoles (Pointing Control and Experiments) which were attached directly to the LM structure, and a movable console (TV monitor) which was mounted on a single cantilever arm attached to the back of the Pointing Control Console. Ladder isolators were placed between the upper and lower sections of the console with the arm attached to the lower section. This configuration allowed equal vibration isolation in all planes and was required to prevent damage to the cathode ray tubes in the TV monitors.



TOTAL PANEL AREA 167

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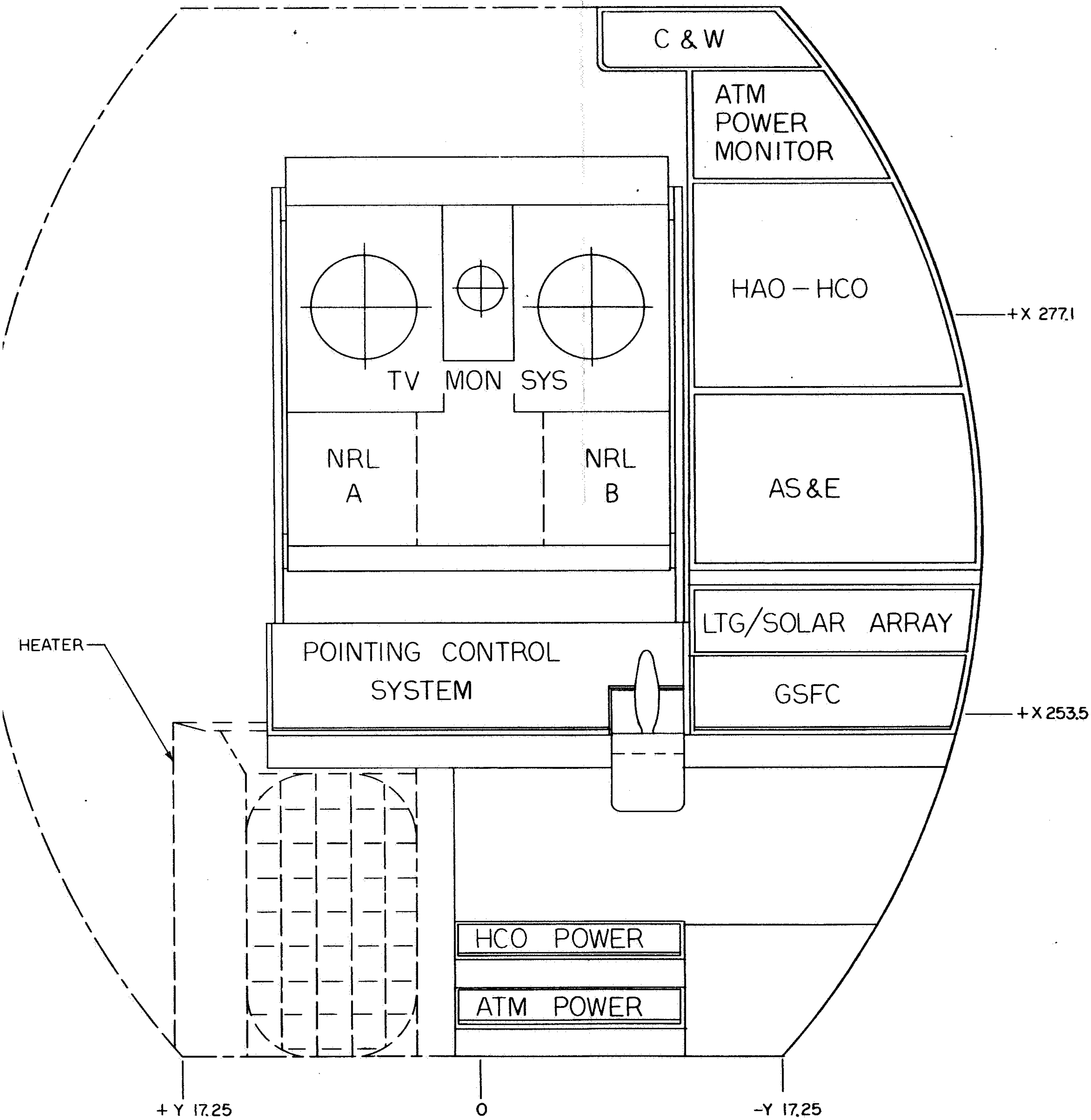

FIGURE 2-1

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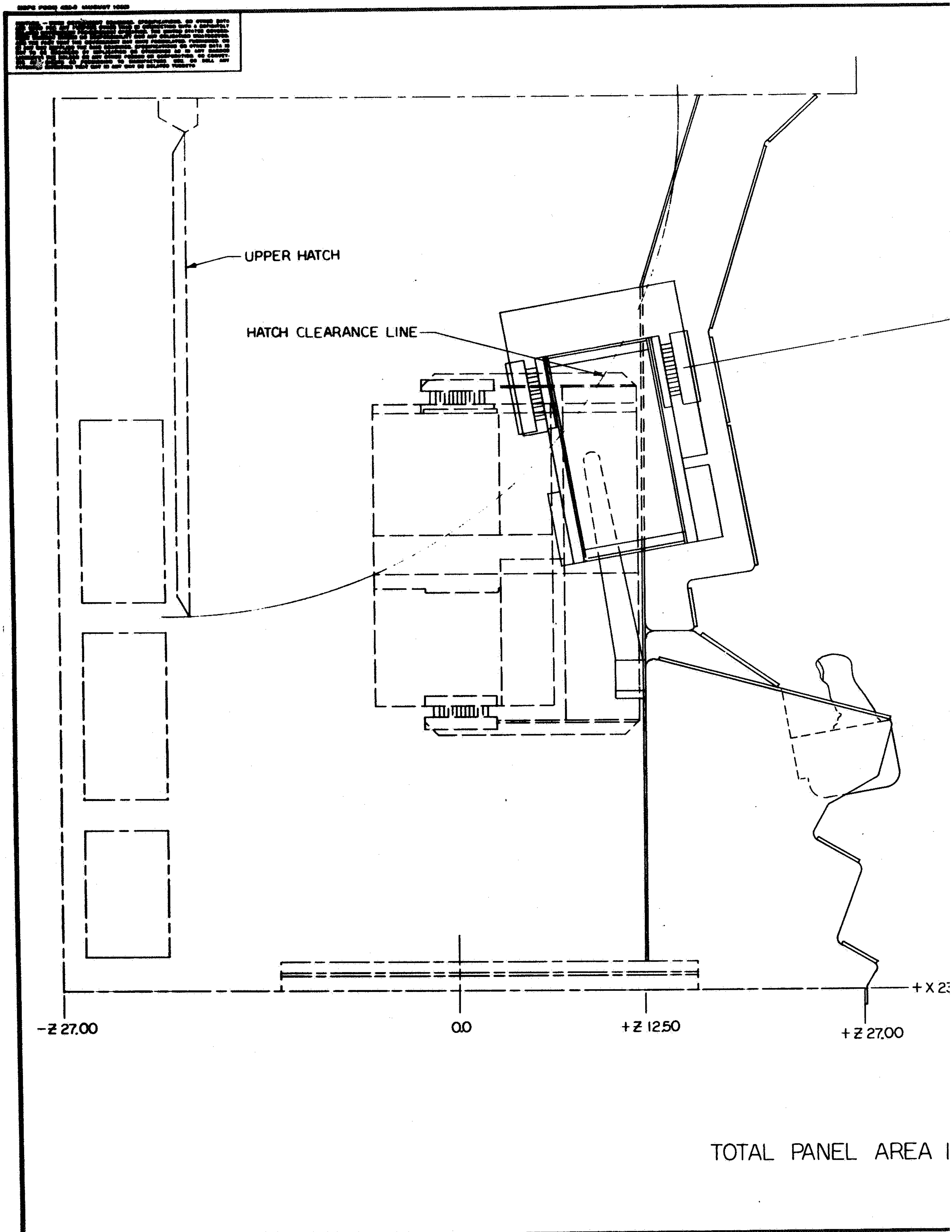
FOLDOUT FRAME

4-C



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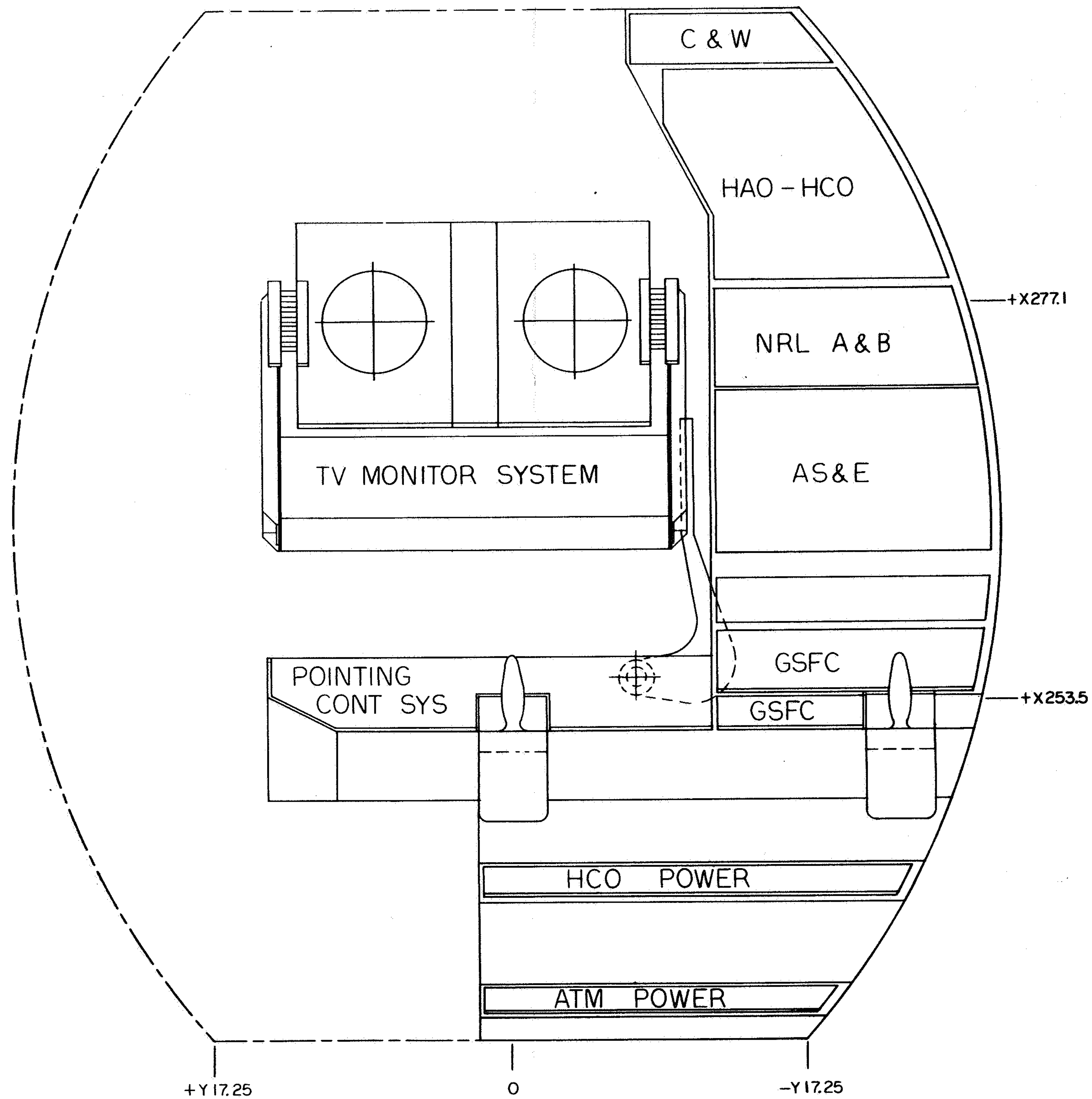

FIGURE 2-2

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Since the configuration required motion of the TV monitor console in three dimensions, a quarter-scale mock-up of the affected areas within the LM was made to verify clearance margins. It was made from information in LM structural drawings and stress analysis documents. This mock-up served as the first accurate view of the critical areas within the LM interior.

Although this configuration met the design guidelines, there were two major deficiencies. First, the TV monitor folding mechanism was quite complicated, and required considerable activity by the crewman to move the TV console into operating position. Second, due to the two rotations, the electrical cables would be subjected to considerable twisting which required extra length and bulk.

A design review meeting held on 9 July 1967 resulted in a reconfiguration of the console. Two major changes to the ground rules were given:

- Elimination of one hand controller.
- Waiver of the requirement for access to a lower hatch which was used for passing film cassettes into the LM.

In addition, the following changes to the panel layouts were ordered:

• TV Monitor:	Added 1 thumbwheel actuated rheostat
• NRL Experiment:	Added 2 flags
	Removed 1 toggle switch
• AS&E Experiment:	Added 4 flags
	Added 5 toggle switches
	X-Ray scope grew from 3 1/2" x 6" x 9" to 3 5/8" x 6 1/2" x 9 1/2"
	Intensity modulator grew in size from 2 1/2" x 5" x 6 1/4" to 4 3/8" x 5" x 11 1/2"
	Exposure display counter grew from 2 5/8" x 3" x 3 3/4" to 2 5/8" x 4 3/8" x 10 3/4"

Intensity display counter grew from 2 5/8" x 3" x 3 3/4" to 2 5/8" x 4 3/8" x 10 3/4"

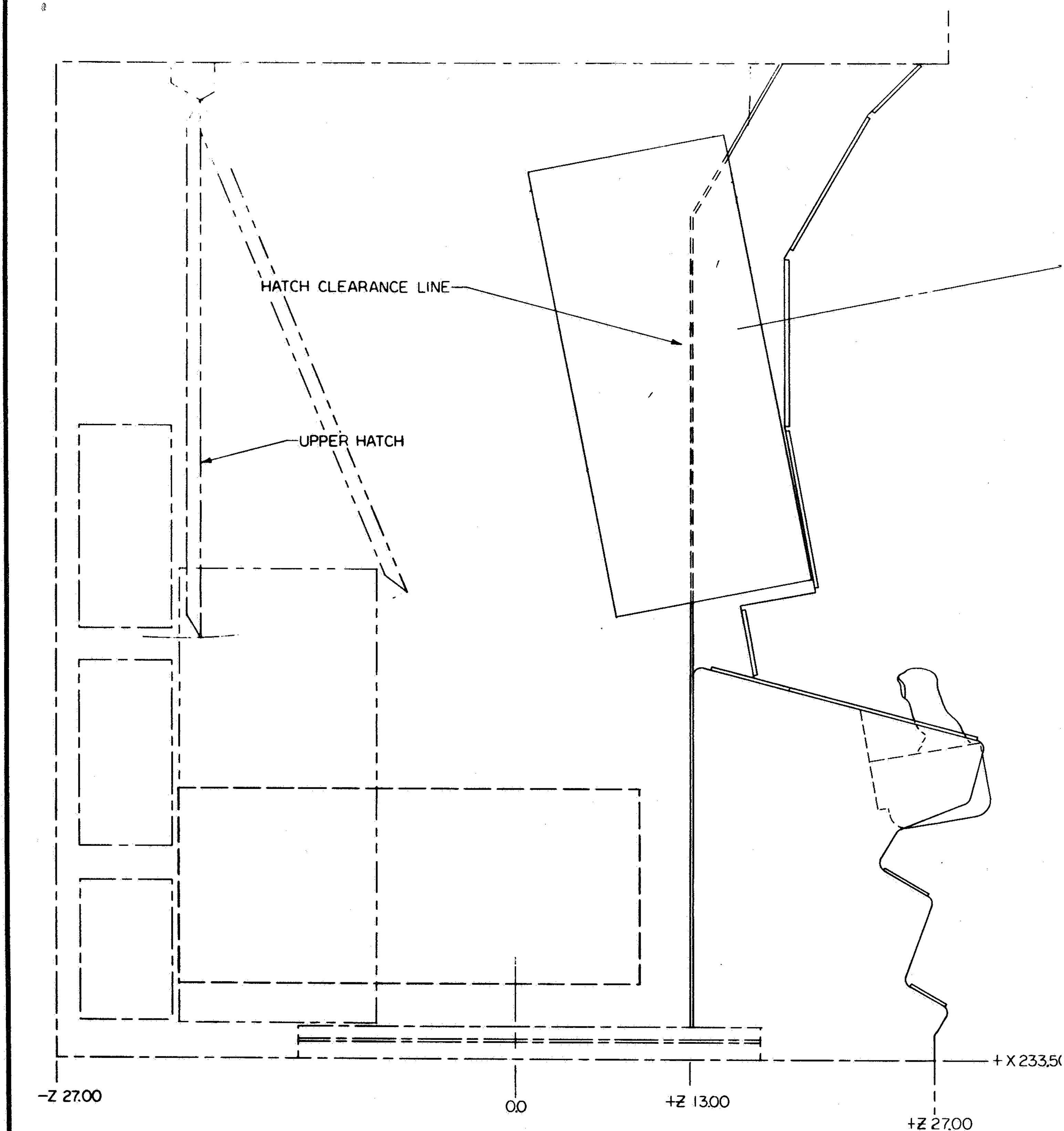
- HCO Experiment: Added 3 flags
  Added 1 rotary switch
- HAO Experiment: Added 1 toggle switch
- GSFC Experiment: Added 1 flag
- Pointing Control: Changed the Command Address System from 4 rotary switches, 3 toggle switches and digital display to a single integral system
  Added 18 flags
  Added 14 toggle switches
  Added 1 rotary switch.

These additional components meant that additional panel space was urgently needed. In order to provide this space and to accommodate the obvious appreciable growth rate, a maximum panel space configuration was next considered.

