PR 29-83 PART I
COMPILATION OF TRADE STUDIES,
ENGINEERING ANALYSES AND OTHER
REPORTS PREPARED DURING AAP MISSION
1A 60-DAY STUDY

Contract NAS 8-21004

20 September 1967

N68-24579

MARTIN MARIETTA CORPORATION
DENVER DIVISION

FOREWORD

This document, in three parts, consists of trade studies, engineering analyses, and other technical reports prepared during the AAP Early Applications Mission 1A 60-day study period. These reports are support data to the Final Report, PR 29-81.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

PR 29-83 PART III

PR 29-1

TRADE STUDY REPORT

OPTIMUM ORBIT INCLINATION

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

August 4, 1967

Prepared by: D. B. Cross

Approved by: J. T. Keeley

Martin Marietta Corporation
Denver Division

1. INTRODUCTION

1.1 Purpose - The purpose of this report is the documentation of trade study efforts to define an optimum orbit inclination on the basis of preferred target coverage.

1.2 Objectives - The study objectives include a review of mission requirements and experiment objectives to indicate constraints on the orbital inclination. Subsequent to definition of the constraints and within these constraints the orbit inclination is optimized.

2. SUMMARY

The constraints of available launch azimuth, experiment site location, and payload capability are considered. The available data show the 50 deg inclination to be best. However further experiment definition could lead to reduction in the desired inclination to approximately 44 deg.

3. DISCUSSION

3.1 Requirements and Constraints - The ground target pattern is restricted initially to the Continental U.S. and the immediately surrounding sea areas. The northern boundary of the U.S. lies along the 49th parallel indicating an orbit inclination requirement of at least 49 degrees. Specific truth sites are located at lower latitudes; the majority of which (all but ~12) are below 45 deg North Latitude. In addition experimental data on air pollution involves viewing seven metropolitan areas tabulated below:

	N. Lat	W. Long
Boston	42° 21'	70° 3'
New York	40° 42'	74° 0'
Toronto	43° 40'	79° 30'
Detroit	42° 20'	83° 0'
Chicago	41° 51'	87° 38'
Salt Lake City	40° 40'	111° 50'
San Francisco	37° 47'	122° 25'

The principal investigators have expressed an opinion that 50 deg or greater inclinations are preferred while 30 to 50 deg is acceptable in many cases. The higher inclinations provide a wide range of background environments for data collection.

3.1 Requirements and Constraints (Continued)

The available launch azimuths from KSC allow inclinations between 28.5 deg and 51 deg without yaw steering. The payload trade-off being about 116 lbs per degree between 28.5 and 51 deg and 225 lbs per degree where yaw steering is concerned.

3.2 Study Results - The best target coverage occurs where the maximum viewing opportunities are available. Figure 1 indicates the area placements that enhance coverage. The lower figure shows the case where coverage may be available on four different orbit passes. In general, the cross-range viewing distance is too great for good optical resolution and the best area placement is the three orbit coverage picture shown at the top of Figure 1. This is an instantaneous situation where the relative target position will shift with time. Thus, the coverage opportunities will vary between 2 and 3 chances per day.

As noted earlier, to cover the Continental United States an orbit inclination of at least 49 deg is required. To cover the seven cities of interest in air pollution studies an inclination of at least 43 deg is required. For best coverage of the northern-most points the three orbit concept will result in slightly higher inclinations. Figure 2 shows that a 50 deg inclination gives best coverage along the northern border and a 44 deg inclination will provide best coverage of the northern-most cities in air pollution studies. This inclination would also include the majority of the truth site locations now specified. The payload at a 50 deg inclination is approximately 700 pounds less than that at 44 deg.

Additional experiment requirements are expected to further constrain the results of this study. These requirements will be considered as they become available.

4. CONCLUSIONS AND RECOMMENDATIONS

A high inclination of at least 44 deg is required to meet the constraints of the mission. Depending upon the full experiment definition the 50 deg inclination appears to be the best and most conservative selection at this time. This choice is within the available direct launch (no yaw steering) opportunities and is presently within the payload constraints. All truth sites are included also. Future experiment definition and payload growth may make the 44 deg inclination the best choice.