2.3 CONFIGURATION OF 23 JULY 1967

During the period from 12 July through 23 July, several panel and console configurations were considered. Figure 2-3 illustrates this configuration with two variations in stowage. The major common physical features of these systems were:

- The AS&E Experiment was moved to the TV console. This grouped all the large, deep components into one console, thus the depth of the Experiments Console was reduced and the stowage space behind it was increased. This grouping gave a total panel area of 1782 square inches, an increase in panel space of 17 percent.
- The Power Monitor meters were moved from the Pointing Control Panel and placed on the Experiments Console just below the Caution and Warning Array Panel. This move



TOTAL PANEL AREA

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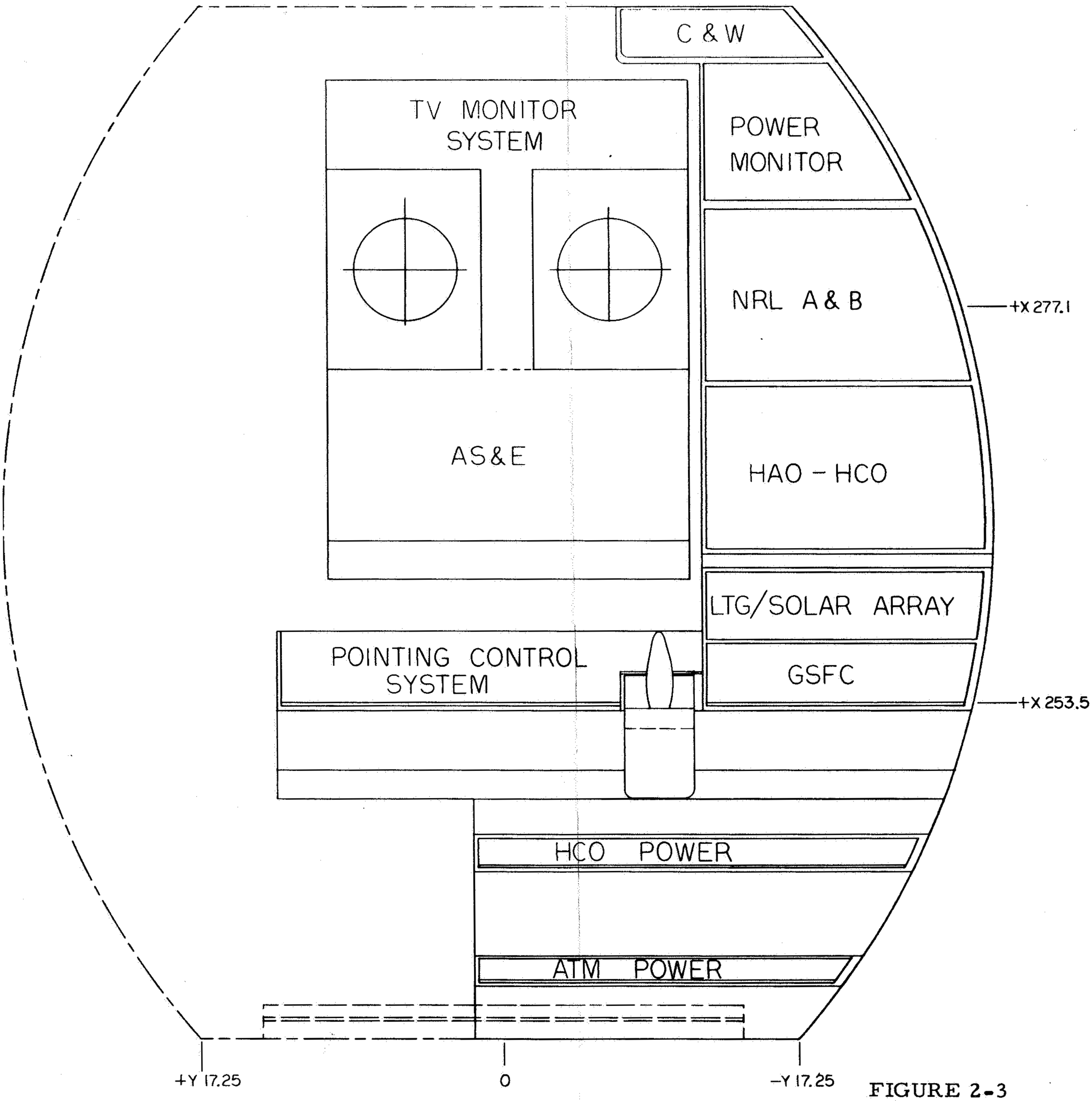

FIGURE 2-3

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FOLDOUT FRAME

made additional space available for the flags and toggle switches that were added to the Submode and Redundant System groups of the Pointing Control System.

- The left edge of the Experiments Console was straightened (rather than expanded to the width of the Caution and Warning Panel) to increase the entry/egress area. This was a major improvement from the human factor standpoint. There had been some concern about this bulge impeding the astronaut and catching a corner of his backpack.

The optimum viewing of the TV monitors is at 10 degrees below a horizontal line at a distance of 18 inches. In order to obtain this viewing angle, a 5-inch high panel was placed above the TV monitors. This panel was limited to visual displays to obviate use of the astronaut's arm over prime viewing area.

The only difference in these configurations is shown in the side view. Two stowage arrangements are shown in Figure 2-3. The vertical position was the first considered. The mechanism needed for stowing the TV console was simple, however, the hatch (as shown in the figure) could not be fully opened. The opened angle (70°) is equivalent to the normal angle shown for the LEM-4 vehicle (in that configuration, the latch on the hatch was engaged by a coupler on the engine well cover); however, to avoid possible damage to the TV console due to an uncontrolled hatch, a horizontal stowage arrangement was studied.

The horizontal configuration avoids this hatch interference but creates additional problems. The mechanism required to correctly place this console in the stowed position would require additional mechanisms. A cam-actuated arm attached to the back of the pointing control console allowed the console to move vertically into the required position. Also, a sturdy cover would be required over the entire exposed horizontal face of the console to protect the components. Due to these problems, further alternatives were examined.

While these configurations were being developed, the rate of increase in components had slackened. During the three-week period, the following number of components were added to the various panels:

- 10 flags
- 10 toggle switches
- 3 rotary switches

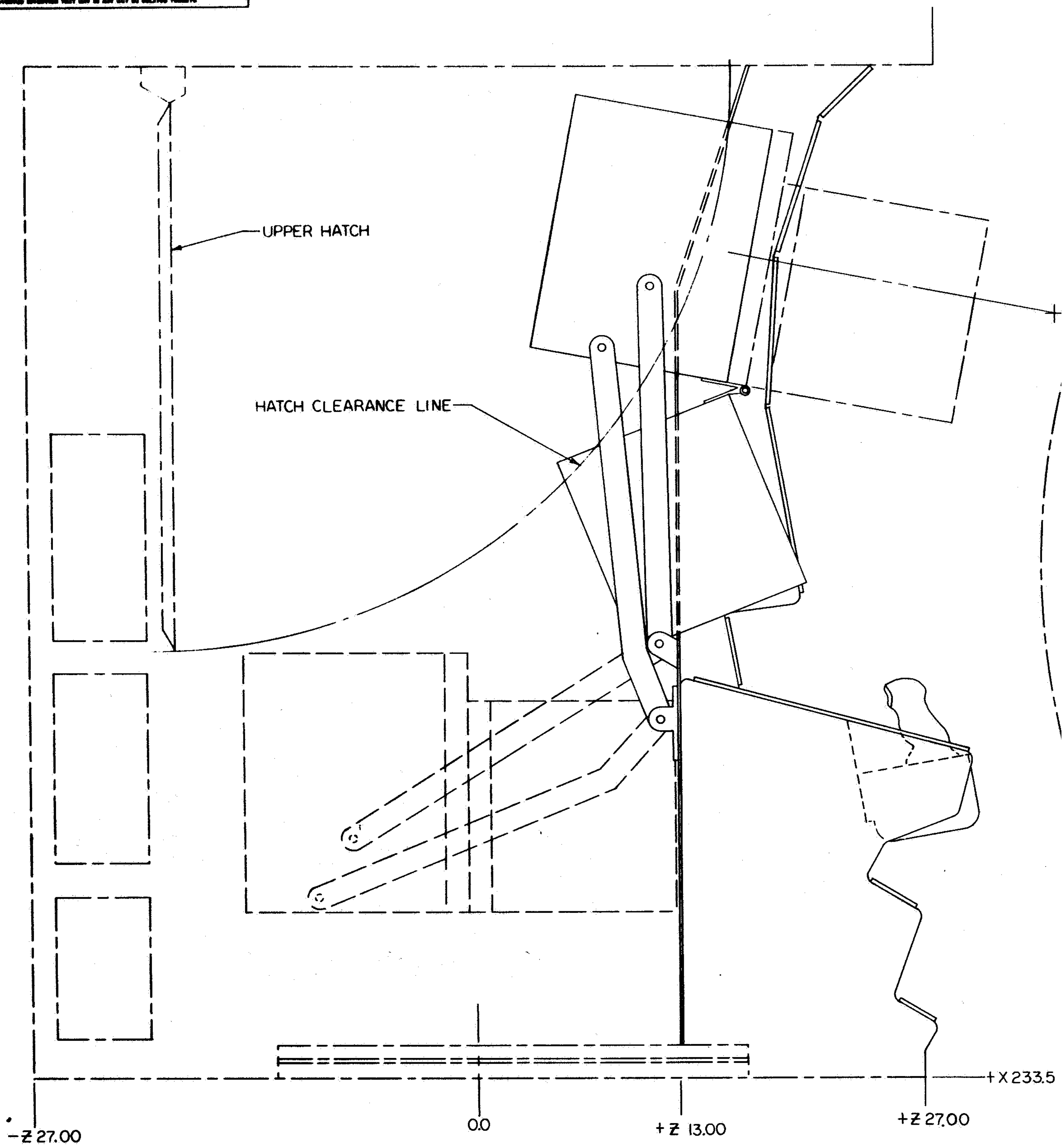
These components were incorporated into the panels and a new set of panel drawings was prepared.

2.4 1 AUGUST 1967 CONFIGURATION

The configuration shown in Figure 2-4 was an attempt to preserve the best features of the previous configuration. The Side Console (previously called the Experiments Console) and the Lower Console (which was the Pointing Control Console) remained the same. Only the configuration of the Center Console (nee the TV Monitor Console) and mechanism were changed. Since the new configuration of the panels made the original titles of the consoles inappropriate, these titles were revised.

The Center Console featured a secondary folding mechanism, which permitted AS&E Experiment in the lower section to be folded up; thus, the faces of both sections were protected. The primary folding mechanism was simple and lowered the console far enough to clear the upper hatch. In addition, there was a large space under the console in which other equipment, such as film casettes, spare equipment, etc., could be stored.

The complications caused by complexity of the secondary folding movement, however, rendered the console impractical. The short distance between the two sections and the large angle (80°) through which the lower section turned would cause severe design problems in the electrical harness.



TOTAL PANEL AREA I

FOLDOUT FRAME 11-A

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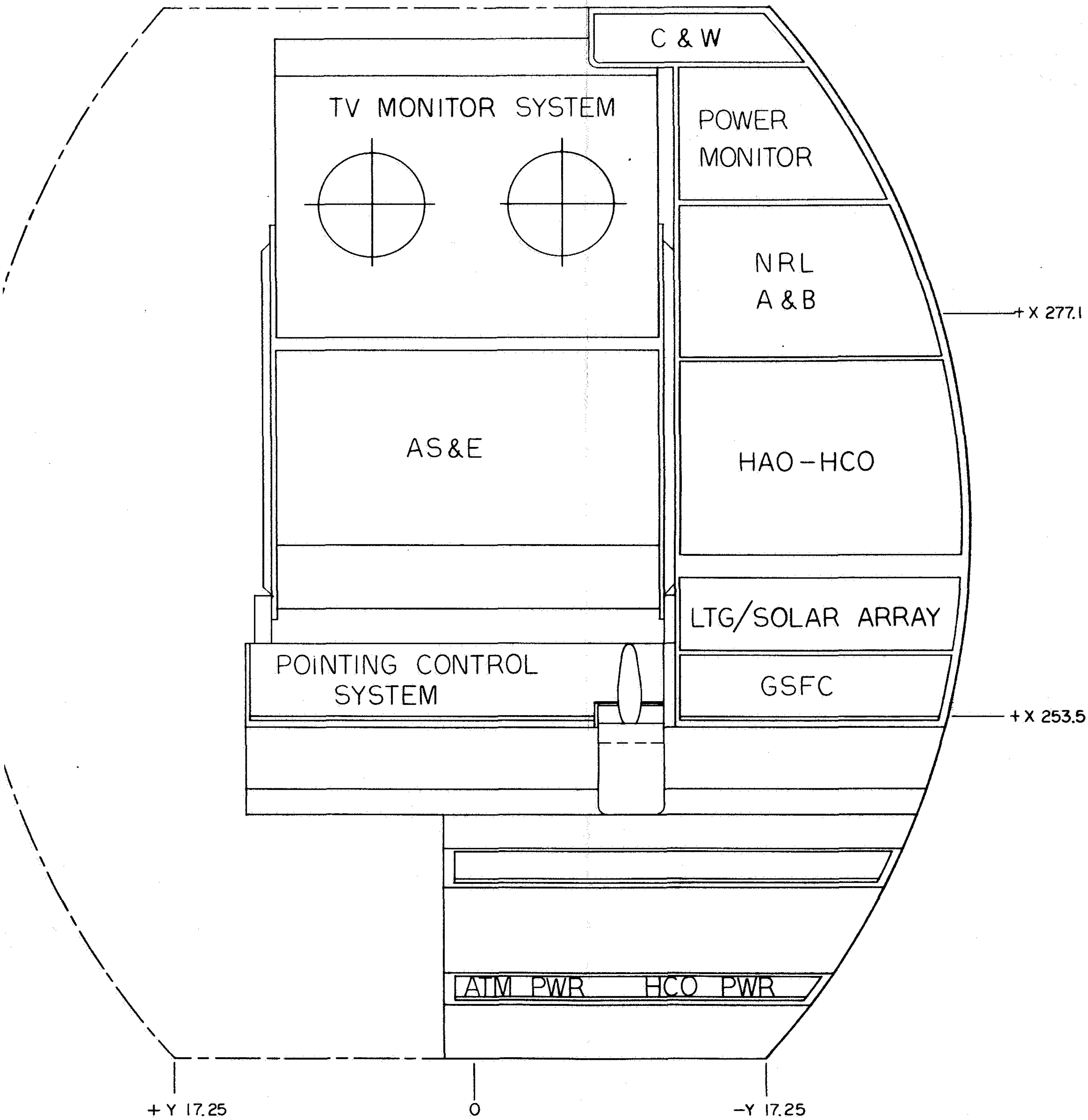

FIGURE 2-4

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Also, the viewing angle of the TV monitors was no longer optimum. The LMSC Human Factors Group felt that such a compromise of the viewing angle could not be tolerated.

By the end of the study it was evident that very few additional components would be added. Therefore, by careful consideration of the required space for the present total and a small safety margin, the total panel area was reduced from 1733 to 1676 square inches.

A reduction in the height of the Center Console to clear the upper hatch with the stowed console in a vertical position resulted in a very simple mechanism. By placing the NRL Experiments on the Center Console, a better balance of panel space was achieved, and resulted in the final configuration (see Figure 2-1).

Section 3
PANEL ASSEMBLY DESIGN

To give the reader a better appreciation of the arrangement of control and display (C&D) panels and components, this section presents comments that will further define the criteria which was used in optimizing the allocation of C&D panel space to components. The following subjects will be discussed: C&D Console profile, experiment and component locations, component and panel mounting, and C&D safety considerations. These comments will be based on the Design Guidelines in Reference 2 and will apply to the final configuration discussed in Section 2.1. Figure 3-1 illustrates the overall LMSC ATM Console concept.

3.1 CONTROL AND DISPLAY PROFILE

The profile chosen was a compromise considering the following factors: the maximum panel surface available, the optimum display viewing angle, the optimum viewing distance, the maximum reach distance and the hierarchy of system functions.

The panels were defined by experiment, rather than by a purely functional criterion.

This system was chosen to simplify the astronaut's duties in the locating of experiment tasks and in the performance of these tasks. Due to experimenter changes, console and panel modifications can be made more readily, with a minimum of scrappage and cost.

3.2 EXPERIMENT AND COMPONENT LOCATIONS

Experiment and component locations are shown in Figures 3-2 and 3-3. The caution and warning indicators were located on the uppermost panel on the

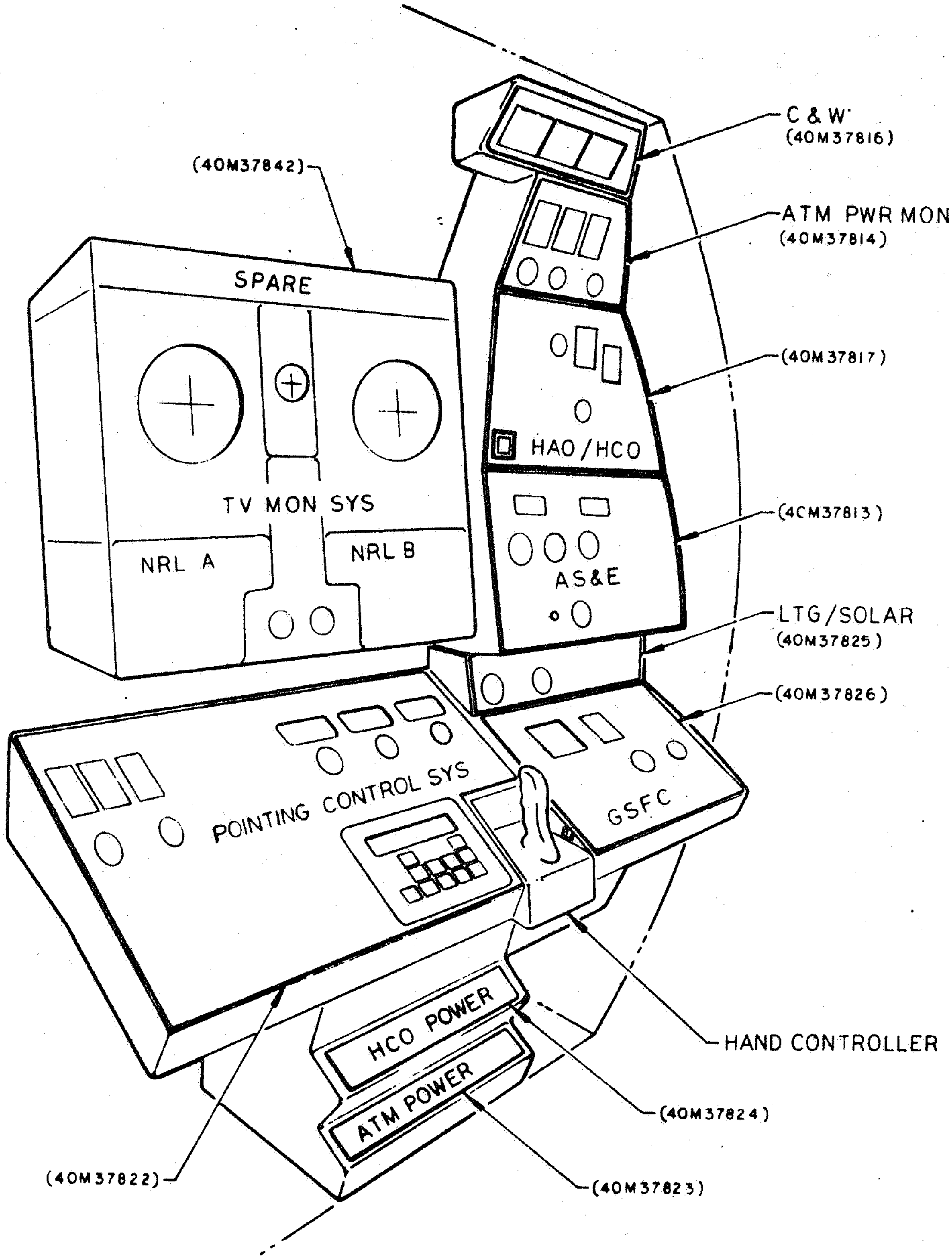
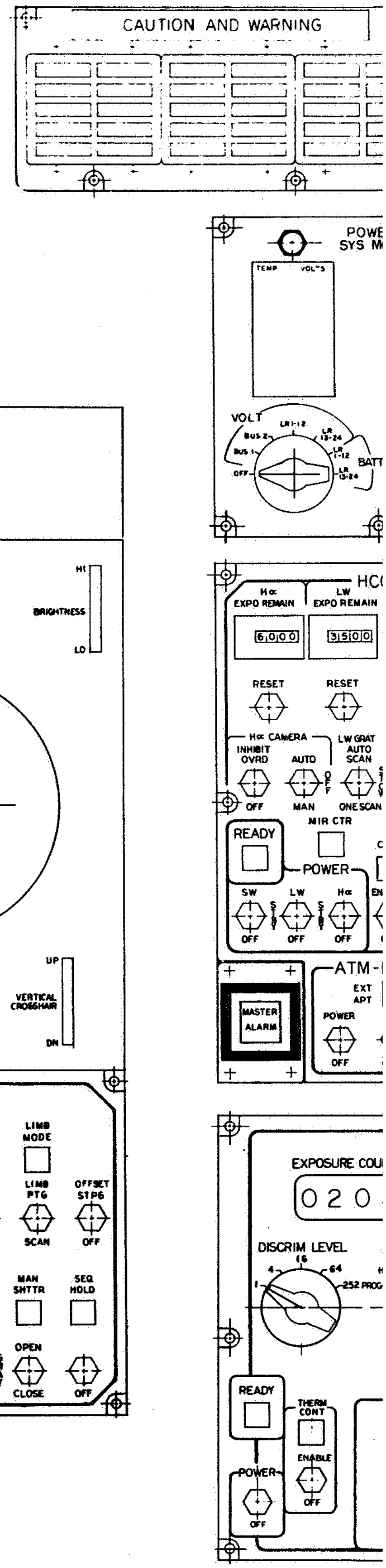
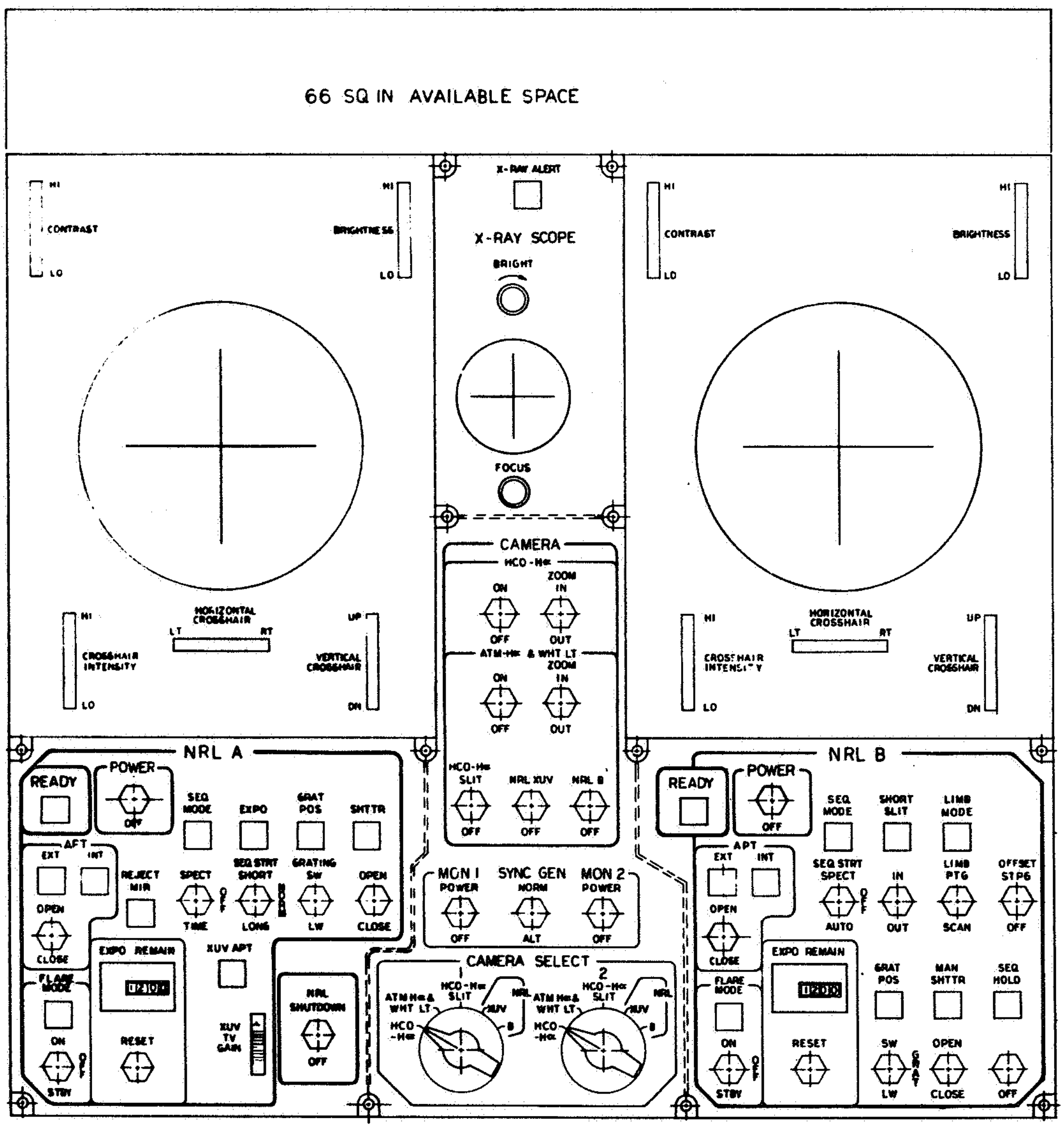