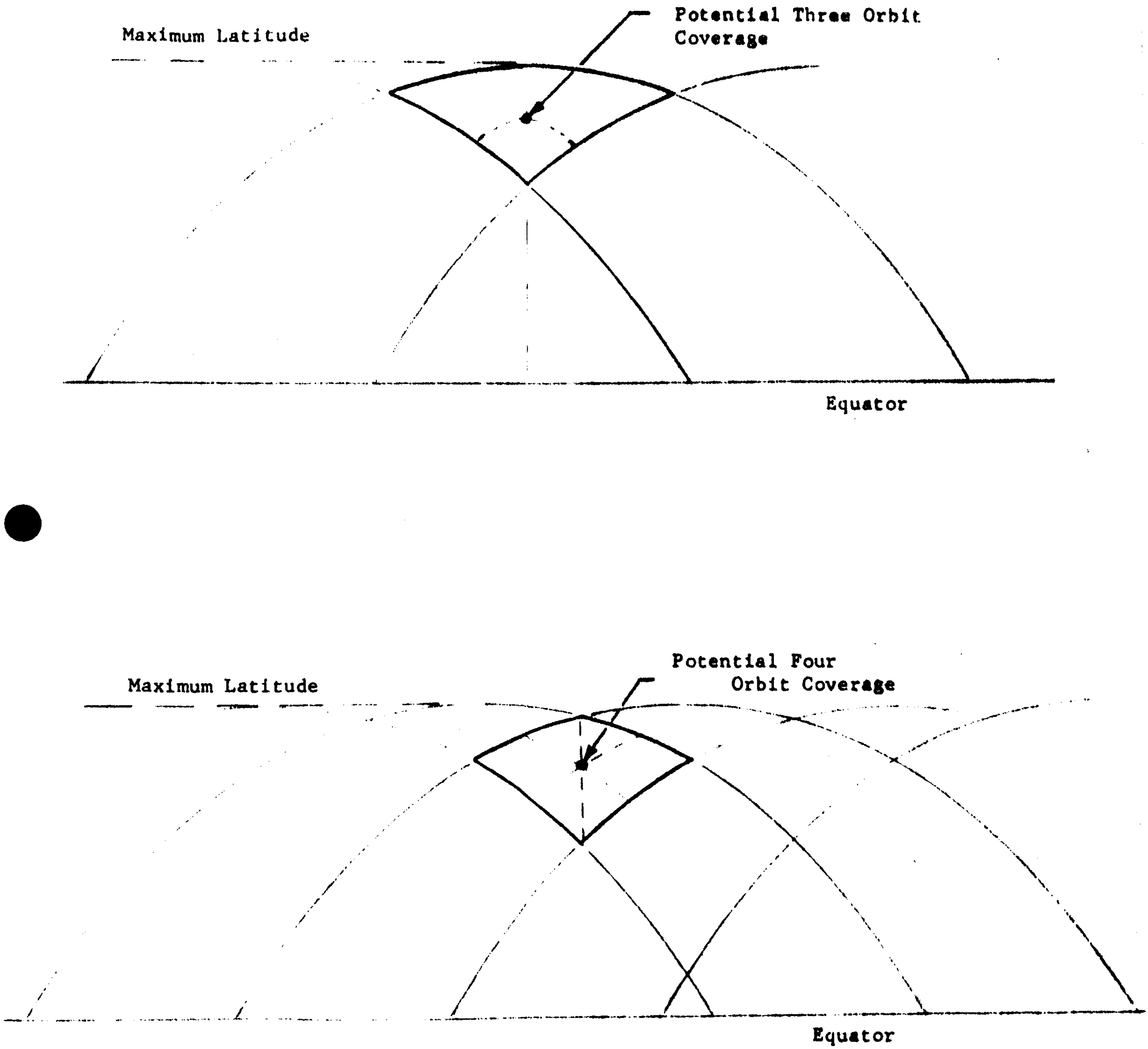


FIGURE 1 COVERAGE CONCEPTS

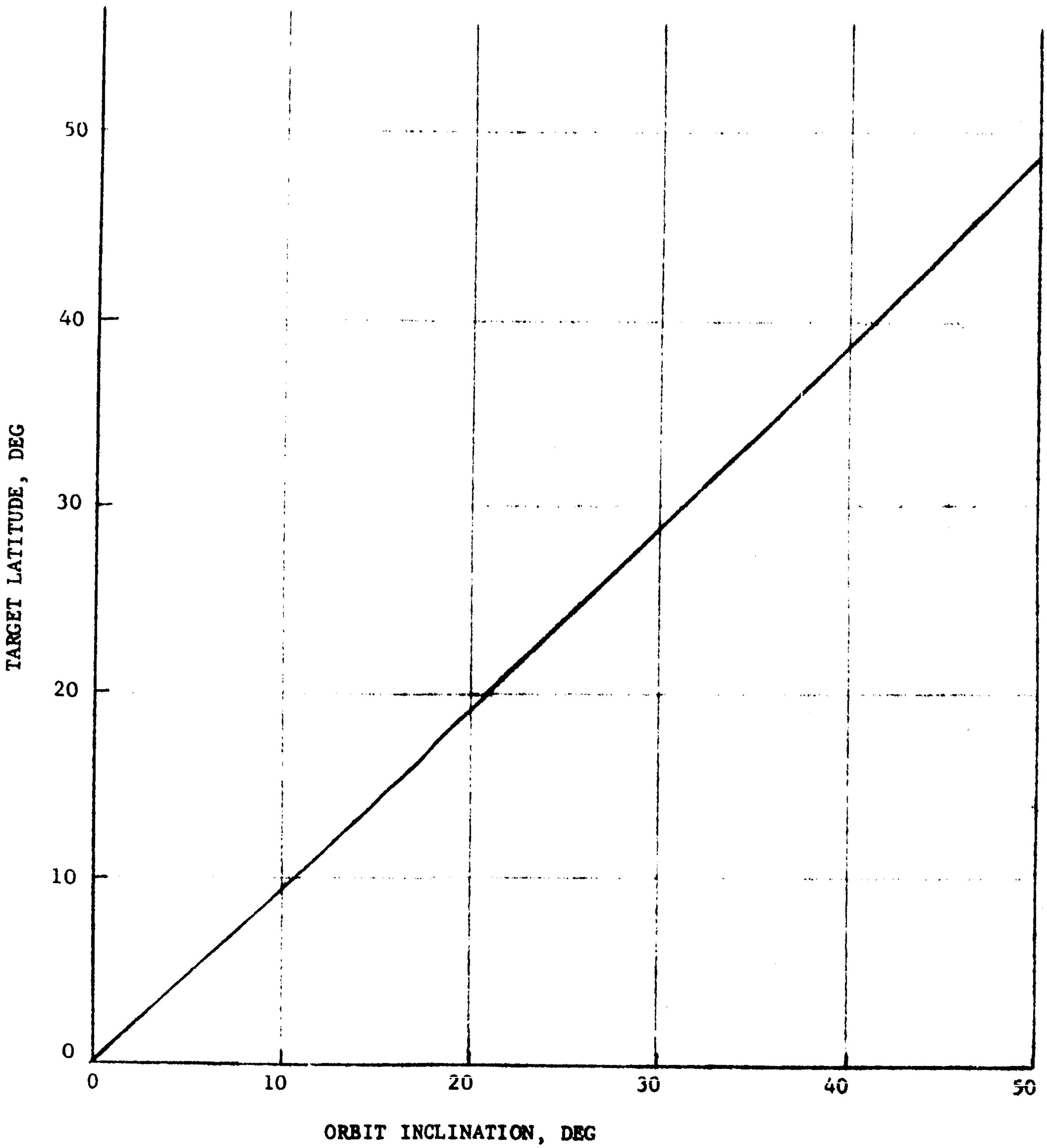


FIGURE 2 PREFERRED ORBIT INCLINATION

PR 29-2

TRADE STUDY REPORT

COMPARISON OF LAUNCH TIMES FOR BEST MISSION OPERATION

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

August 18, 1967

Prepared by: ____________

Approved by: ____________

Martin Marietta Corporation
Denver Division

1. INTRODUCTION

1.1 Purpose - The purpose of this report is the documentation of studies conducted to determine the best launch date and time of launch.

1.2 Objectives - The objective of the trade-study is a comparison of local sun altitude and orbital eclipse times to provide a balance between thermal control and ground illumination for optical viewing and recovery operations. These conditions are compared for various launch times and three launch dates; September 1, 1968, January 1, 1969 and April 1, 1969.

2. SUMMARY

Three launch dates are compared and the January 1, 1969 date appears least favorable. Launch dates of September 1, 1968 and April 1, 1969 exhibit similar characteristics with the April 1 date appearing most favorable. Launch times between 0800 and 1200 EST provide the best illumination of the Continental United States with the later time being more favorable for recovery in the Atlantic Ocean.

3. DISCUSSION

3.1 Requirements and Constraints - Three launch dates are investigated; September 1, 1968, January 1, 1969 and April 1, 1969. No initial restriction is placed on the launch time during any one day but launch during daylight and in the morning would be preferred. The mission duration is 14 days and the sun position must be favorable for daylight in the northern or upper limb of the orbit throughout the mission. In general it is assumed that the sun must be 20 deg or more above the horizon for suitable optical viewing of the ground. Also it is assumed that a normal eclipse time (30 to 37 min) is favorable for thermal control system design. Recovery is preferred in daylight in the vicinity of 60 deg West Longitude and 31 deg North Latitude. Orbital inclination is 50 deg.

3.2 Study Results - The maximum solar altitude is a measure of the available light. A September 1 launch will experience a solar altitude at the maximum target latitude of 50 deg that varies 46 deg to 42 deg during the mission. This date meets the constraint of a solar altitude of 20 deg or more.

3.2 Study Results (continued)

A January 1 launch will exhibit a solar altitude at maximum target latitude of approximately 18 deg. This angle will not change significantly during the mission. At 40 deg latitude the solar altitude will be 28 deg. Thus, the January launch date is marginal to unacceptable from the standpoint of ground illumination.

The April launch date is similar to the September launch date and shows a solar altitude at 50 deg latitude of 48 deg. This angle increases to 50 deg during the mission and as a result the April launch with improving illumination is more favorable than the September launch with diminishing illumination.

The orbital eclipse time will affect the thermal control system design of the spacecraft. The maximum eclipse time is 37.5 minutes. September and April launches are similar and result in an eclipse time of about 33 minutes when the sun is situated to provide daylight along the northern or upper limb of the orbit. Similar conditions for a January launch result in eclipse times as low as 15 minutes. This condition imposes the most severe thermal loading and shows the January launch date to be least favorable.