Figure 3-1 – ATM Control and Display Console





Center Panels

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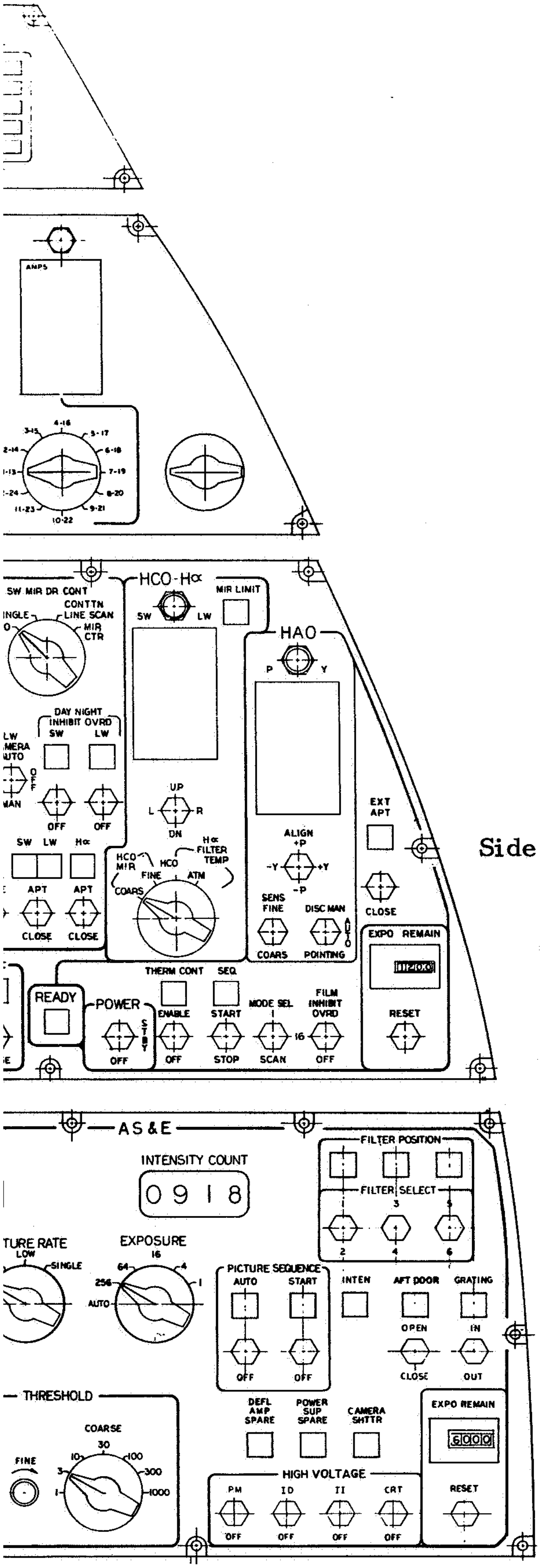

Side Panels

Figure 3-2

ATM CENTER AND SIDE PANELS

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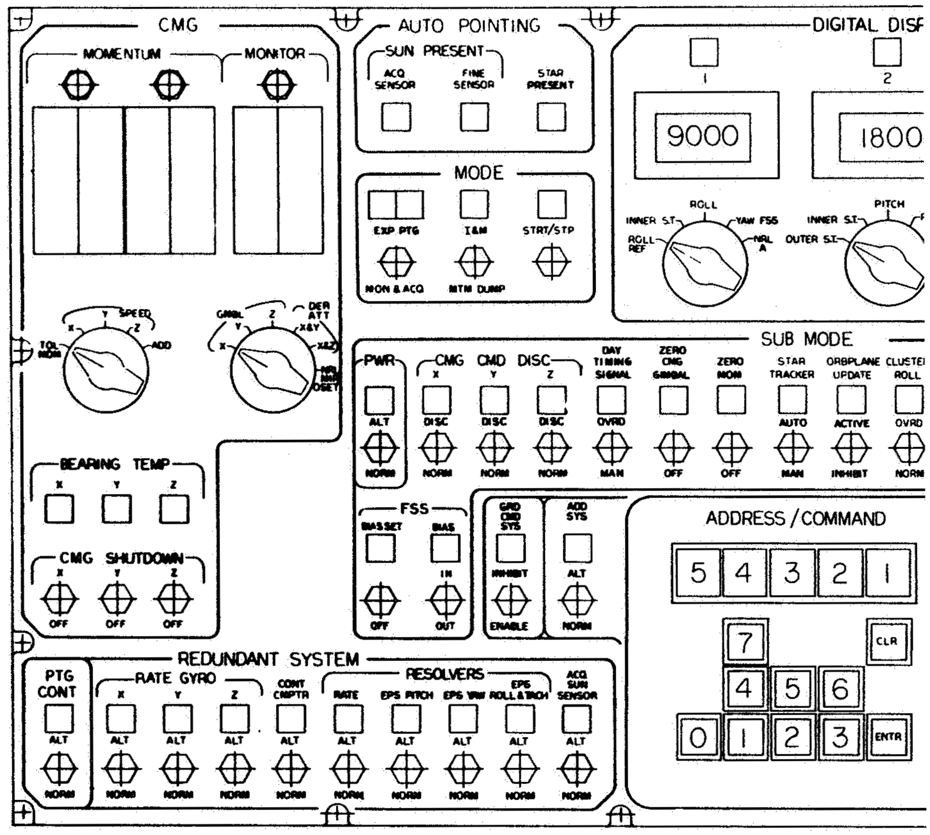

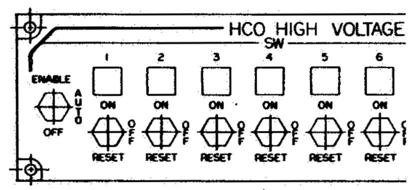

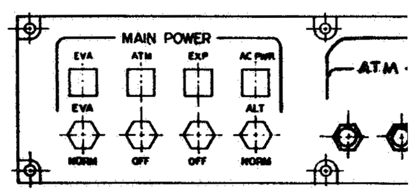

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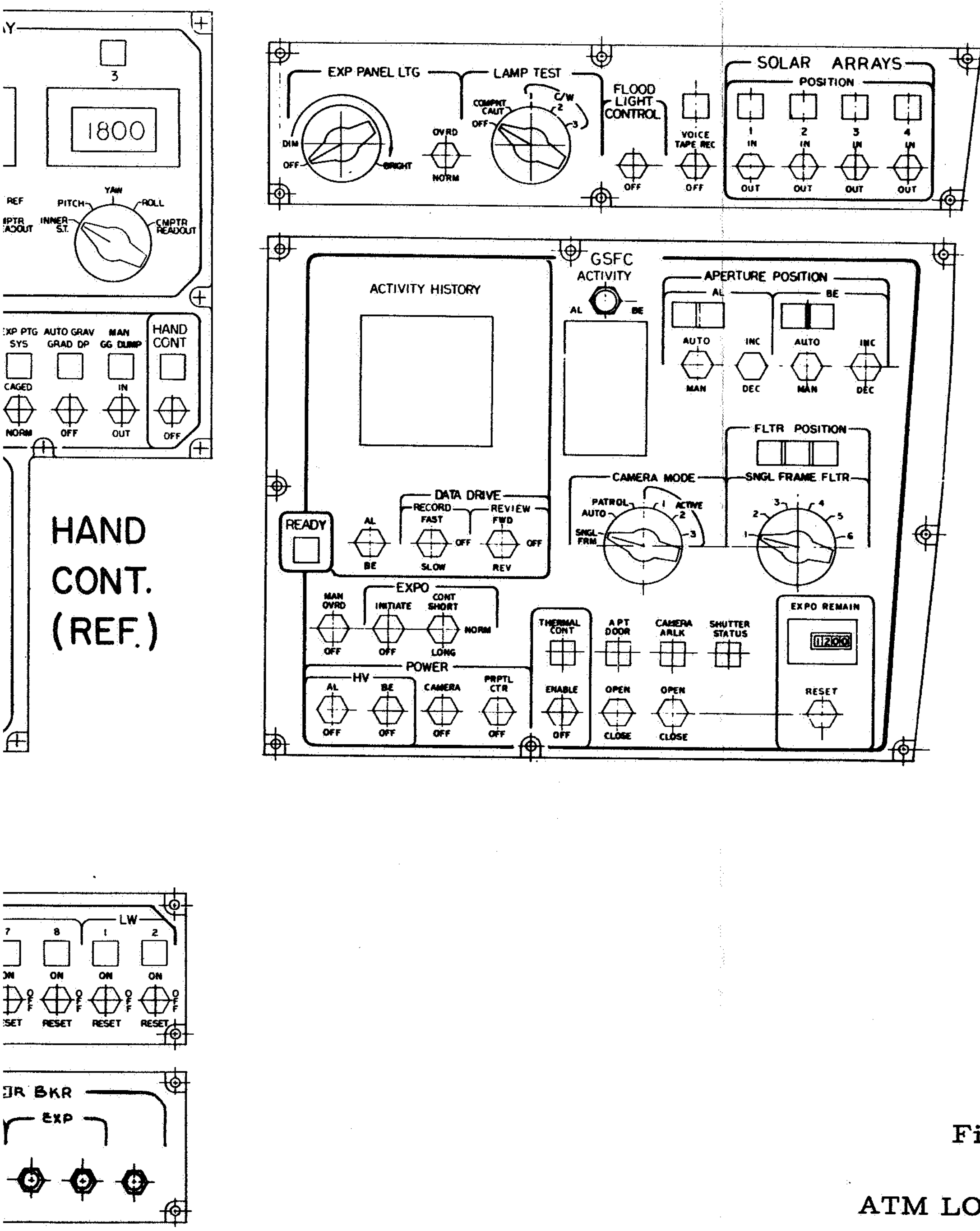


Figure 3-3

ATM LOWER PANELS

Side Console. Since they require only visual contact, constant monitoring is not required. Monitoring is required only when a signal is given by the Master Alarm Indicator.

Since the ATM power monitor system requires infrequent use, it was also located in the upper right side of the console.

The HAO/HCO and the AS&E experiment panels were then located in the upper area of the prime space, due to the requirement of accurate indicator and readout monitoring.

The Master Alarm indicator is located near the center of the edge of the Side Console, thus making it very conspicuous.

The TV monitors and the AS&E X-Ray Scope were located in an optimum position for viewing, without parallax in making precise measurements and object alignments. These items, along with the NRL A&B are located on the movable Center Console.

The Lighting/Solar Array Deployment Panel is located in an area that is less prime due to the infrequency of use.

Due to the size of the Activity History Plotter on the GSFC Experiment Panel, this panel was located below the rest of the experiments in the same plane as the Pointing Control System.

An effort was made to locate all experiment ready indicators and activator switches in line and near the exterior border of the panels. This permits the astronaut to quickly check experiment conditions.

The Pointing Control System was located in the center of the ATM for easy accessibility for both astronauts. The Command Address System and the hand controller are easily reached by either astronaut.

The power control panels were located on the lower portion of the Lower Console. They were located in secondary space due to their infrequent usage. The electrical circuit protection will be located on the ATM main power panel.

3.3 COMPONENT AND PANEL MOUNTING

An assembly and a number of detail drawings were produced to illustrate and document the LMSC design approach to component and panel mounting. The GSFC Experiment S-056 (panel 709A610) was used as an example because it has not changed appreciably in the last two months.

The GSFC assembly is shown in Figures 3-4 and 3-5 (Ref 40M37815). The assumbly consists of an overlay sheet as shown in Figure 3-6 (40M37792), an electroluminescent lamp, Figure 3-7 (Ref 40M3773) and a face plate (.080 thick aluminum sheet) (40M37794), with all of the electrical components specified and mounted. The overlay sheet is a .036 thick polycarbonate plastic material with translucent markings capable of being transilluminated on an opaque background. Clear areas for transillumination of knob skirts are also required. The field of the sheet is gray.

The electroluminescent lamp is composed of a .024 thick sheet that has the proper holes and cutouts for mounting and component clearance. The overlay is bonded to the electroluminescent lamp with double face tape. This combined assembly is then secured to the face plate with corrosion resistant steel (CRES) fasteners. A metal spacer and nylon washer are used to control the amount of restraining pressure on the assembly.

The small components such as lights, switches, etc. are secured directly to the face plate with CRES locking hardware. The larger components such as meters and rotary switches are CG-mounted to brackets (40M37795) that are .063 thick aluminum (bent up and welded) and riveted to the panel face plate. The brackets were detailed separately since they are used repeatedly.