Now consider the time of launch selection to maximize the available illumination. The target area is assumed to be the Continental United States. Since this area is entirely in the northern hemisphere we will select a launch time that yields daylight along the upper limb (northern half) of the orbit. Figure 1 shows the geometry of the problem. The angle, δ_1 , is a measure of the available illumination. If the angle is negative the sun is north of the orbit plane and for moderate to highly inclined orbits the northern limb of the orbit is in darkness. This condition is noted as unfavorable in Fig. 1. If the angle is positive the sun is south of the orbit plane and the northern limb is in daylight except for very slightly inclined orbits and nearly polar orbits in winter. The angle is a maximum positive value when noon occurs at the most northerly point of the orbit.

Figure 2 presents a history of the angle, δ_1 , as a function of days from the first day of the launch month. All three launch dates are shown along with two launch times; 0800 and 1200 EST. As noted earlier the maximum positive value indicates noon at the most northerly point and since the

3.2 Study Results (continued)

angle is the complement of the solar altitude at a given subsatellite point this value should be minimized to yield the best ground illumination. Again it can be seen that January is marginal from illumination considerations and September and April are comparable for a 14 day mission. Longer missions favor April launches.

The zero value of δ_1 indicates that the sun-earth line is in the orbit plane. When this condition coincides with the equinox then the extremes of the orbit limbs are at dawn and dusk. The dusk line moves westerly along the orbit path approximately 30 deg when the sun-earth line coincides with the ascending leg of the orbit and the season approaches mid-winter. In mid-summer the dusk line is approximately 30 deg east of the most northern point of the orbit when δ_1 is zero. The dawn line moves in a similar manner. The conditions are reversed when the sun-earth line coincides with the descending orbit leg. This condition can be interpreted from Fig. 2 by symmetry. The curves will be symmetric about the zero value near the equinox date with the big positive loop occurring at mid-winter and the small positive loop occurring at mid-summer. Hence, the lighting is most favorable in the northern hemisphere when the time span for daylight conditions is the shortest.

To maximize the available illumination at 50 deg latitude along the northern limb of the orbit we would like to keep the orbit oriented such that noon would occur at the most northerly point or that the angle, δ_1 , would be a maximum for a given launch date. If the angle is a maximum initially it can be seen from Fig. 2 that the upper limb of the orbit is passing into darkness within 12 days for April and September launches. The best illumination would occur during the first days of the mission and would degrade with time. To improve the illumination throughout the mission launch should occur with noon on the ascending leg of the orbit. In this case the sun moves about 5.5 deg eastward relative to the orbit each day and noon will pass through the most northern point of the orbit and end up on the descending leg after 14 days. An April first launch at 1000 EST would place noon at the most northerly orbit point after seven days and would provide the best illumination of the target area during the 14 day mission.

3.2 Study Results (continued)

The final consideration is the recovery lighting considerations. For April launches an 0800 launch time would result in recovery before dawn at the end of 14 days. As the launch time is made later the recovery time similarly becomes later in the day. A noon launch will result in a noon recovery about 17 days later; thus at the end of 14 days recovery will be in early afternoon. The 1000 launch time will result in a morning recovery 14 days later and will meet the recovery lighting constraints. One further consideration should be noted. To reach a recovery area at about 60 deg West Longitude and 31 deg North Latitude in the Atlantic Ocean may require a few orbits more or less than those making up a nominal 14 days. This condition will affect the lighting slightly and more detailed analysis of the orbit tracks may result in a slight shift in the most desirable launch time.

4. CONCLUSIONS AND RECOMMENDATIONS

As a result of the trade study discussed in this report an April 1, 1969 launch at 1000 EST appears to be the most favorable selection. Consideration of ground illumination, orbital eclipse times and recovery lighting form the basis of this conclusion.

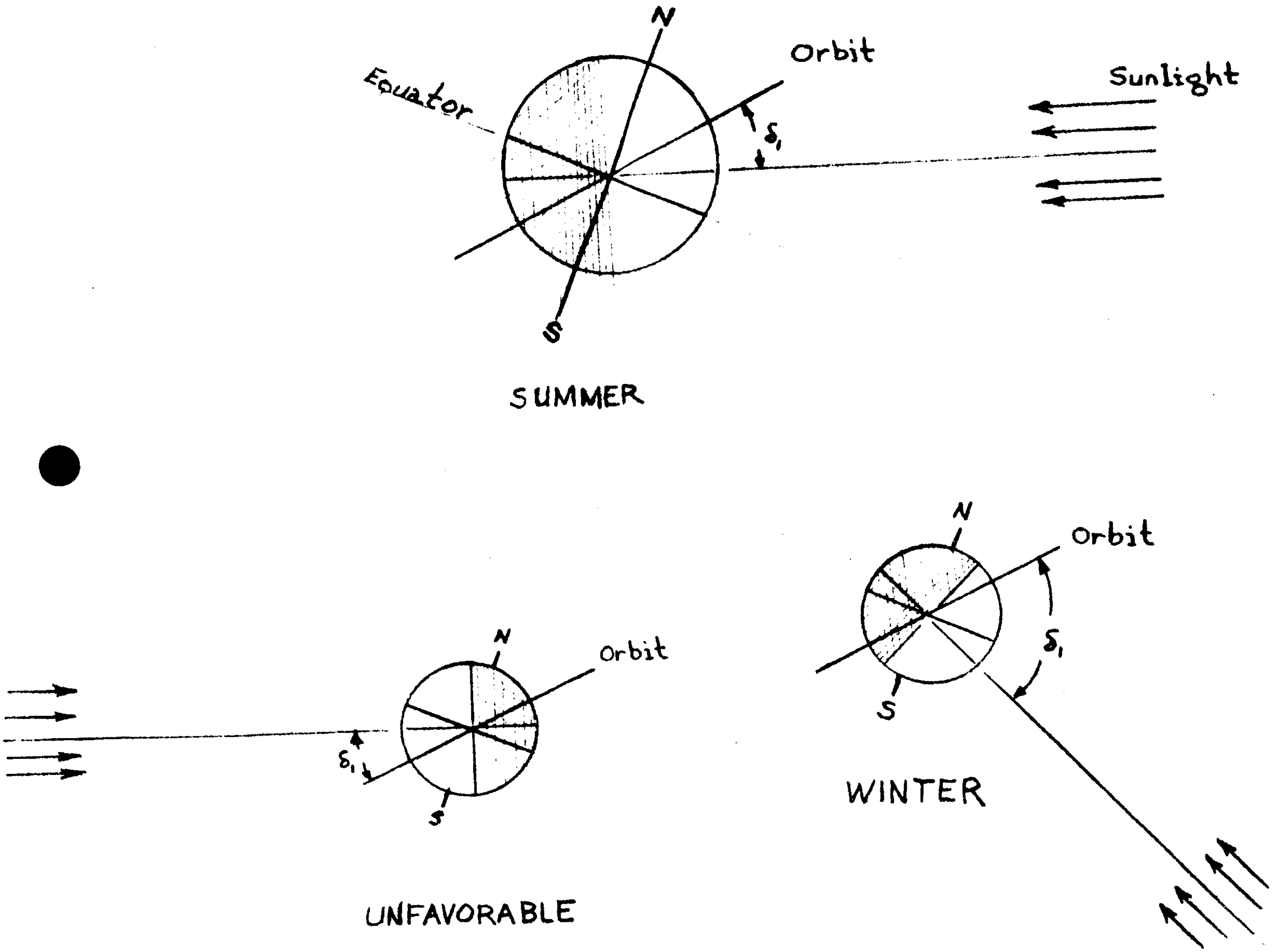


FIGURE 1 PROBLEM GEOMETRY

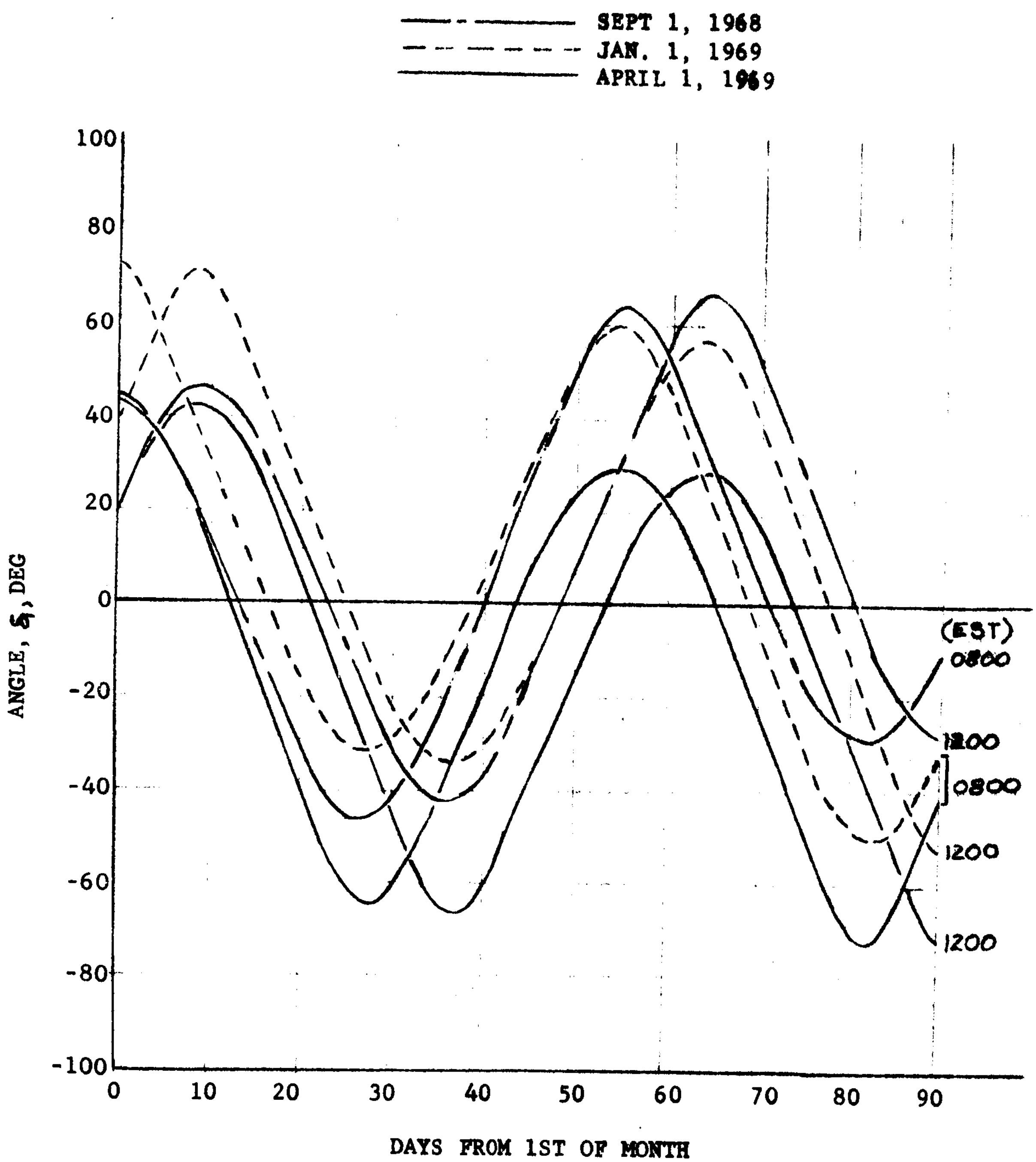


FIGURE 2 SUN HISTORY

PR 29-2 (Suppl 1)

TRADE STUDY REPORT

COMPARISON OF LAUNCH TIMES FOR BEST MISSION OPERATION

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

21 August 1967

Prepared by: [signature]

Approved by: [signature]

Martin Marietta Corporation
Denver Division

1. INTRODUCTION

1.1 Purpose - The purpose of this report is the documentation of additional data pertinent to the optimum launch time study.

1.2 Objectives - The objectives of the supplementary study are to expand upon the original data to present an optimum launch date and time for any period of the year.

2. SUMMARY

The study shows the period from May 21 to July 21 to be the most favorable from the standpoint of solar illumination of the ground. Data are presented for a 1 July 1969 launch date. It is observed that the period between 1000 and 1100 EST is the most favorable launch time throughout the year.

3. DISCUSSION

The solar altitude is presented in Fig. 1 as a function of launch month with the day of the month shown being the 21st. Data are presented for both 40 and 50 deg North Latitude. The period from 21 November to 21 January is not favorable for optical viewing in the northern United States. The period from 21 May to 21 July is best.

Figure 2 presents the angle, δ_1, as a function of days from launch for a 1 July 1969 launch date. These data supplement that presented in the original trade study report. Optimum launch time falls in the 1000 to 1100 EST period as noted for other launch dates. Review of the data for the entire year shows that the optimum launch time does not vary significantly with launch date. The important parameter is mission duration. A launch time of 1000 EST will provide daylight on the northern limb of the orbit throughout the 14 day mission and will provide daylight for recovery in the Atlantic Ocean during a descending orbit leg on the fourteenth day.

4. CONCLUSIONS AND RECOMMENDATIONS

Midwinter launches are not favorable for optical viewing of the northern United States. Midsummer launches are best. The optimum launch time does not vary significantly with the launch date and appears to fall in the 1000 to 1100 EST period.