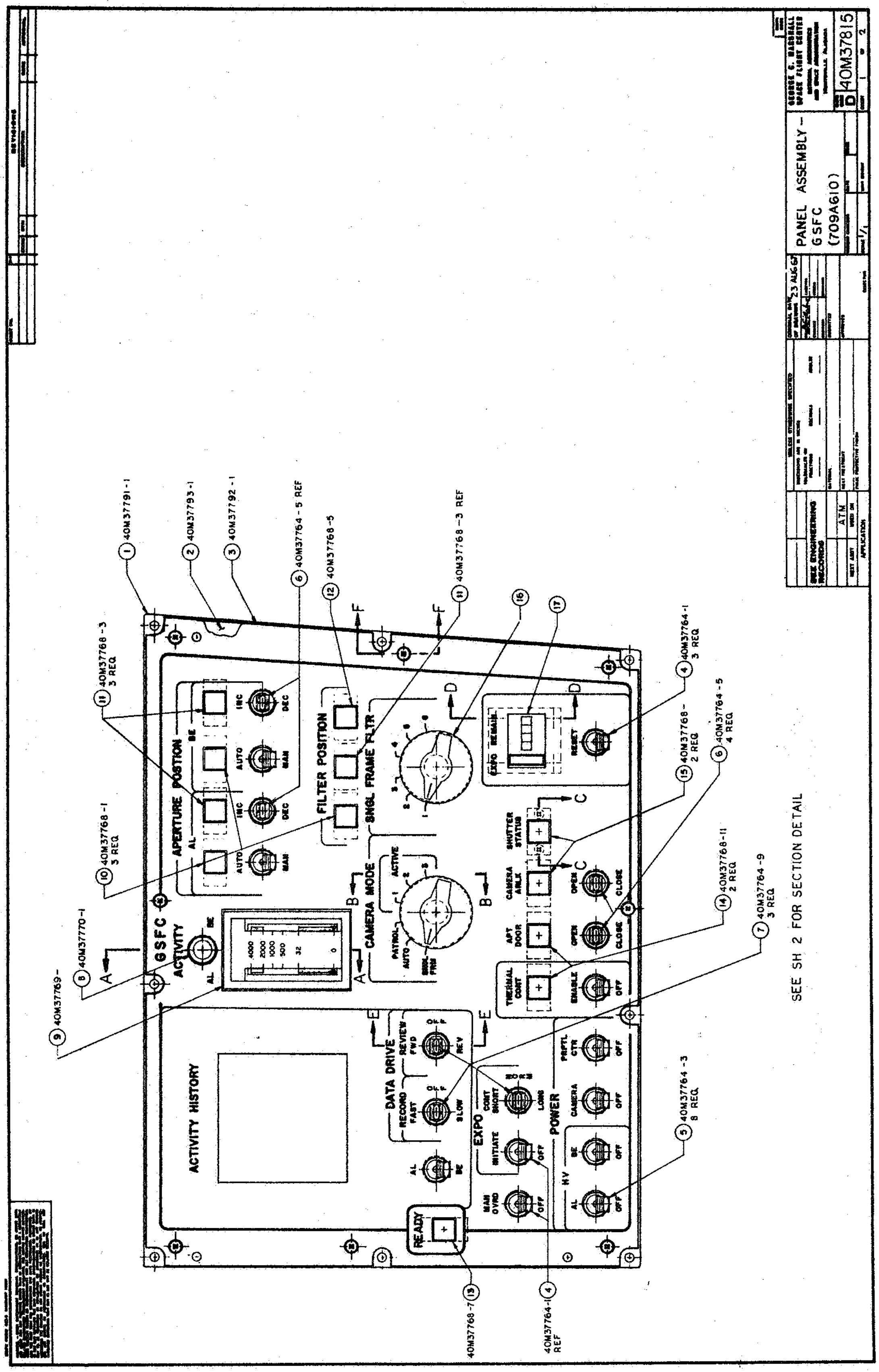


Figure 3-4 - GSFC Panel Assembly

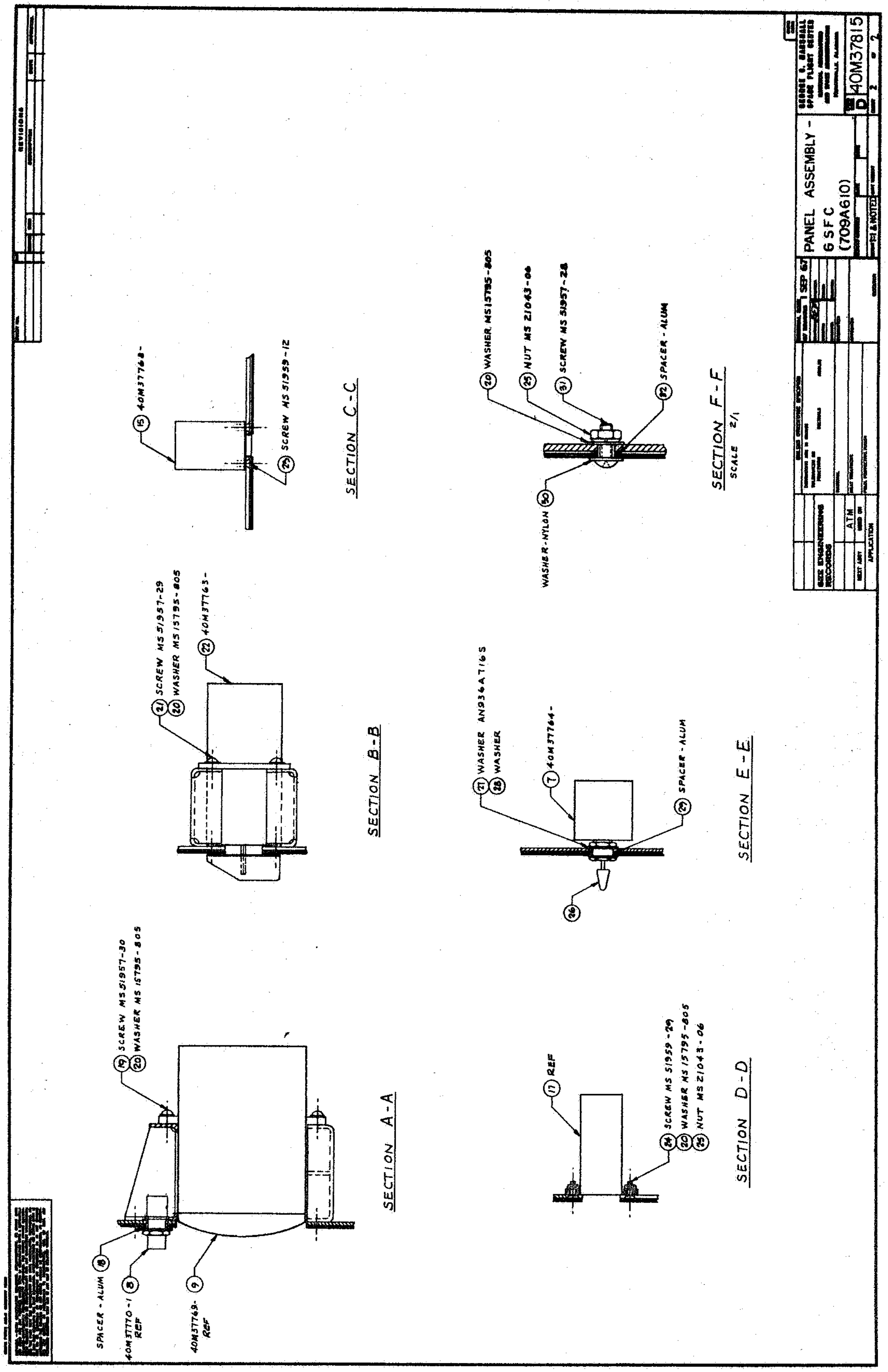


Figure 3-5 – GSFC Panel Assembly Sections

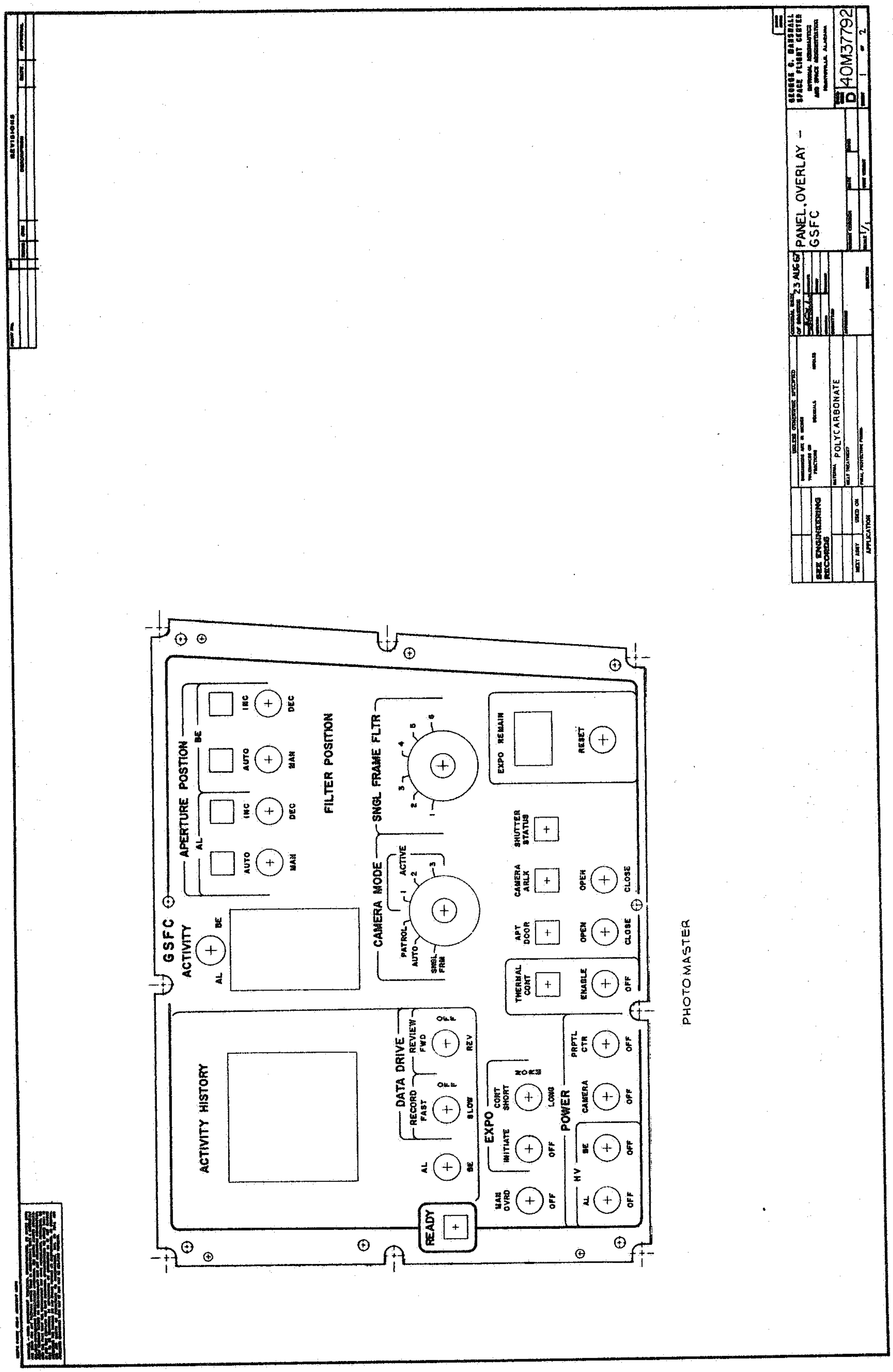


Figure 3-6 – GSFC Panel Overlay

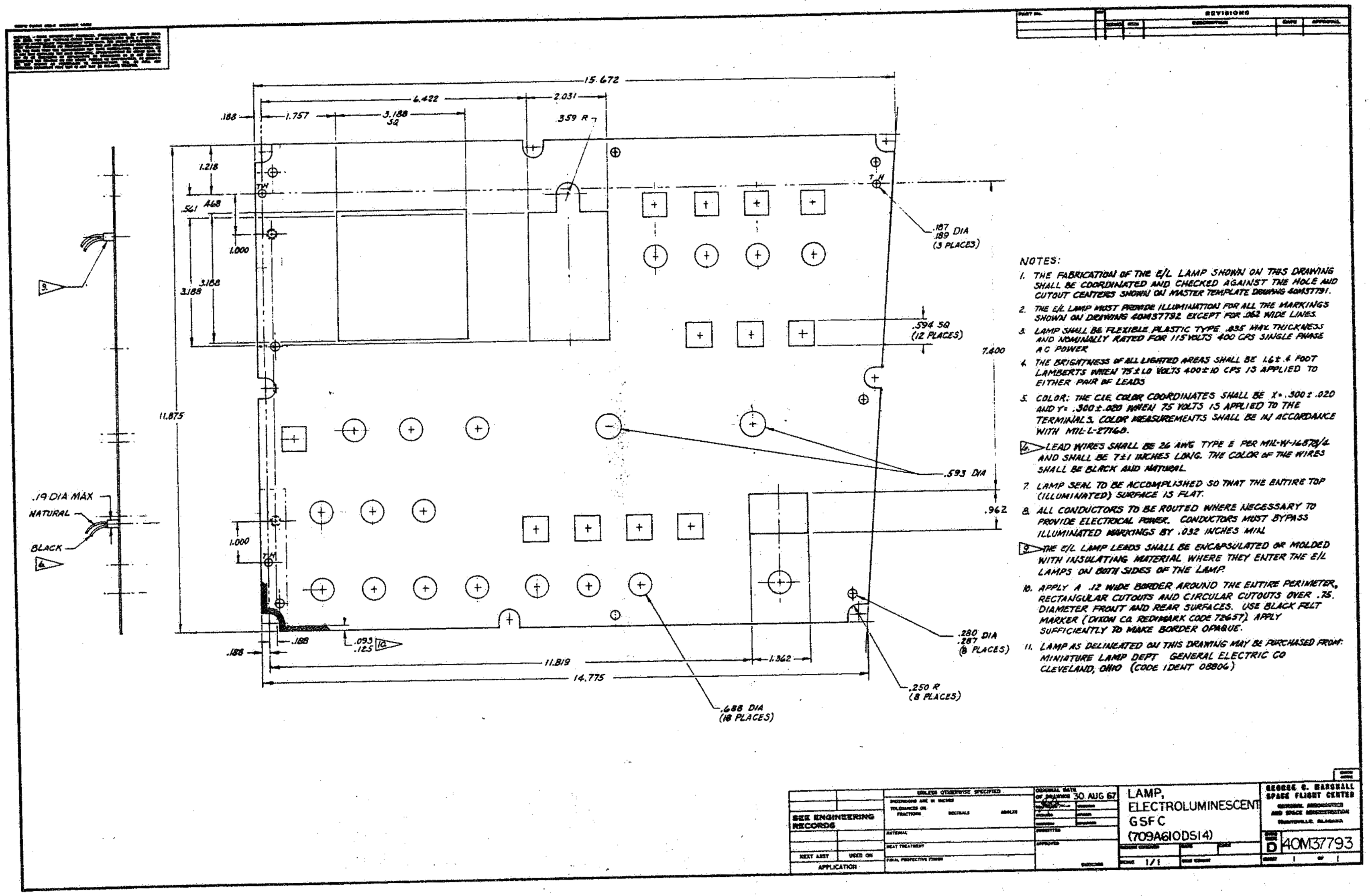


Figure 3-7 - GSFC E/L Lamb

Very large and heavy components such as the Activity History Plotter are CG-mounted to the panel support structure on the consoles, with only minor contact to the panel back to provide vibration damping. The panels are mounted to the consoles by CRES fasteners retained by self-locking nut plates. The panels can be removed for maintenance etc., from the front, with the larger components being removed from the rear of the consoles.

A master tooling template drawing (40M37791) was made to coordinate and control most common hole locations in the overlay, EL and panel face. Tooling template can be made from this master and sent to the detail vendors for part consistency.

3.4 C&D SAFETY CONSIDERATIONS

To eliminate an accidental actuation of a component and to aid the astronauts during the ingress/egress maneuver, a safety bar will be added to the left-hand side of the side console (x-z plane). A safety bar will also be added over both of the lower power panels in the lower console, to prevent the astronaut from inadvertantly actuating a component with his foot or knee during the experiment operations or during the ingress/egress maneuver.

A transparent plastic cover will be pulled over the pointing control panel to protect the PCS components and the hand controller.

A cover will be installed over the exposed face of the center console when it is in the stowed position.

Section 4
STRUCTURAL CONFIGURATIONS

The panel and console structural design criteria was based on the inertia loads occurring during the Boost Phase and the Ground Handling and Transportation Phase as discussed in the Design Guidelines (Reference 2).

4.1 BOOST PHASE:

Rigid Body Loads:

$$n_x = 4.9\,g$$

$$n_y = 0.65\,g$$

$$n_z = 0.65\,g$$

Vibration Loads:

The individual panels were designed for a dynamic response of 31 g's. These loads were used in the design and analysis of the panels and panel attachments, and they correspond to localized vibrations.

For design of the console structure a dynamic load factor 5.0 g's was applied in each of three axes. These inertia loads correspond to an overall dynamic response due to the vibration environment during boost. The Center Console, however, presents a special problem which is covered in a later paragraph.

4.2 GROUND HANDLING AND TRANSPORTATION PHASE

The maximum accelerations during this phase are:

$$n_x = 3.5\,g$$

$$n_y = 2.0\,g$$

$$n_z = 4.0\,g$$

4.3 SUMMARY OF DESIGN LOADS:

From the above, it can be seen that the maximum design loads will result from vibrations during boost. For the console structure a load factor of 5.0 g will be used; for design of individual panels and panel attachments a load factor of 31 g was used.

4.4 CENTER CONSOLE

The Center Console is mounted on a parallel bar linkage that permits the console to take two positions: During boost and ground handling of the L/M, the console is stowed on shock mounts; and during use the console is locked at eye level above the Lower Console.

Shock isolation is required in the stowed position to protect vibration sensitive components in the console. To isolate the console in all directions it is necessary to disconnect the parallel bar linkage from the console. Shock mounts will have reasonably high damping and be soft enough to result in a rigid body, natural frequency for the console of 7 Hz or below. The low resonant frequency will provide vibration attenuation for input vibrations above 10 Hz. This low resonant frequency is required to protect the console components for the environment specified in Reference 3.

LM Ascent Stage Primary Structure

Sine	
5-20 Hz at 0.2 in DA	5-30 Hz at +6 db/oct
20-2000 Hz at 8.6 g's peak	30-700 Hz at 0.61 6^2/Hz
	700-900 Hz at -18. db/oct
	900-2000 Hz at 0.18 6^2/Hz

The loads on parallel bar linkage will be critical when the Center Console is moved from the stowed position to the readout position during ground checkout. During the actual mission the loads will be minimal since the LM will be operating in an essentially zero gravity environment. Good design practice requires that the linkage have reasonable stiffness and strength to withstand loads that might occur during ground checkout and positioning.

4.5 ANALYSIS

The stress analysis was based on the following factors of safety:

- Limit Load, F.S. = 1.00 on yield strength
- Ultimate Load, F.S. = 1.25 on ultimate strength

Material properties were based on minimum guaranteed properties per MIL-HDBK-5 or other approved sources.

Section 5
THERMAL ANALYSIS

Primary emphasis of the thermal investigation of the display panel has been the preparing of a thermal model for analysis by the Lockheed Mark -5C Digital Computer Program. An initial calculation of the steady state radiative heat removal mode from the panal to the LM cabin walls was made and documented in Reference 4. This document was supplied to NASA, Houston, Texas, as a basis for the radiative LM thermal control test series as outlined in NASA Specification Number 50M02808. From this initial study, the ground work for the following thermal analysis was laid.

The intention of the basic thermal analyses digital representation is to provide a basic monitor panel structure analytical model to which the different heat sources can be added, and perhaps rearranged, at a later date. Provisions for an investigation of possible cooling methods are also contained in the basic digital model of the display panel.

At the present time, the thickness of the aluminum panel structure is a preliminary value. For design purposes, however, it is assumed that the components are connected by sufficient thermal paths to permit rapid heat transfer to the walls of the Center Console. In this respect, and to simplify the thermal digital model input, the walls of the panel are assumed to be .16 inch thick. This thickness should give a good representation of the thermal capacitance of both the outer skin and structural members of the panel.