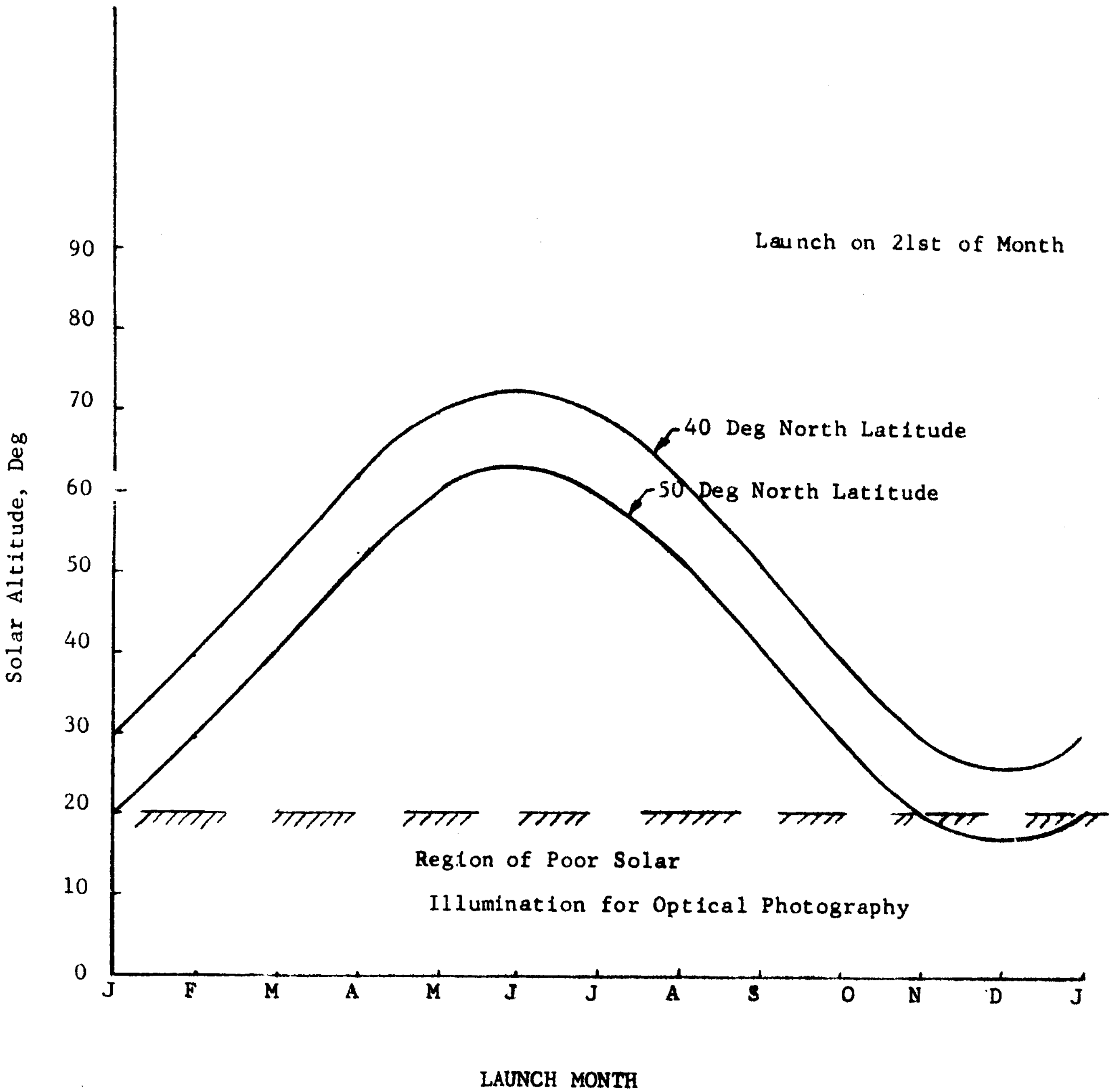


Figure 1 Optimum Launch Month

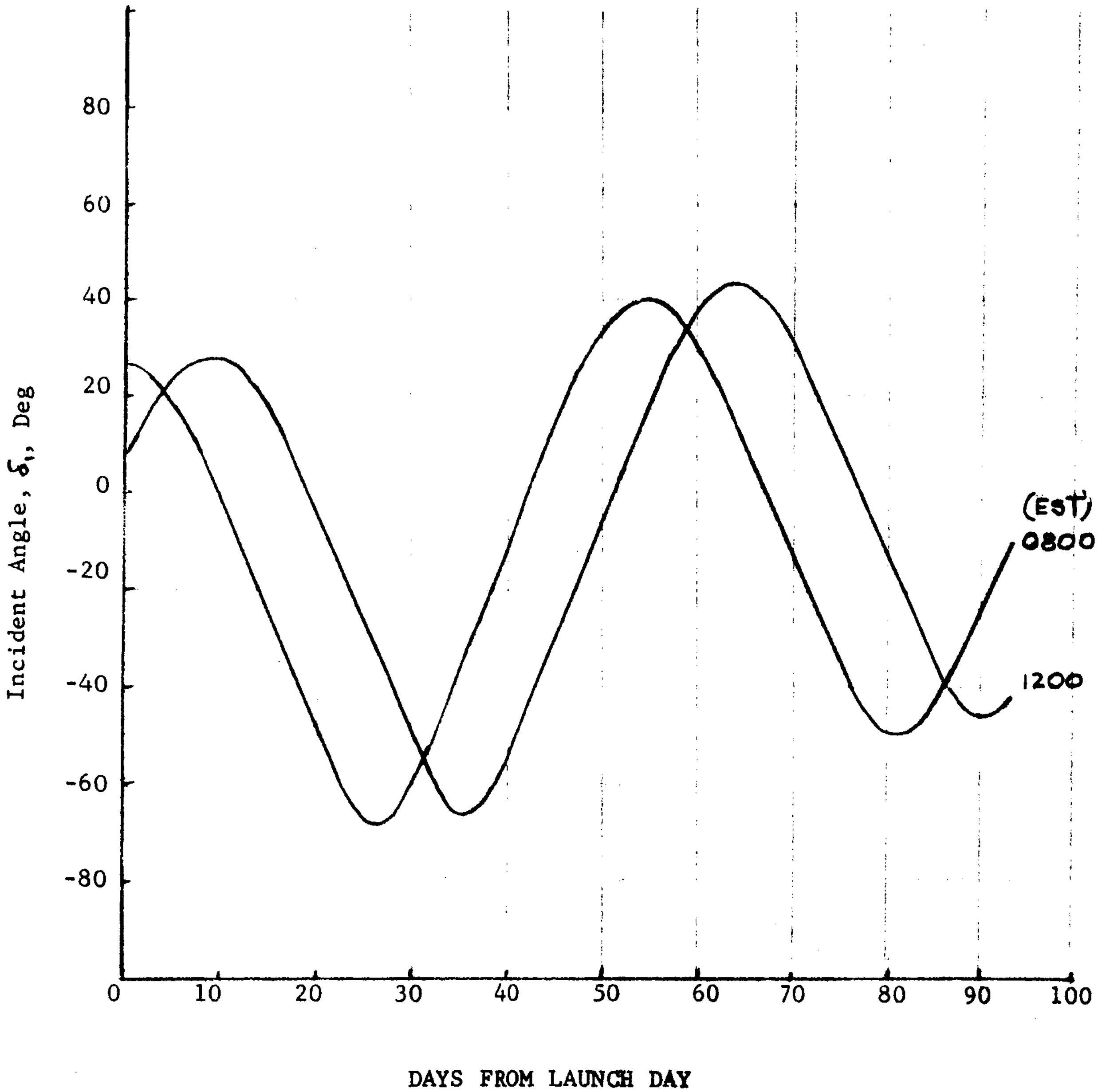


Figure 2 Solar History for July 1, 1969 Launch Date

SUPERSEDED BY PR29-46 MISSION TIMELINES

PR 29-3

MISSION 1A 24 HR SAMPLE TIMELINE

AAP MISSION IA

Contract NAS8-21004

August 7, 1967

Prepared by: R. W. Walker

R. W. Walker

Approved by: J. T. Keeley

J. T. Keeley

MARTIN MARIETTA CORPORATION
Denver Division
Denver, Colorado

GROUND RULES

1. Altitude - 140 to 150 n.m.

2. Inclination - 50°.

3. No crew operation in carrier during selected 24 hour periods.

4. CSM/carrier will be oriented nose down over earth targets.

5. Selected 24 hour period starts at 1700 GMT local time at 0° latitude, 105° longitude.

6. S044A - Electrically Scanned Microwave Radiometer,
   S044C - Microwave Radiometer, and
   S048 - UHF Sferics Detection run continuously for this period requiring minimal crew input.