Figure 5-1 shows the basic breakdown of the elemental structural network used to represent the structure of the Center Console Panel. Only one-half of the structure is modeled, since the system is symmetrical in nature. The left side of the panel is represented by the resistor-capacitor network shown

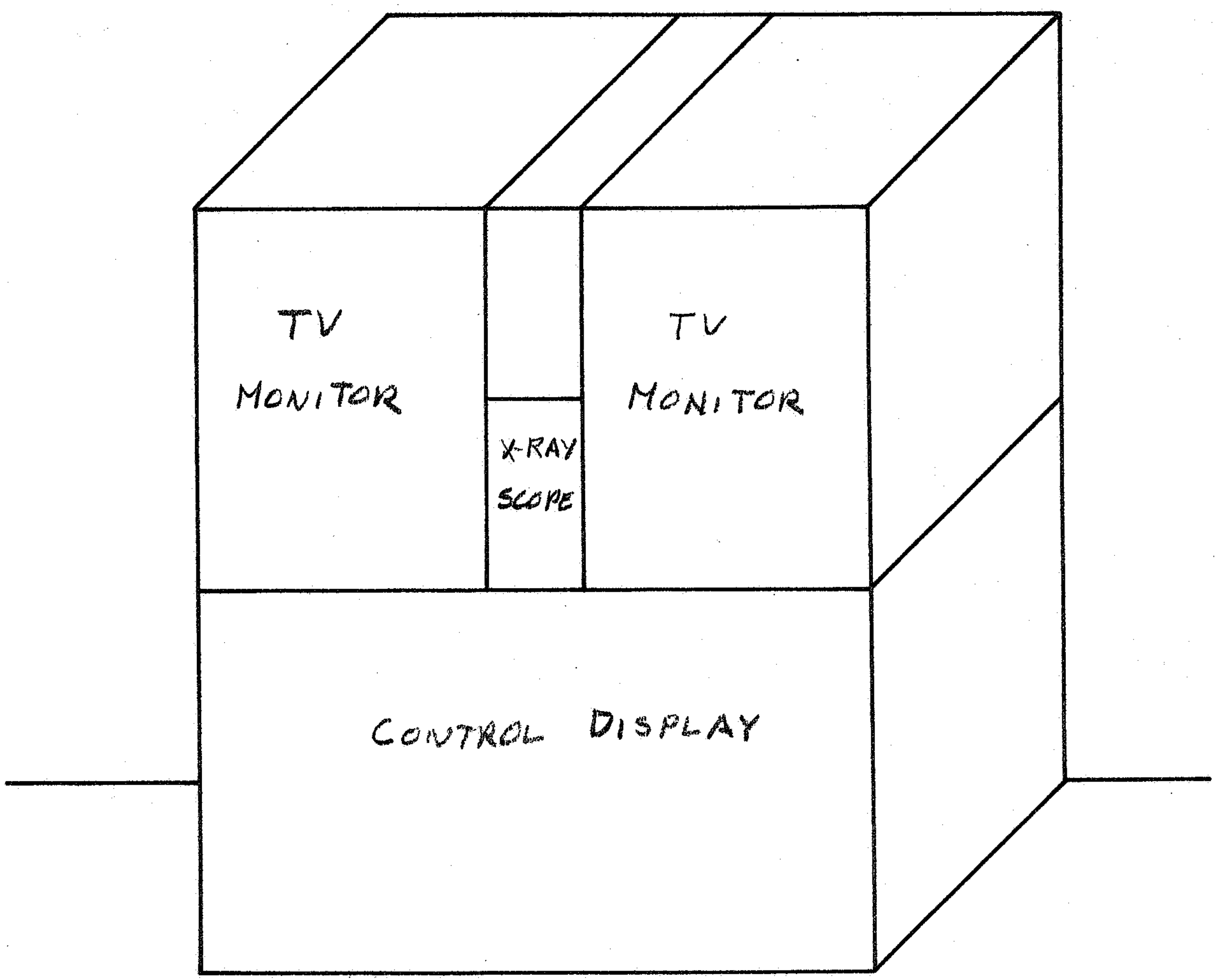


FIGURE 5-1 SCHEMATIC OF CENTER CONSOLE STRUCTURAL ARRANGEMENT

in Figure 5-2. The location of each node in respect to its conduction and radiation paths to other elements in the thermal model is listed in Appendix A, which also contains the pertinent thermal parameters of each node. The calculation details of all conduction resistors, thermal capacitors, and radiation view factors have been intentionally omitted to keep this document brief.*

The following components have been treated as contributing heat sources in the basic digital thermal model of the Center Console:

• 1 AS&E Box	5.00	watts
• 11 Flags	.45	
• 2 TV monitors	88.00	
• Electroluminescent Lighting	13.89	
TOTAL	107.34	watts

Both the TV monitors and the AS&E X-ray scope heat inputs to the panel structure are represented as passing equally through all sides of each component. With this approach, no local hot spots on each component are accounted for in this analysis. As the system design becomes finalized, the digital model may be readily changed to account for such hot spots.

The remaining heat energy from the lighting and other small instruments is calculated as being evenly distributed over the forward face of the panel. The schematic of Figure 5-3 shows the input locations of the heating (described above) as coded to the digital thermal model. All surface emissivities are assumed to be .95 for calculation of radiative heat removal from the display panel.

*The original working notebooks which give all details of the digital model assembly are being retained at Lockheed/Huntsville and are available by contacting the Thermal Environment Section.

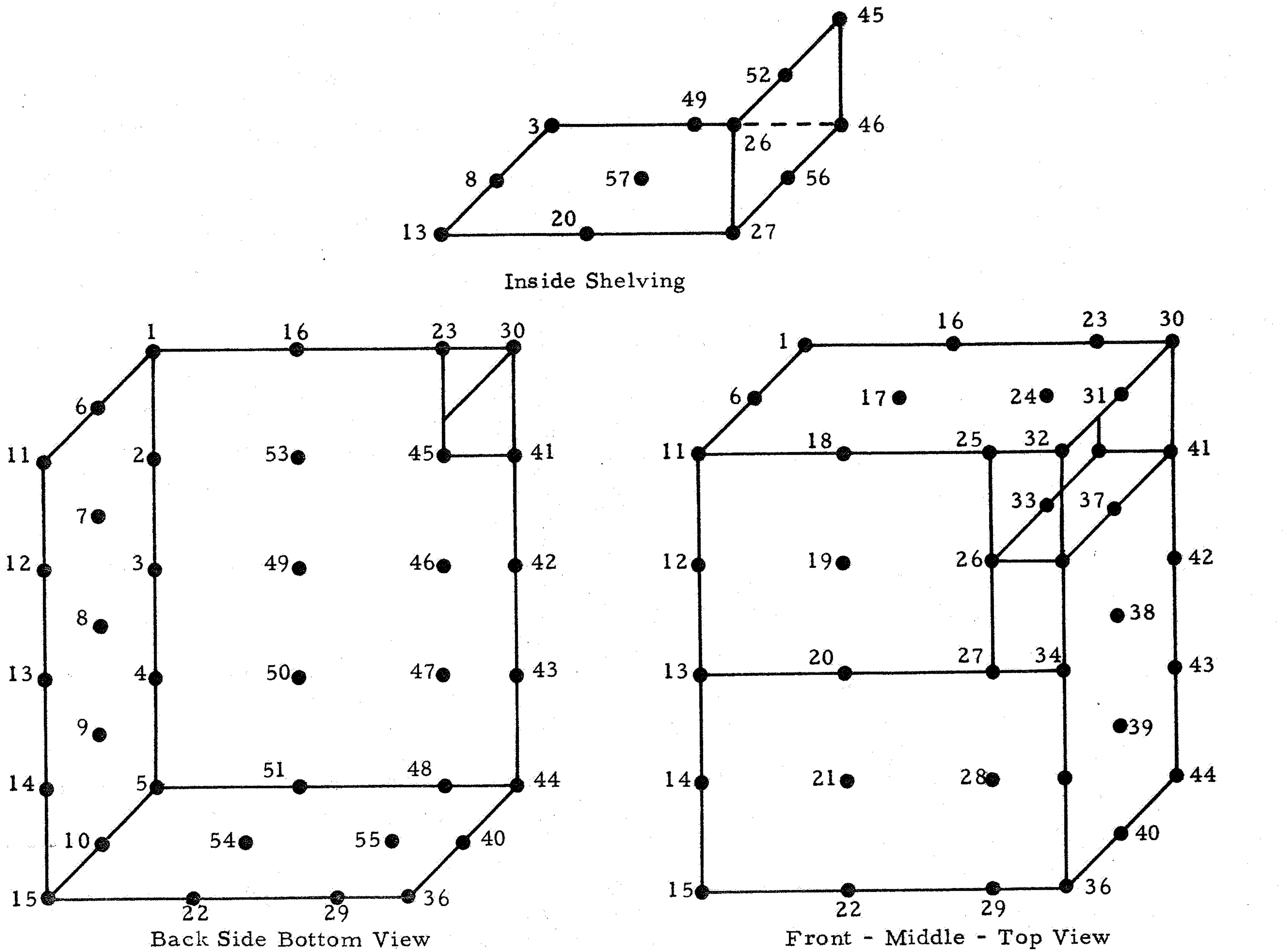


Figure 5-2 - Nodal Breakdown of Thermal Model of Center Console

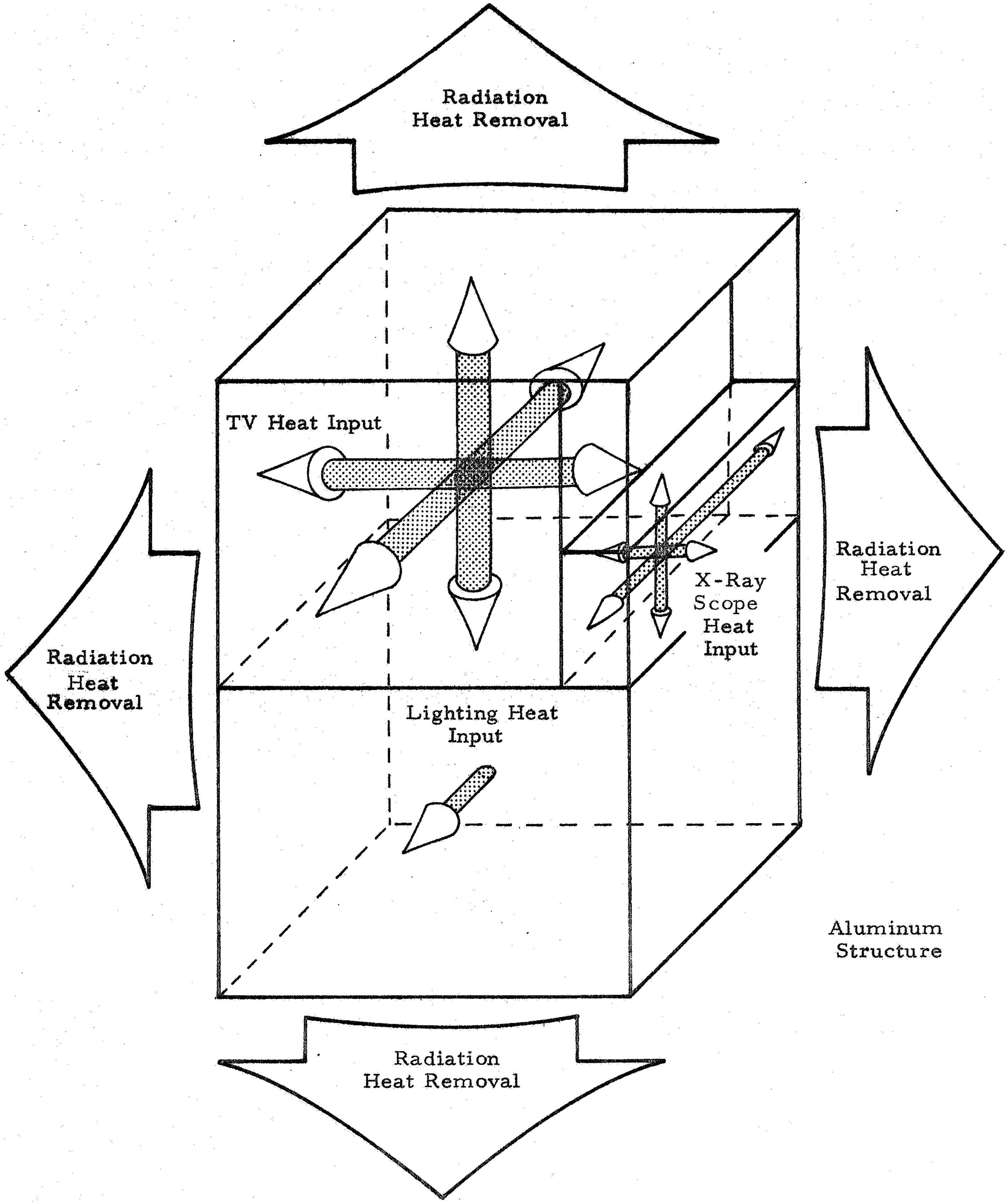
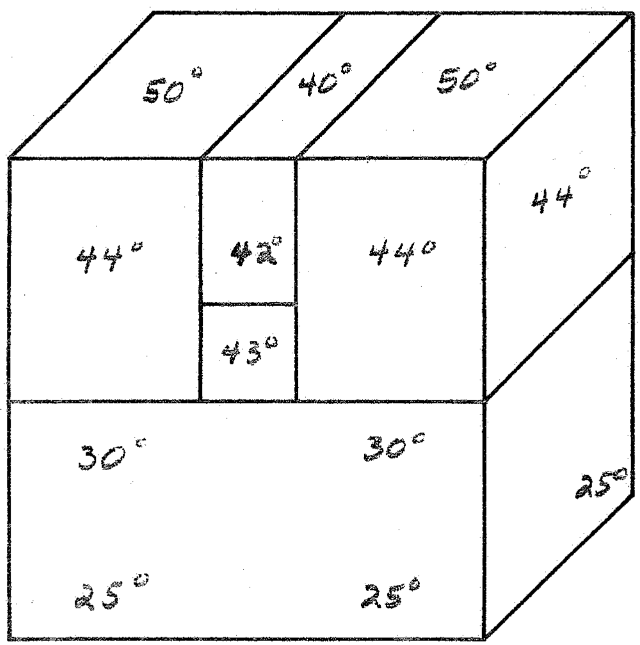


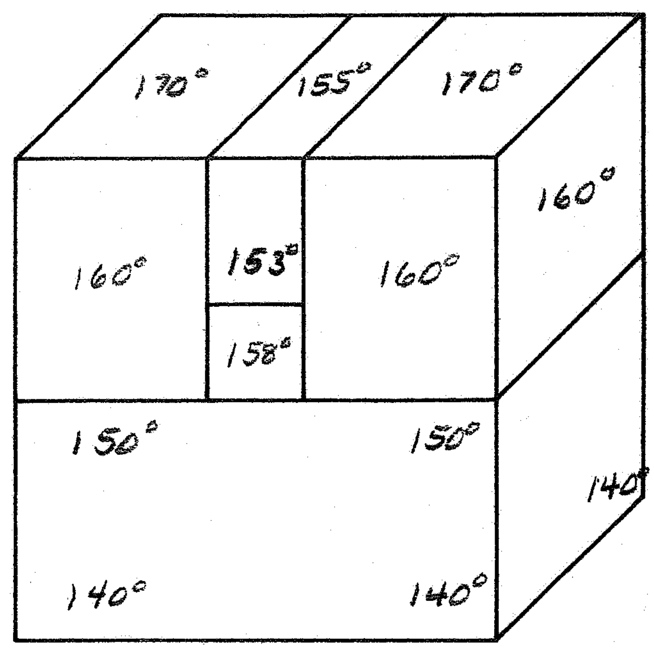
Figure 5-3 - Schematic of Heat Input to Thermal Model

The present digital model (i.e., cooling other than radiation) has been run for three cases for this report. Two of the cases are steady state with the radiative sink temperature being set at -35 and +160 degrees Farenheit. Figure 5-4 shows the steady state temperature at different locations on the console for each of these cases. A third case considered was transient, with the assumption that the instruments were turned on 10 minutes and then turned off. Temperature time histories of this case are shown in Figure 5-5.

As can be seen from this initial study, the temperatures reach prohibitive values. For this reason, it is recommended that further investigation be done to establish design criteria for a cooling system to transport the excess heat from the display panel. This can be done by simple additions to the thermal model which is described above.



-30°F LM Cabin
SINK TEMPERATURE



+165°F LM Cabin
SINK TEMPERATURE

FIGURE 5-4
STEADY STATE TEMPERATURES
OF CENTER CONSOLE

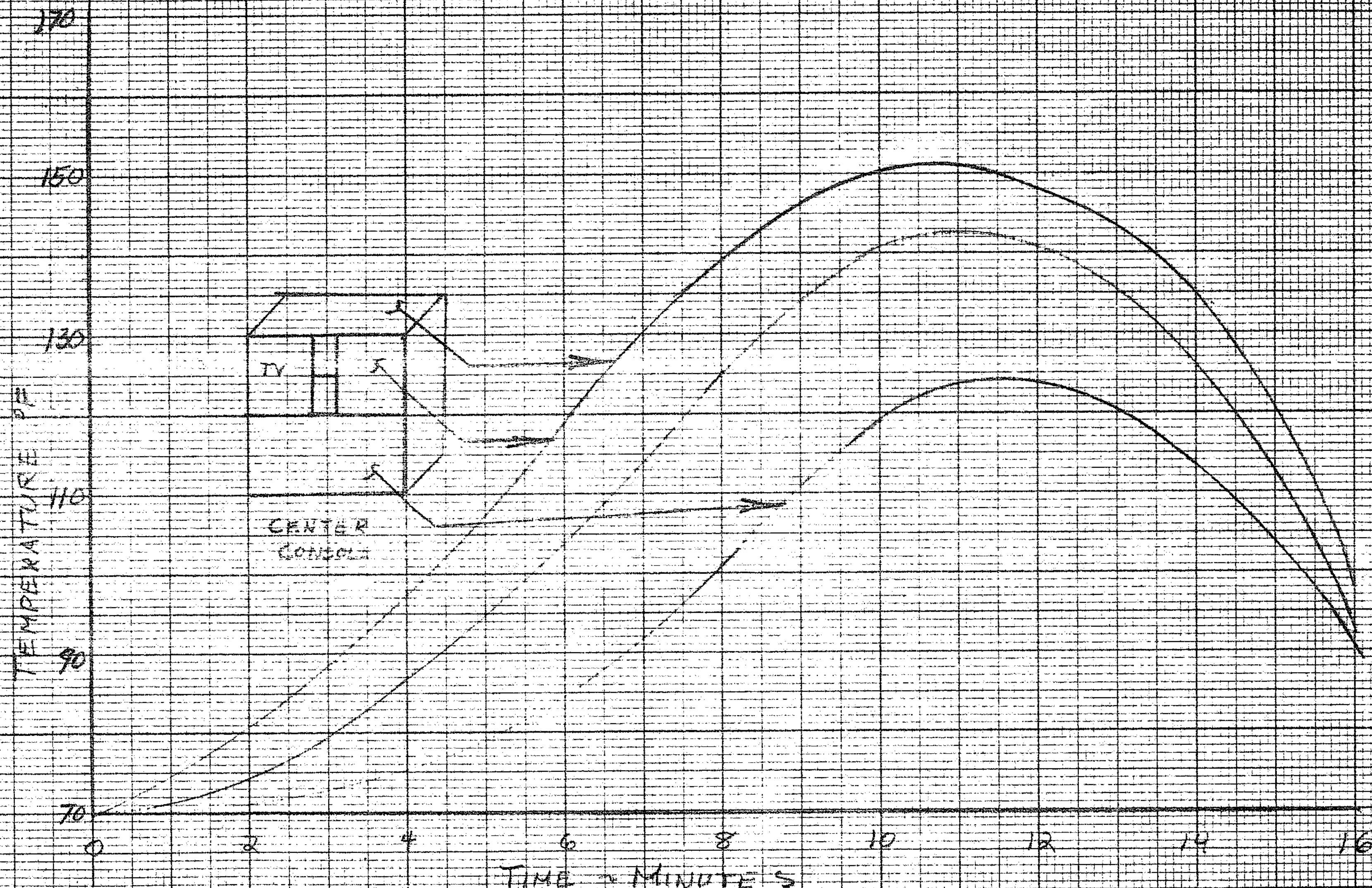


FIGURE 5-5 10 MINUTE TRANSIENT
TEMPERATURE HISTORY
-165 °F HEAT SINK

Section 6
ELECTRICAL DESIGN

The major electrical work on the ATM Console design was concentrated in the following areas:

1. Ground rules
2. Interface control document
3. Electrical schematics.

The first two areas are discussed in Sections 7 and 9, respectively. The third area of concentrated effort was in the electrical design of the ATM Console and to a lesser extent the ATM Distribution Box. Intercabling between the bulkhead, the Distribution Box, the existing LM equipment and the ATM Console have been considered and appropriate allowances have been made. However, the intercabling aspect has been thus far considered secondary to intra-panel electrical design.

This design was documented on inked schematics, Class I format. (Reference 7). The electrical design of the Distribution Box is incomplete because:

- Whether or not a wire (or all wires) should go through the Distribution Box was not finally resolved. The schematics presently route a minimum number of signal wires (largely Caution and Warning) in addition to control power through the Distribution Box
- Final decisions as to optimum power bus arrangement, the use of power isolation diodes, and circuit breakers were not made in time
- No mechanical design of the Distribution Box has been made due to lack of time and resolution of problems.

The electrical design of the ATM Console and the preparation of schematics required close coordination with the Ground Rules and the Interface Control Document in the field of pin number assignment.

The design of the Caution and Warning System required special consideration. Incomplete information on this system left unresolved whether the ATM system required its own Master Flip-Flops, Relay Drivers, Electronic Switch and Tone Generator, and whether the system should be inter-connected to any or all of these components in the existing equipment. In the present schematics, all boxes in the ATM system are duplicated for reliability purposes. Appropriate connections are provided between the ATM console and the existing LM equipment. These connections include a LM caution signal, a LEM warning signal and two independent 115 volt, 400 Hz, power sources.

A simplification made in these schematics over those of 7 July is the use of ring-type wiring in place of buss bars. This simplification provides more reliability (a break in one wire in the ring does not disable any component) and a saving in mechanical weight and space (no buss terminal strips with extra potting required).

A major project during this schematic revision period has been the updating of the required controls/displays and the introduction of the DSKY type ATM address system.

The major portions of the switches drive relays in the rack either with a constant 28 volt signal or a standard 20 to 50 millisecond pulse. These relays then activate cirucits which perform the indicated operations. Very few of the switches drive circuits directly. Among those which do are the GSFC switches which are provided signals to be switched by the experiment package. The power system has two rotary switches which select any one of the twenty-four batteries to be evaluated through dual meters. These switches are inter-connected in the most efficient manner to activate relays and thus perform the required selection of functions to be displayed.

Component caution lights are wired so that they all may be tested through the setting of a rotary switch. 28 volt dc power for each meter is used to hold open a relay in the rack. If the meter power is lost, the relay closes and the component caution light above the meter which has failed is lighted by a 5 volt source.

Consistency has been maintained among the following:

- Design Guidelines (Reference 2)
- Electrical schematics dated 5 September 1967 (40M37830)
- Interface Control Document (Reference 7)
- Panel layouts with designators as of 18 August 1967 (40M37801)

Section 7
DESIGN GUIDELINES

A single document (Reference 2) was written to compile all information which influenced the design of the console. This information was presented in four categories as follows:

1. Operational Requirements, such as the number of crewmen used at various times, modes of equipment operation, and areas which must remain clear. These requirements were stated mostly in general terms.

2. General Design Guidelines, such as handling, storage, checkout, and maintenance considerations. In this category was included all information which was not peculiarly pertinent to either mechanical or electrical design of the console.

3. Mechanical Design Guidelines, which include mechanical and electromechanical component and system requirements, limitations and application considerations. Also included were the structural ground rules and the basis for them.

4. Electrical Design Guidelines, which specified techniques of bussing and grounding, circuit protection, circuit redundancy and electrical interconnection hardware.

The guidelines document produced during this performance period was an upgraded version of one delivered on 7 July. Much of the information contained in it was provided verbally during this formative stage of ATM development. Incorporation of portions of the document into console specifications and interface documents is anticipated.

Section 8
SPECIFICATION CONTROL DRAWINGS

Work continued in the preparing of specification control drawings for console components. These were based primarily on similar documents previously issued by Grumman for the LM components. The MSFC SCD's indicated: (a) exceptions to the Grumman-specified parts; and (b) previously unspecified versions of the part (by dash number), such as new indicator flag legends and new toggle switch configurations. The vendors were contacted for clarification of technical points, such as practical limitations to the adaptations of LM qualified components. Most of the SCD's prepared under this task have already been used to order ATM components. All SCD's cannot be completed, however, until the console design is frozen.

The following list shows the status of Specification Control Drawings as of completion time of this task:

ITEM	SCD No.	INITIATED	COMPLETED	REMARKS
Indicator, Caution & Warning	40M37762	Previously	This period	
Switch, Rotary	40M37763	Previously	No	
Toggle Switch	40M37764	Previously	No	
Indicator, Flag	40M37768	Previously	No	Sixteen legends released this period
Meter	40M37769	Previously	No	Meter faces released this month
Indicator, Component Caution	40M37770	Previously	Previously	
Flood Light	40M37771 40M37772 40M37773	Previously	Previously	Three types
Indicator, Digital Display	40M37774	Previously	Previously	

Section 9
INTERFACE CONTROL DOCUMENTS

Three interface control documents were prepared to record the aspects of the control console which would be required to mate with other systems. The panel layout is included because it is the man/system interface; the console structure is included because it must occupy and share space within and attach to the LM; and the electrical wiring is included because it must connect with the experiments on the ATM rack and a few points within the LM itself. These three documents serve to formalize interface information which has been obtained through interpretation of documents which were mostly for the most part uncontrolled. A brief discussion of these three documents is presented.

9.1 PANEL LAYOUT

A detailed layout of panel components within the Control and Display Console was compiled as an 11-page interface control document (Reference 5). This document will include all changes made through 29 August.

9.2 CONSOLE STRUCTURE

An assembly drawing of the Console and Display Console structural installation was made. This large drawing (Reference 6) included detailed mounting of the console to the LM primary and secondary structures. These mounting details are related to LM station numbers and are consistent with the structural guidelines discussed in Section 4 of this report.

9.3 ELECTRICAL INTERFACE CONTROL DOCUMENT

This 250-page document (Reference 7) was originated to define clearly the connector number, connector type, pin number, and a brief description of each signal entering or leaving the ATM Console. In addition, the origin and termination of each signal is defined. The designator is given for the control panel component to which each wire is connected. A sample page is shown in Appendix B.

Section 10
COMPARISON OF COMMAND ADDRESS SYSTEMS

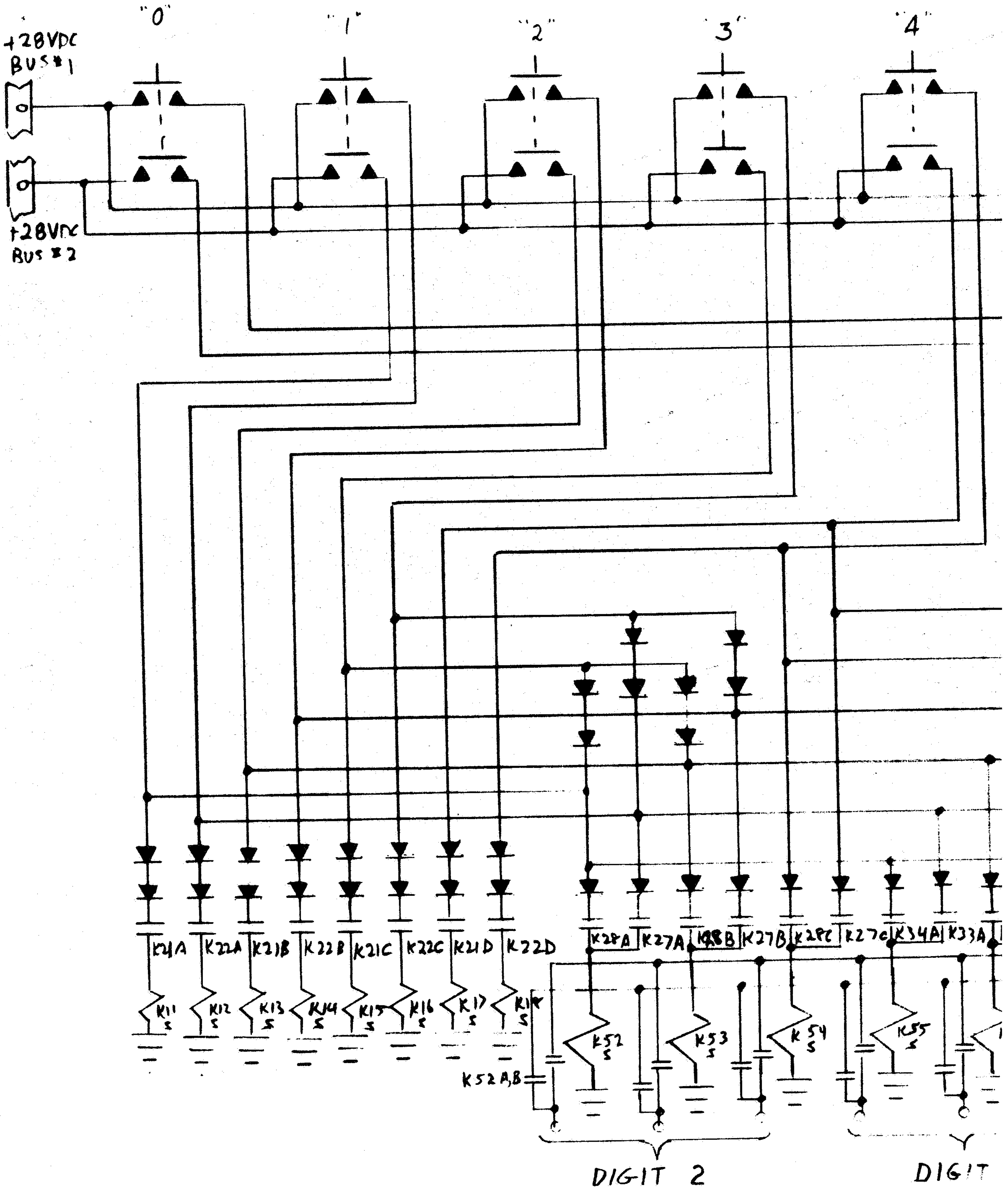
Two systems designed to satisfy the requirements of the Command Address System were compared for function and reliability. Because of the greater redundancy in the digit counter, and because of less use of latching relays, the Lockheed system is judged to be slightly better. The Sperry system, however, is satisfactory and could be used with confidence. It should be possible to combine some of the best features of each in the final system.

10.1 DESCRIPTION AND DISCUSSION OF THE TWO SYSTEMS

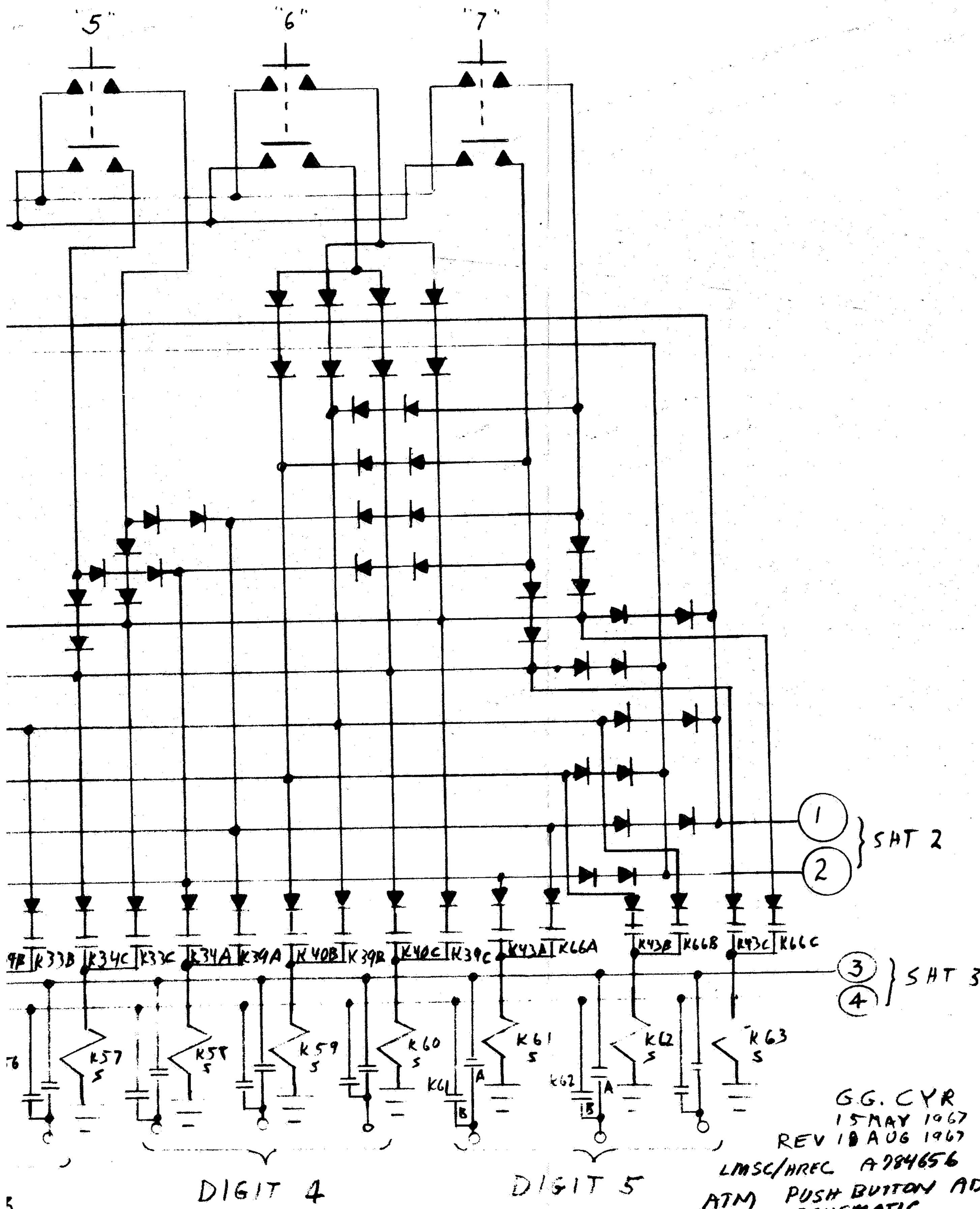
Of the several system variations possible, each designer chose the duplex version in which the pushbutton contacts and the digit sequence counter are duplicated, but the remainder of the logic is simplex.

The Lockheed design (Reference 8) has been slightly modified in Figures 10-1, 10-2 and 10-3 to bring it up to present requirements by providing for twelve bits or three octal digits; and by providing latching relays K52 through K63 to hold the command bits until the fifth digit has been depressed, energizing K43 and the selected command lines.

The Lockheed design selects the actual digit selected and stores it in the command relays K52 through K63. Inversion is accomplished by the normally closed contacts of relays K1 through K10 and K64 and K65 operated by the selector outputs. Sperry's design, (Reference 9) cleverly obtains the logic inversion by labeling the pushbuttons inversely, i.e., the button labeled "7" is wired as octal "0", "6" as "1", etc. The commands must also be inverted so that the operator reads "7" in the command list, pushes the "7" pushbutton actually getting "0" which the computer inverts to "7". Since "7" is displayed, the operator is satisfied. The desired selector, however, is not actually