7. The 1968 Apollo MSFN will be used without augmentation.

8. An up-data link will be provided for ground command of data dump.

9. Experiment and subsystem D&C panel will be operated in CM only.

10. No suit donning or doffing during this 24 hour period.

11. All three crewmen will sleep simultaneously.

12. Hot water makeup for use in preparing hot meals is available in 30 minute increments. Dinner and breakfast will be hot meals. Lunch and snack will be cold.

13. Three 10 minute exercise periods per crewman per day are scheduled.

14. IMU alignments to be made every third orbit with S/C left in drift mode during sleep period.

15. Systems checks and systems housekeeping have been scheduled per SID66-1501, "Mission Modular Data Book: First Block II Manned Mission", dated 1 December 1966.

EXPERIMENT GROUPING

1. Radar Scatterometer
2. IR Radiometer Scatterometer
3. IR Imager
4. Multispectral Camera
5. Metric Camera
6. IR Temperature Sounding
7. Electrically Scanned Microwave Radiometer
8. Microwave Radiometer
9. UHF Sferics Detection

TIMELINE SUMMARY

FUNCTION			TOTAL TIME
Sleep			8 hours/crewman
Eat			3 hours 9 min/crewman (average)
Exercise			30 min/crewman
Waste Mgt & personal hygiene			78 min/crewman (average)
Systems check			66 min
Systems housekeeping			25 min
Crew housekeeping (other than above)			110 min
Miscellaneous (work-station transfer, etc.)			30 min
IMU alignment			100 min
Experiment operation (ref. numbers on preceding page)			
	#1	Prep	83 min
		Operate	2 hr 33 min
	#2	Prep	42 min
		Operate	56 min
	#3	Prep	23 min
		Operate	53 min
	#4	Prep	23 min
		Operate	53 min
	#5	Prep	25 min
		Operate	59 min
	#6	Prep	48 min
		Operate	38 min
	#7	Operate	24 hr.
	#8	Operate	24 hr.
	#9	Operate	24 hr.

Total experiment prep and operating elapsed time (excluding #7, #8, #9) -

5 hr. 32 min.

GENERAL NOTES

1. No specific time allocation has been made for battery recharge.

2. No specific time has been allotted for experiment post operating requirements such as post calibration, lens closure, etc.

3. No specific time has been noted for crew initiated data dump.

4. Experiment preparation functions have not been categorized by specific tasks such as warmup, calibrate, annotate, etc.

5. This schedule requires the third crewman to wait 1½ hours after waking before eating and this period includes over 40 minutes of experiment prep and operation.

6. Consideration has not been given to crew quiescence during experiment operation or IMU alignment.

TIMELINE LEGEND

Numbers 1 through 9 represent experiments listed on Page 2.

SC - Systems Check

Ex - Exercise

SH - Systems Housekeeping

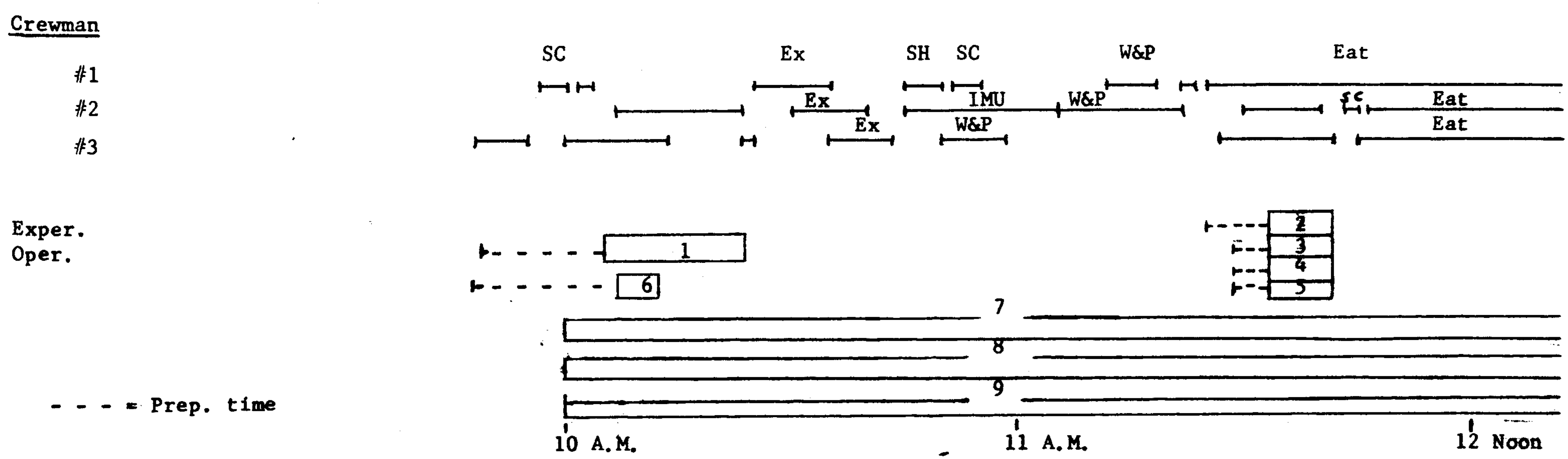
W&P - Waste mgt. and Personal hygiene

IMU - IMU alignment

├──┤ - When unlabeled denotes crew time allocation for experiment prep and operation.

├--┤ - Experiment prep time.

△ - Meal cleanup for third crewman (See Page 7).