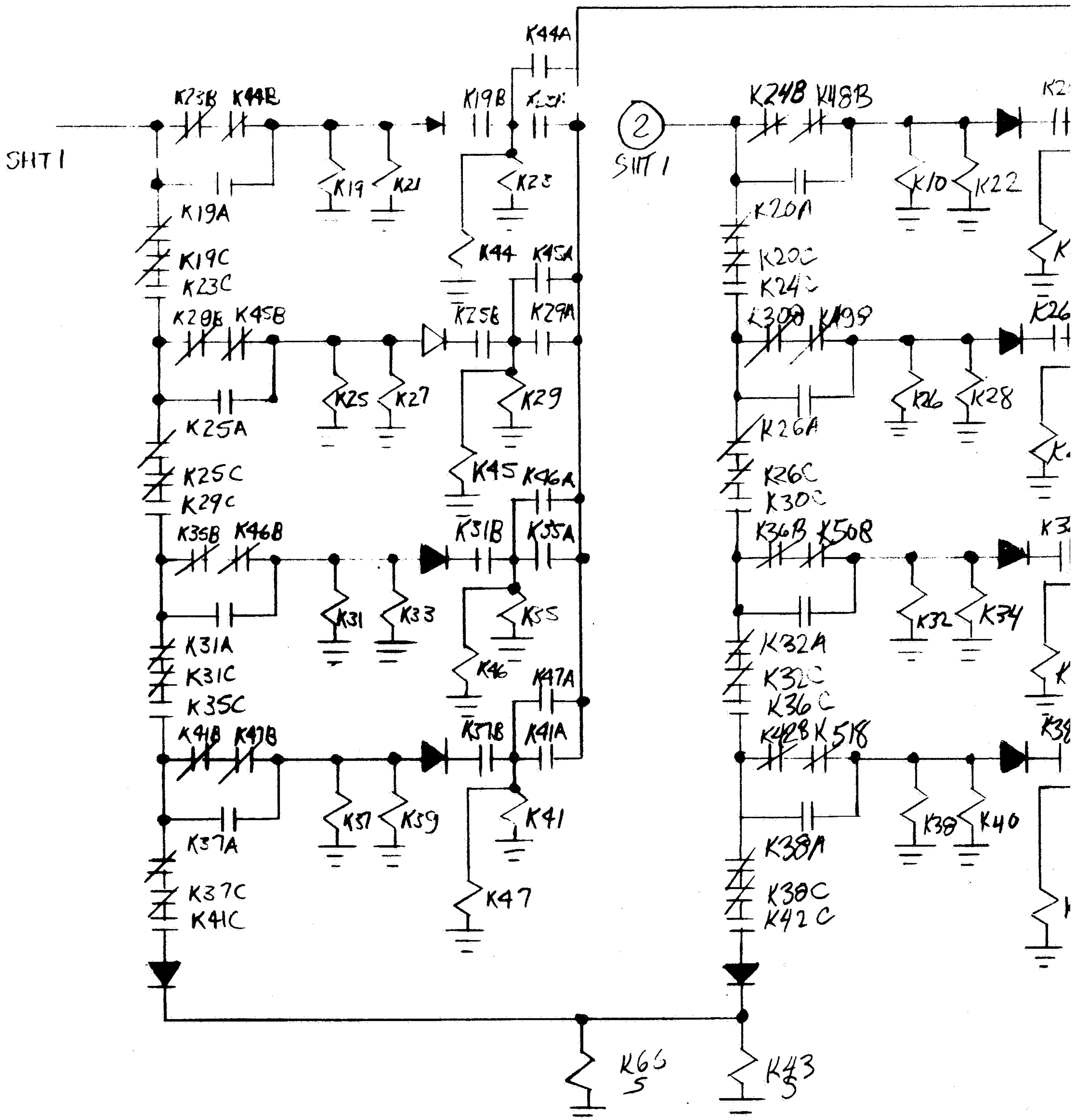
FOLDOUT FRAME 43-A

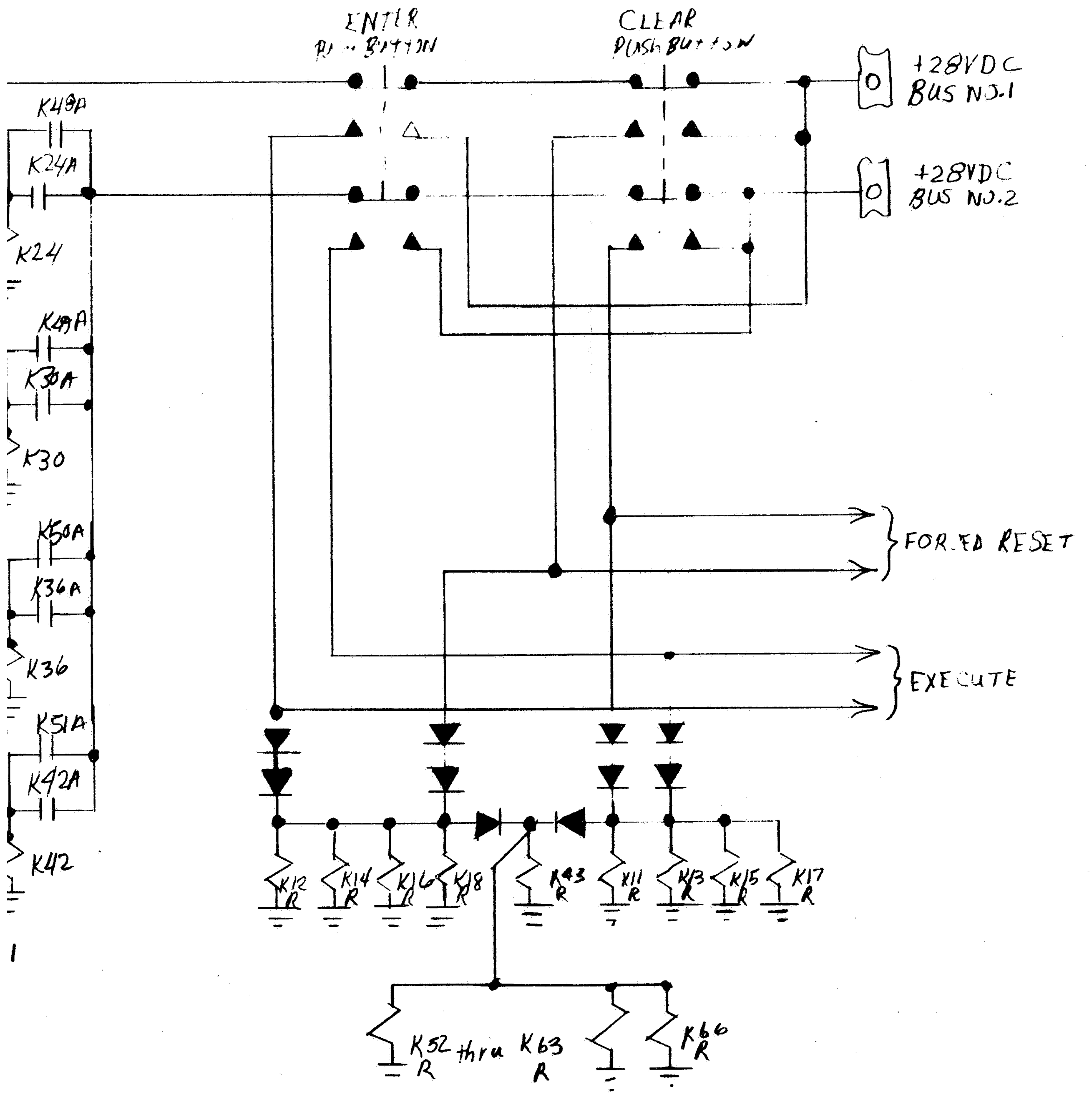


G.G. CYR
15 MAY 1967
REV 18 AUG 1967
LMSC/HREC A784656

ATM PUSH BUTTON ADDRESS SCHEMATIC

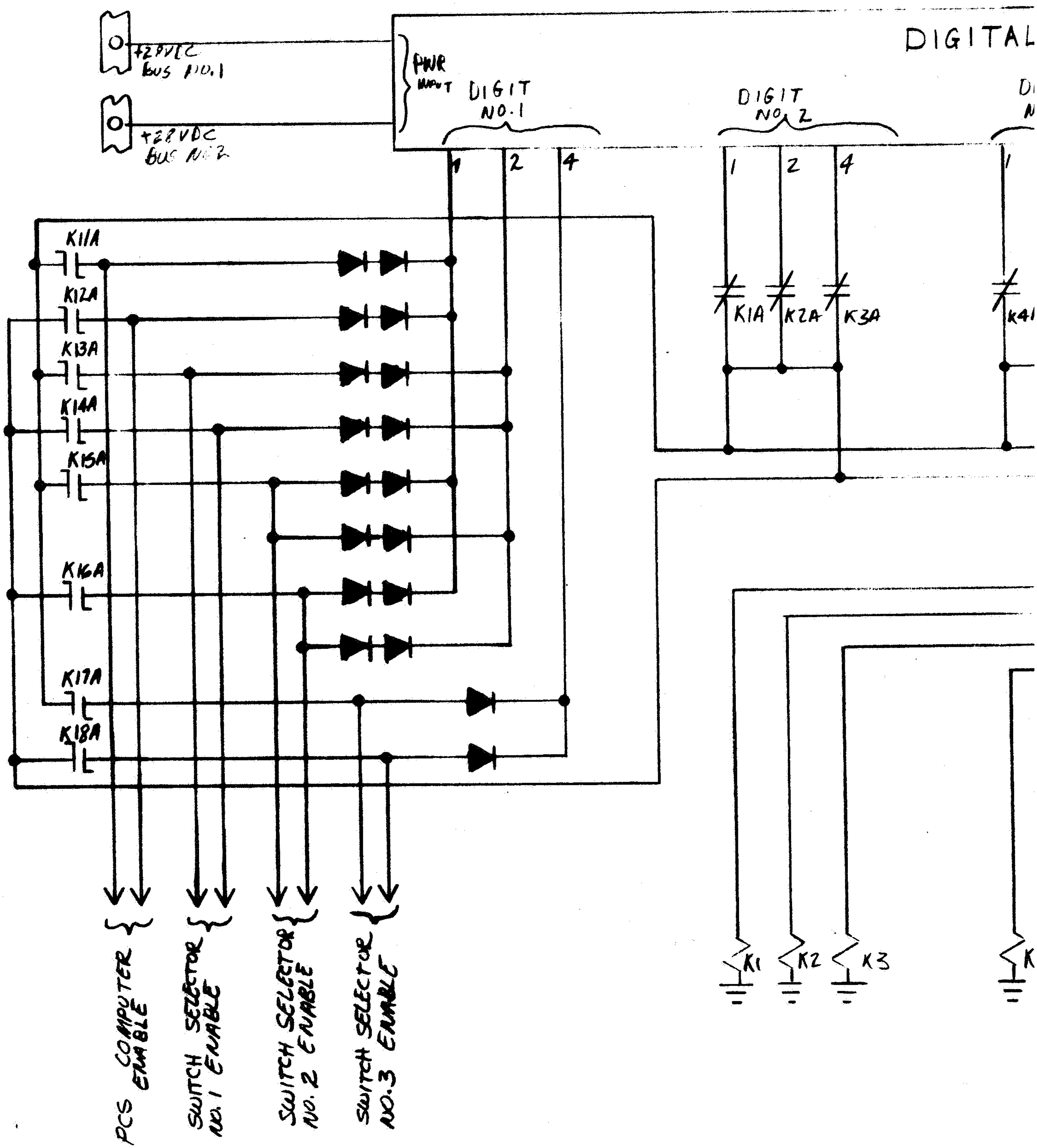
FIGURE 10-1

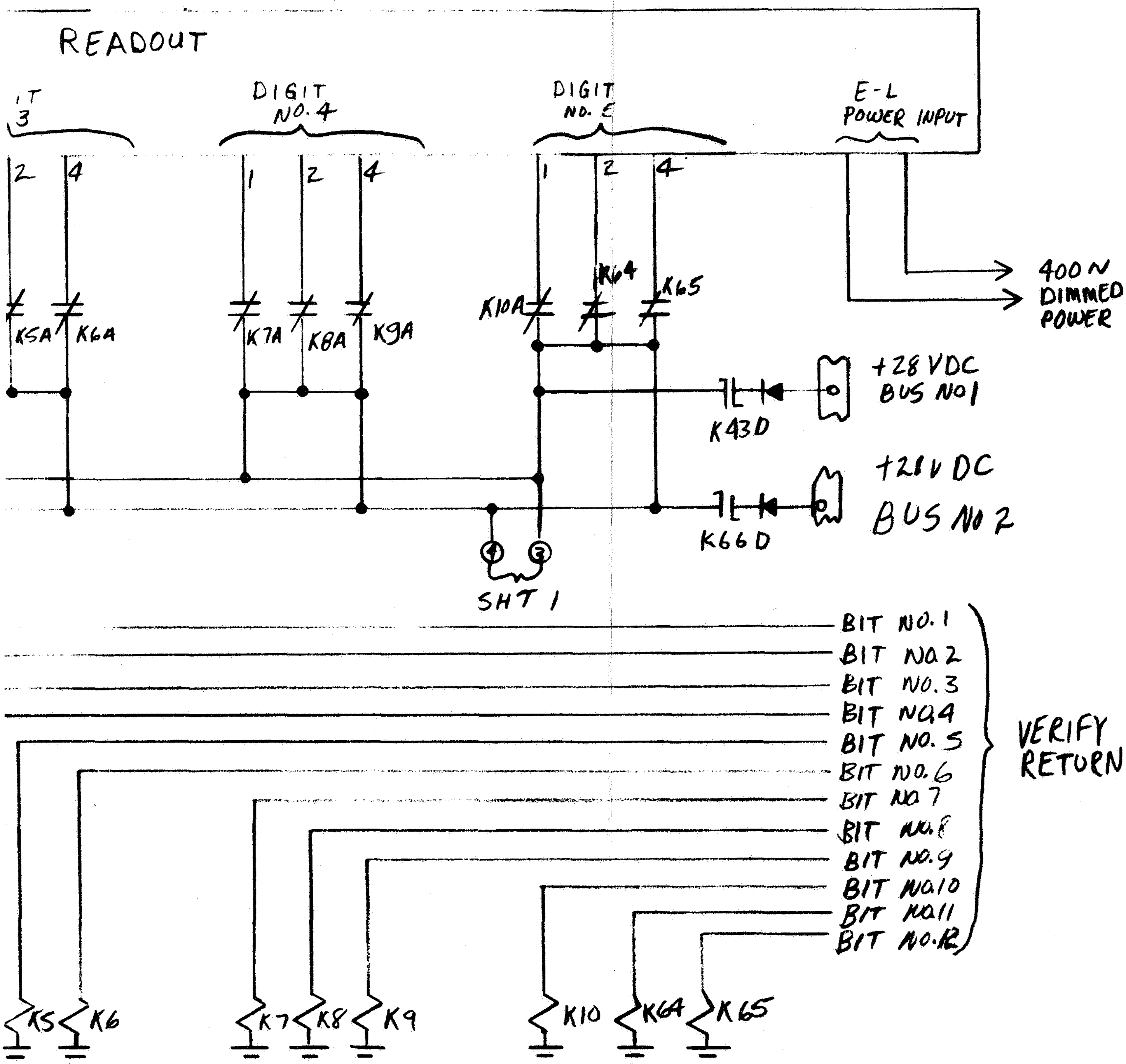

SHT 1
K23B
K44B
K19B
K44A
K19
K21
K23
K19A
K19C
K23C
K44
K45A
K28B
K45B
K25B
K29A
K25
K27
K29
K25A
K25C
K29C
K45
K46A
K35B
K46B
K31B
K35A
K31
K33
K35
K31A
K31C
K35C
K46
K47A
K41B
K47B
K37B
K41A
K37
K39
K41
K37A
K37C
K41C
K47
2
SHT 1
K24B
K48B
K10
K22
K20A
K20C
K24C
K30B
K49B
K26
K28
K26A
K26C
K30C
K36B
K50B
K32
K34
K32A
K32C
K36C
K42B
K51B
K38
K40
K38A
K38C
K42C
K66
S
K43
S



LMSC/HREC A784656
ATM PUSH-BUTTON ADDRESS SCHEMATIC

FIGURE 10-2


+28VDC BUS NO.1
+28VDC BUS NO.2
PWR INPUT
DIGITAL
DIGIT NO.1
DIGIT NO.2
1
2
4
K11A
K12A
K13A
K14A
K15A
K16A
K17A
K18A
K1A
K2A
K3A
K1
K2
K3
PCS COMPUTER ENABLE
SWITCH SELECTOR NO.1 ENABLE
SWITCH SELECTOR NO.2 ENABLE
SWITCH SELECTOR NO.3 ENABLE



LMSC/HREC A784656
ATM ADDRESS VERIFY SCHEMATIC

FIGURE 10-3

energized until the fifth and last digit has been pushed; thus, the display is dark until the command has been completely generated. This makes operation a little more difficult for the astronaut, but it is required by the computer. The use of special (2, 4, 5 and 6) numbers for computer and switch selector designation prevents the choice of a wrong switch selector because of a failure in the selection circuitry (any failure will result in an "illegal" and therefore unwired selection). In contrast, Lockheed's 1, 2, 3, 4 system would choose "2" if "3" were selected but "1" were defective.

The Sperry system does not require the signal inverting relays (K1 through K10 of Lockheed's scheme) because the inversion is performed in the labeling of the pushbuttons. Thus, the switch selector output can be displayed directly.

In either approach, a failure of a pushbutton mechanism (i.e. broken return-spring, stiching button, welded contacts, etc.) would completely disable the system. For this reason it is recommended that the pushbutton assembly be made replaceable, and a spare be provided. Only 22 or 24 wires are required and the added connector is far more reliable than the pushbutton assembly.

The Sperry system makes extensive use of latching relays, while the Lockheed system uses redundant relays with holding contacts within the redundant counters. Thus, a simple part count is not sufficient to evaluate comparative reliability. In either case the astronaut can clear the entire system and re-insert the command if the digit counter momentarily hangs up.

Noted that with either system, if the astronaut pushs an extra pushbutton by mistake (a total of six digits rather than 5), an erroneous command can be generated. The last digit will consist of the combined (not by true addition) binary ONE's of the last two digits (ex., 2, 2 ⟶ 2; 2, 1 ⟶ 3; 2, 3 ⟶ 3; 5, 4 ⟶ 5 and 5, 6 ⟶ 7). Each system, however, provides a safeguard.

Each system will abruptly display the entire command after the 5th digit has been depressed and thus, signal that the command is complete. The last digit will change if a 6th digit is depressed and causes an error. Either system should thus be reasonably error-proof if it is operated with attention. A more positive safeguard, however, is desirable.

10.2 CONCLUSIONS

- Both systems are satisfactory
- Each system has advantages over the other in various areas
- A combined system which uses the best features of each is recommended. This should include:

  1. plug-in pushbutton assembly
  2. Sperry's pushbutton logic inversion to permit direct readout of computer/switch selector command
  3. either digit counter (preferably Lockheed's) in duplicate for redundance. (The final choice depends on the relative reliability comparison of latching relays versus holding contacts.)
  4. Sperry's switch selector/computer code with the "illegal code on failure" feature
  5. the addition of a disconnect relay operating on the fifth digit to prevent the insertion of an additional digit(s)
  6. two series diodes where full reverse voltage is normal
  7. transient suppression diodes for all relay coils
  8. Sperry's time delay before resetting relays when "Enter" is activated.

Section 11
FLIGHT AND SIMULATOR COMPONENTS GUIDE

This guide (Reference 10) was published to consolidate a miriad of information used by panel layout designers, simulator designers, training organizers, writers of astronaut task analyses and others concerned with operation of the ATM Console. Unlike other documents prepared under this task, the components guide-work was shared equally under another task (Task 25). In this guide the component is thoroughly identified by name, designator, description and part number. Its function, weight, power requirements, availability cost and adaptability to the simulator are given. In addition to its general use for reference, the value of this document to Task 27 is in its consolidation of weights and electrical power requirements.

The weights were essential information for the structural study discussed in Section 4 and reflected in the structural drawings discussed in Sections 2 and 9.2. Electrical power information was used in the thermal study discussed in Section 5.

Section 12

FULL-SCALE MOCK-UP OF CONTROL AND DISPLAY CONSOLE

On 10 August 1967 a full-scale LM mock-up, furnished by MSFC was received at HREC. The latest control and display console configuration (14 August 1967 design) was then mocked-up in the LM in time for a scheduled design review (15 through 16 August). Photos of this configuration are shown in Figure 12-1, a through e. This review was attended by personnel from HREC, MSFC and MSC. The MSC group included two of the Scientist-Astronauts. The mocked-up configuration included the final TV monitor fold-down mechanism design. This mock-up served many valuable purposes, a few of the more important are listed below:

- Visual and spatial verification of the validity of existing design criteria
- Pin-pointing of potential problem areas and anthpometrical limitation
- Demonstration of the clearance between the LM upper hatch and TV monitor in the stowed position
- Demonstration that the ATM tunnel area is not blocked during an astronaut ingress/egress maneuver
- Demonstration of the LMSC console design approach to the ATM personnel, particularly the visiting astronauts.

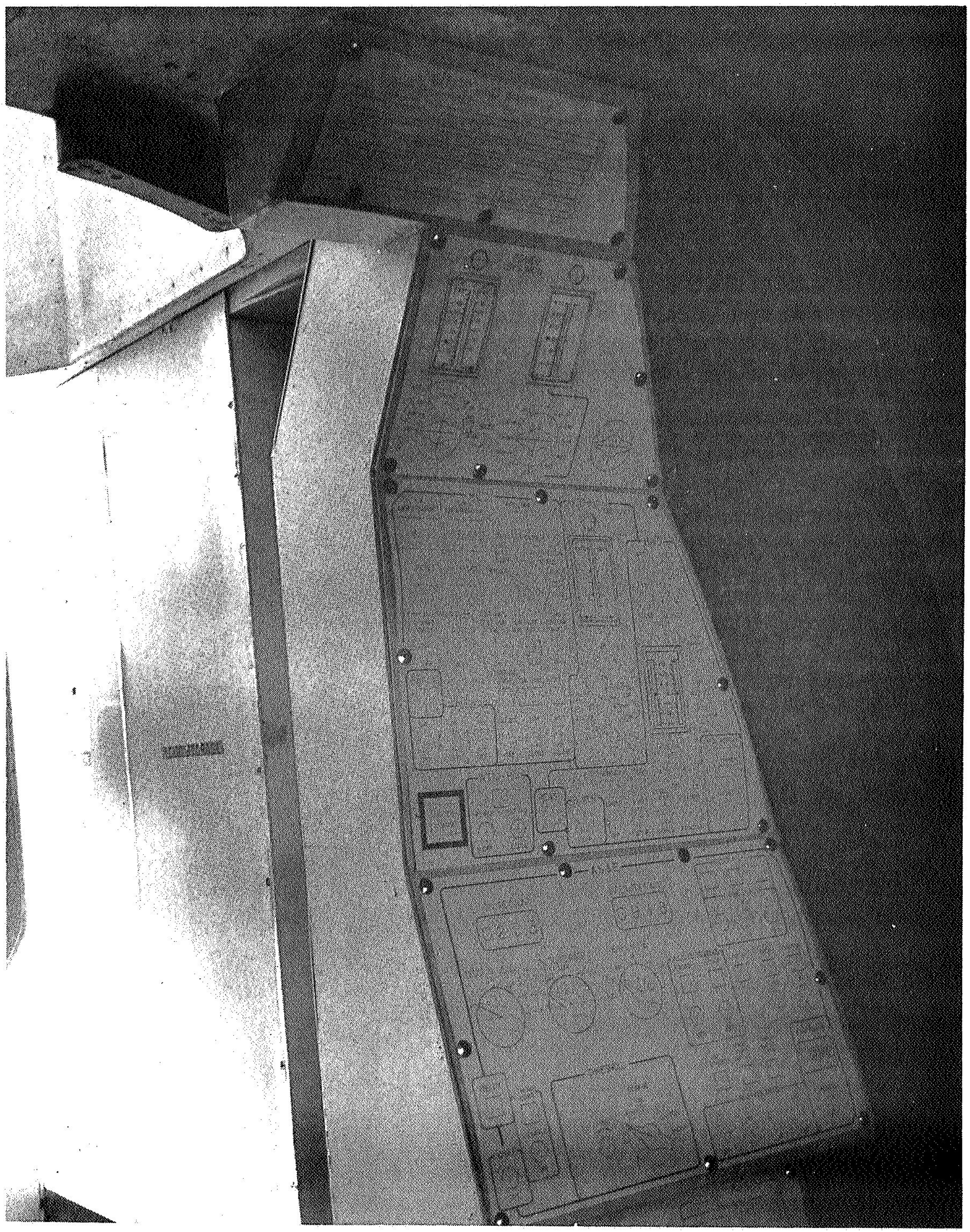


Figure 12-1a - ATM Mock-Up, Side Console (Center Console in Stowed Position)

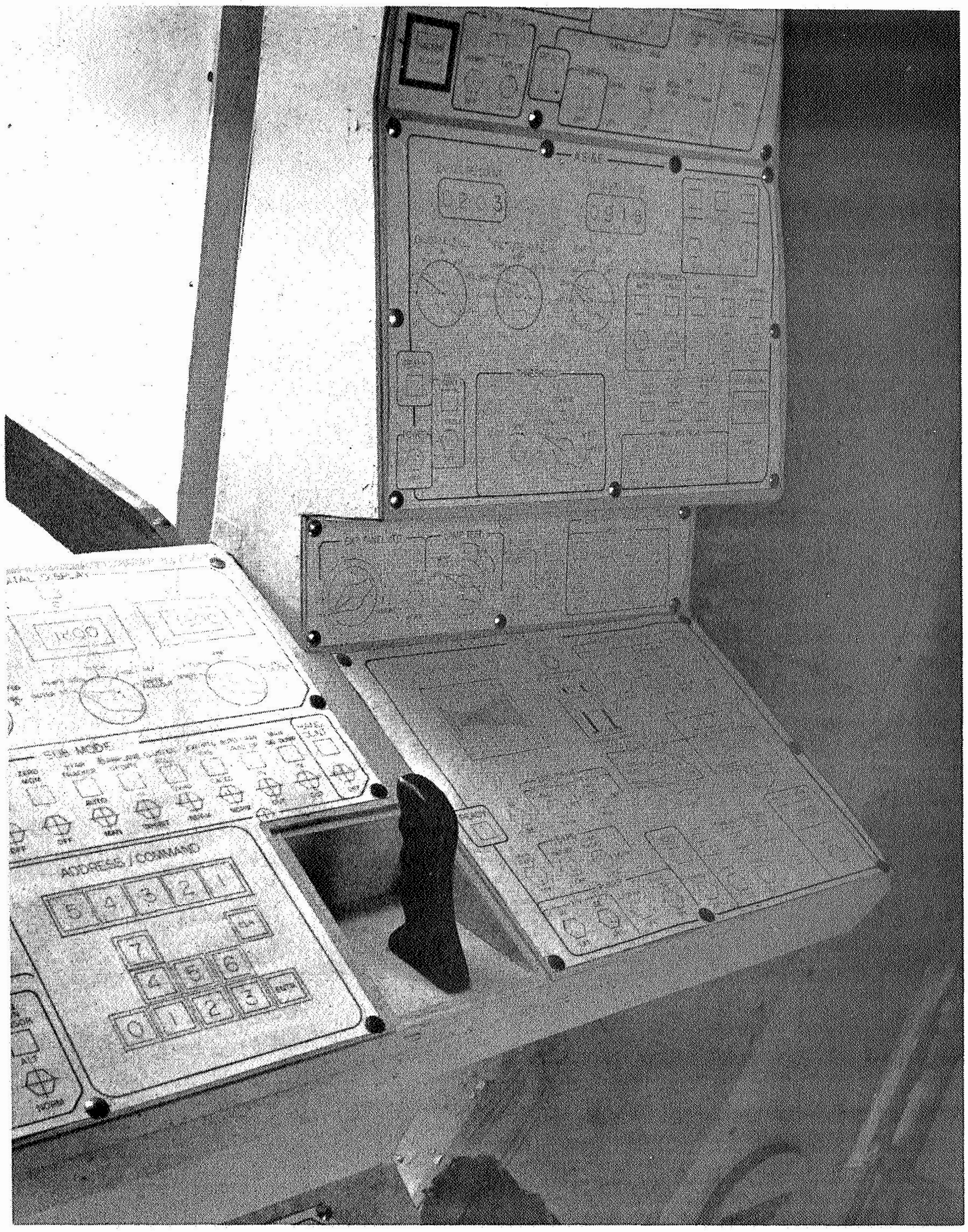


Figure 12-1b - ATM Mock-Up, Lower and Side Console

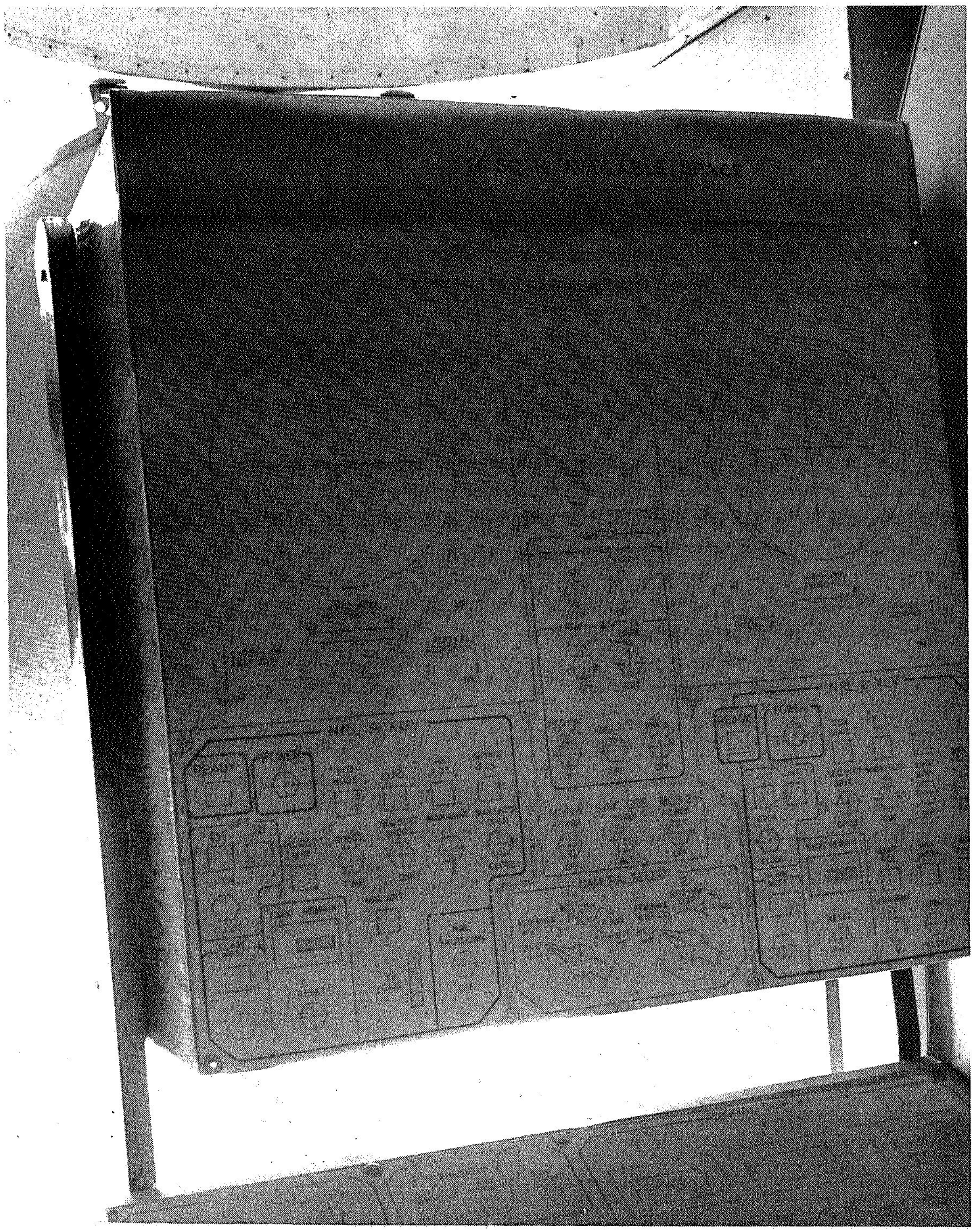


Figure 12-1c - ATM Mock-Up, Center Console in Operating Position

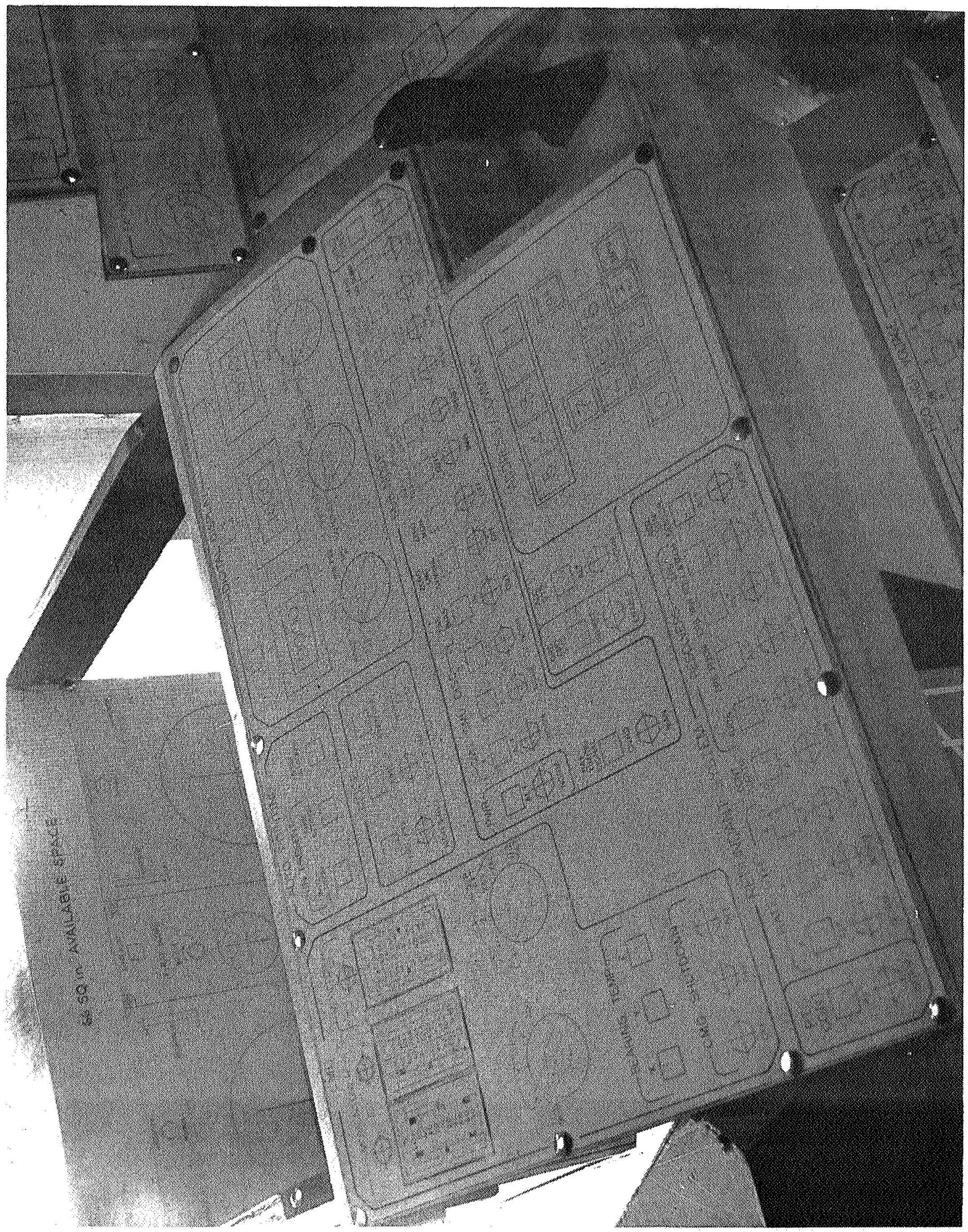


Figure 12-1d - ATM Mock-Up, PCS Panel (Center Console in Stowed Position)

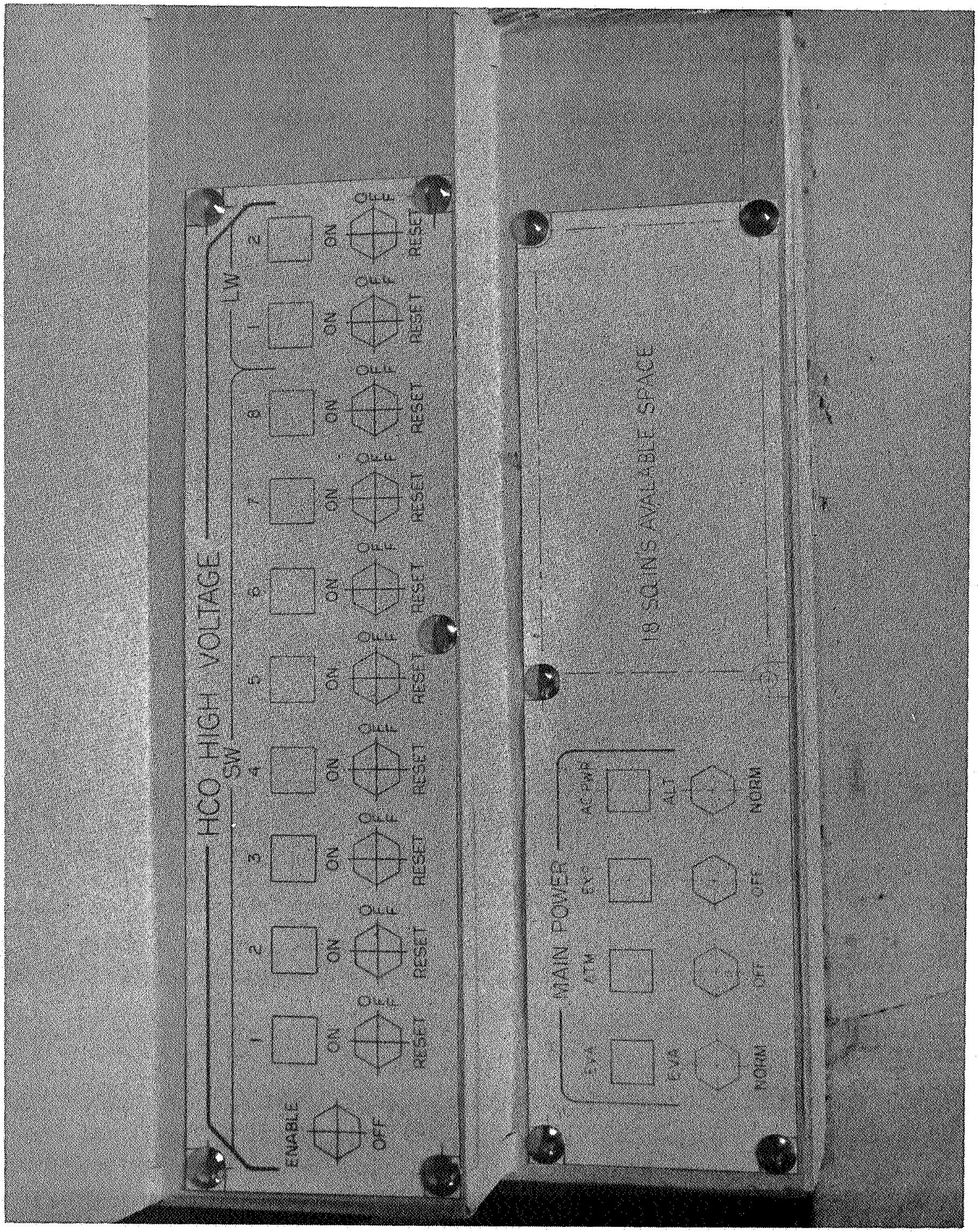


Figure 12-1e - ATM Mock-Up, Power Panels on Lower Console

Section 13
ENGINEERING LIAISON

One engineer was assigned to provide liaison with the cognizant NASA office (R-ASTR-EAS). All instructions and information from that office were received by him for LMSC; conversely, all LMSC transmittals to the office were made through him. He represented LMSC at all ATM meetings pertinent to the task, and arranged for meetings between contractor and customer at NASA or HREC as required. This single-line liaison provided good communications with a minimum of disruptions to both EAS technical directors and LMSC engineering personnel.

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2. Floyd, G., "Design Guidelines, ATM Control and Display Console," TM 54/60-6, LMSC/HREC A784425A, Revision A, Lockheed Missiles & Space Company, 5 September 1967.

3. Astrionics Laboratory, Marshall Space Flight Center, "Environmental Design and Qualification Test Criteria for Apollo Telescope Mount Components," Appendix A, MSFC 50M02408, 31 January 1967.

4. Blackledge, M., "ATM Preliminary LM Panel Thermal Investigation," TDR 54/20-79, LMSC/HREC A784592, Lockheed Missiles & Space Company, Huntsville, Ala., August 1967.

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6. Marshall Space Flight Center, "ATM Control and Display Console Interface Control Document," MSFC 40M37850, 5 September 1967.

7. Marshall Space Flight Center, "ATM Console Electrical Interface Control Document," MSFC 40M37839, 5 September 1967.

8. Cyr, G., "Pushbutton-Display System," LMSC/HREC A7842232, Lockheed Missiles & Space Company, Huntsville, Ala., 19 May 1967.

9. Sperry Rand - Huntsville, "ATM Pushbutton Addressing," drawing by Joe Lundy, 19 June 1967, revised by J. C. Hemby, 30 July 1967.

10. Floyd, G., "Apollo Telescope Mount Console - Flight and Simulator Components," TM 54/60-9, LMSC/HREC A784601, Lockheed Missiles & Space Company, Huntsville, Ala., 5 September 1967.

APPENDIX A

NODAL BREAKDOWN OF THERMAL MODEL

Appendix A
NODAL BREAKDOWN OF THERMAL MODEL

NODE	TO NODE
1	6
	2
	16
2	7
	3
	53
4	9
	5
	50
5	10
	51
6	11
	7
	17
7	12
	8
8	13
	9
	50
9	14
	10
10	15
	54
11	18
	12
12	19
	13
14	21
	15
15	22
16	23
	17
	53

NODE	TO NODE
17	24
	18
18	25
	19
19	29
	20
20	27
	21
	53
21	28
	22
22	29
	54
23	30
	24
	45
24	31
	25
25	32
	26
26	33
	27
	52
27	34
	28
	56
28	35
	29
29	36
	55
30	31
31	32

NODE	TO NODE
33	37
	34
34	38
	35
35	39
	36
36	40
37	41
	38
38	42
	39
39	43
	40
40	44
	45
41	45
	42
42	46
	43
43	47
	44
44	48
45	46
	52
	53
46	49
	47
	56

NODE	TO NODE
47	50
	48
48	51
	55
49	50
	53
50	56
51	54
52	56
54	55

The above list gives the nodal relationship of the point masses used to represent the LMSC thermal model. The thermal capacity and conductance of each node were calculated for input to the digital thermal analyzer. Radiation heat transfer was also included in the model.

APPENDIX B

BULKHEAD CONNECTOR: NO. 12

APPENDIX B

BULKHEAD CONNECTOR: No. 12
709A610

PIN a

Function:	Short Exposure Command
Originates:	Control Panel (S2)
Terminates:	Instrument
Voltage Level:	+28 vdc
Load:	20K ohms
Description:	Divides exposure time by 3.2.

PIN b

Function:	H-α External Door Closed Command
Originates:	Control Panel (S19)
Terminates	Instrument
Voltage Level:	+28 vdc
Load:	10K ohms (min)
Description:	Closes H-α external aperture door. Deactivates experiment.

PIN c

Function:	H-α External Door Open Command
Originates:	Control Panel (S19)
Terminates:	Instrument
Voltage Level:	+28 vdc
Load:	10K ohms (min)
Description:	Opens H-α external aperture door. Also initiates experiment turn on.