Crewman
#1
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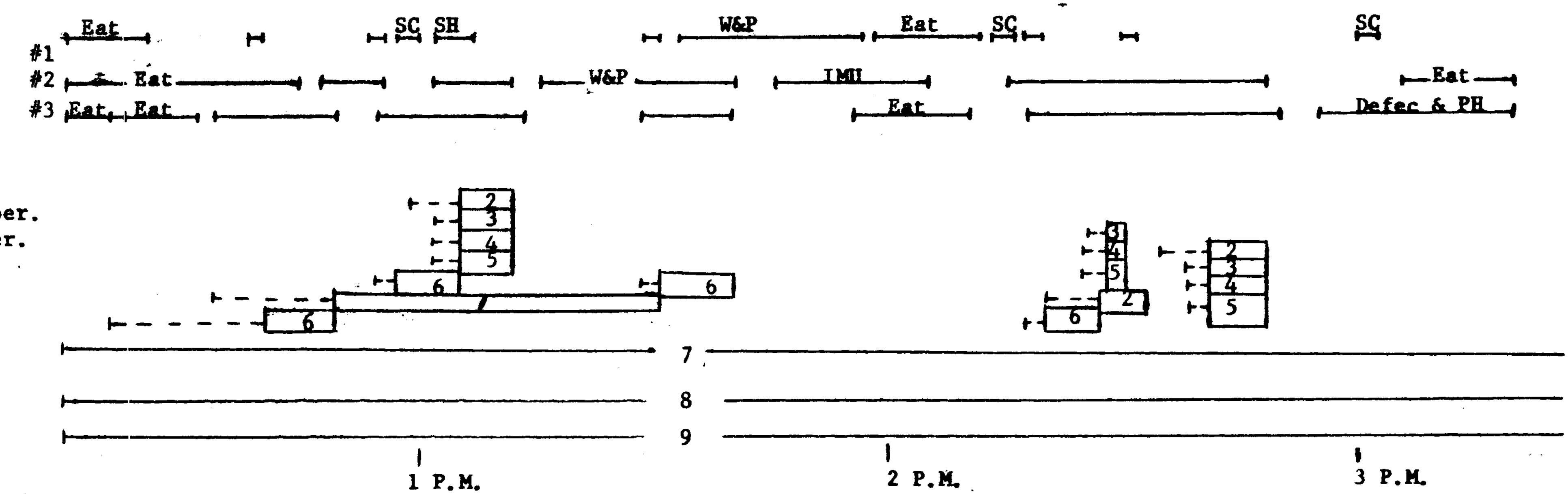
- - - = Prep. time
10 A.M.
11 A.M.
12 Noon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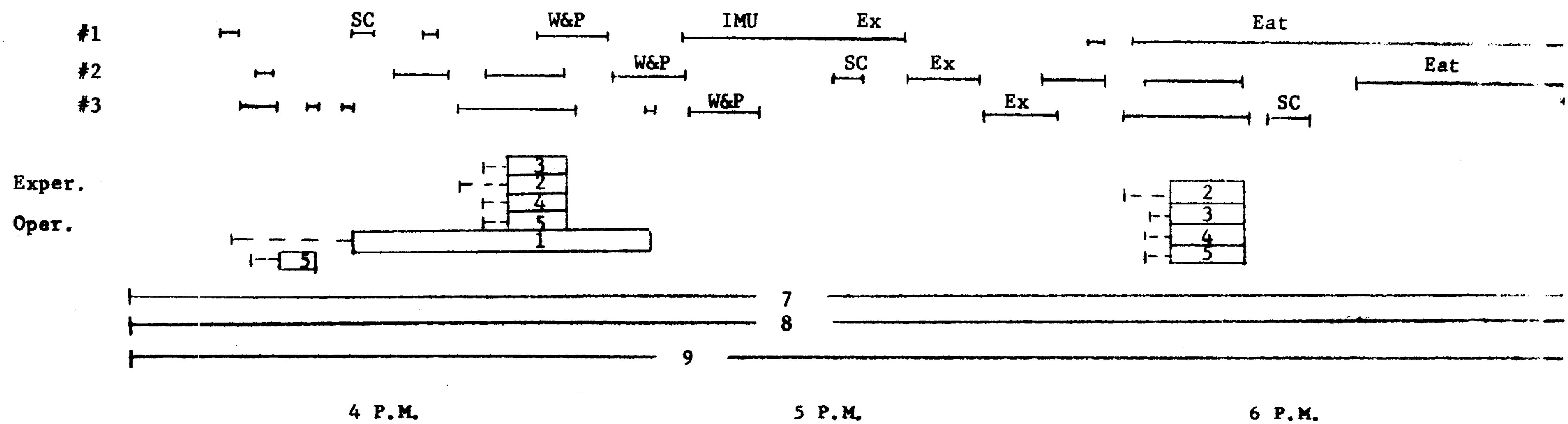
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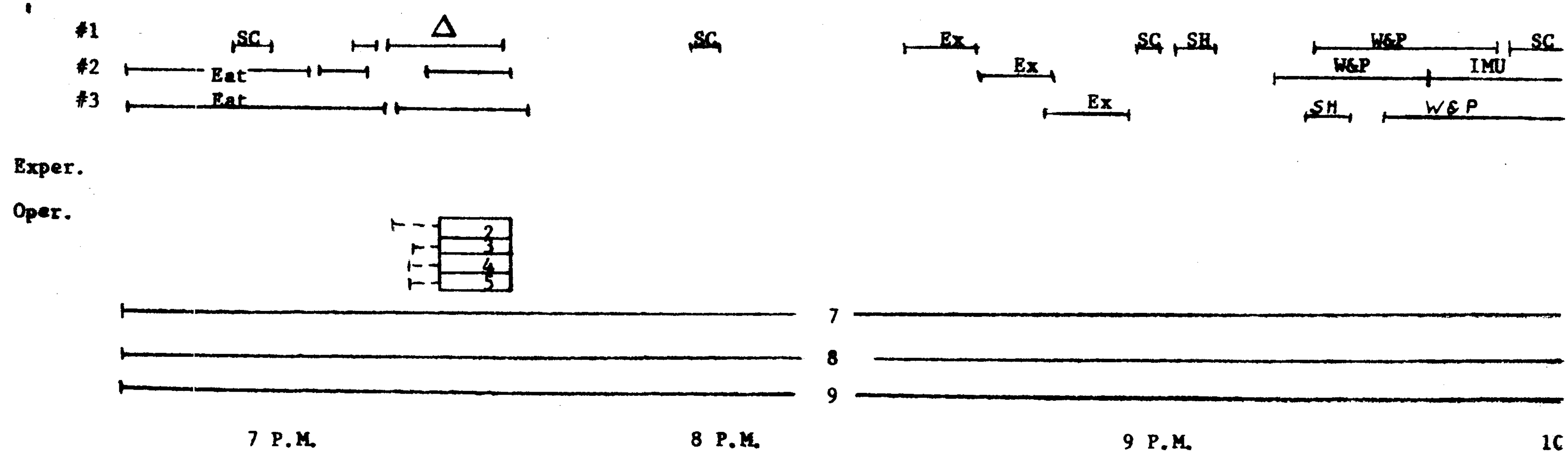
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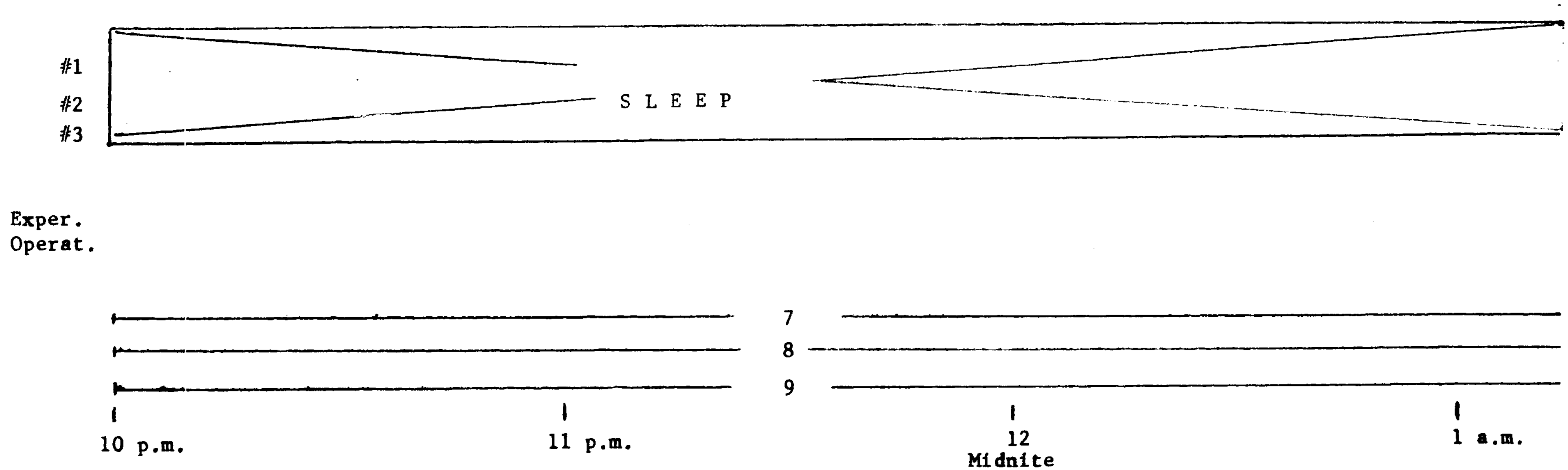

#1
#2
#3
SLEEP
Exper.
Operat.
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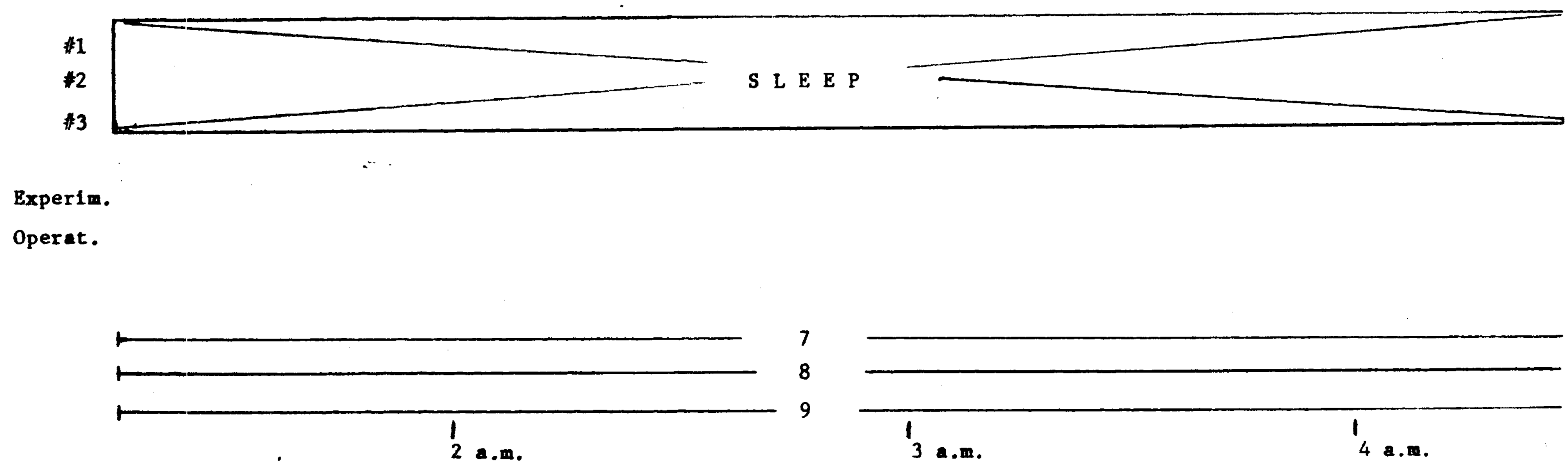
8
9
10 p.m.
11 p.m.
12
Midnite
1 a.m.



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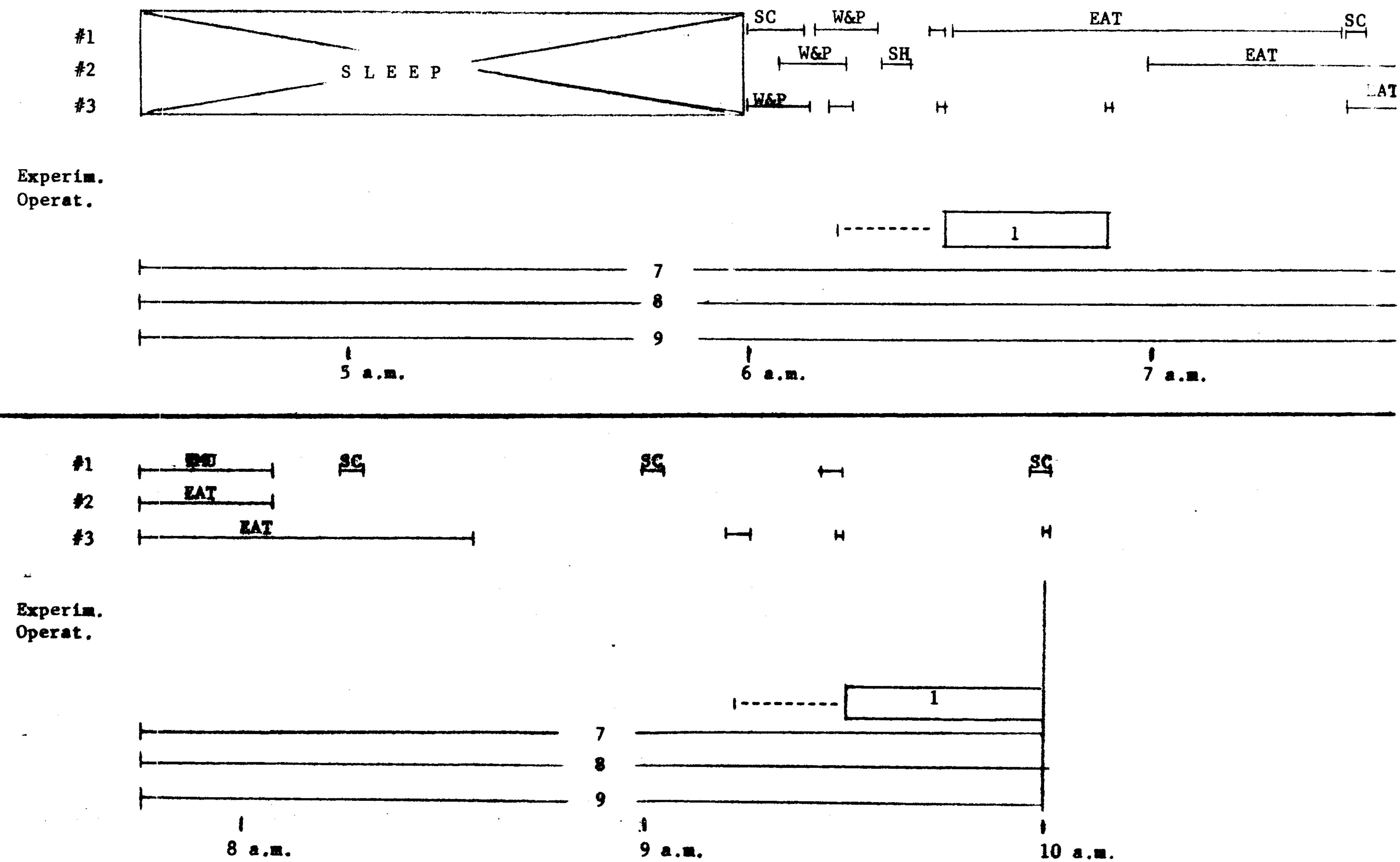
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PR 29-4

Revision A

Trade Study Report

On-Pad Accessibility

AAP/PIP Early Applications

Contract NAS 8-21004

6 September 1967

Prepared by: K. M. Pass

Approved by: J. T. Kuley

MARTIN MARIETTA CORPORATION

DENVER DIVISION

1. INTRODUCTION

This report is the final revision of the preliminary report by the same name and number, dated 10 August 1967.

Access to the experiments carrier will be required after the carrier has been installed within the SLA, at the MSOB and on the Launch Pad. Maximum utilization of the carrier structure is planned for the mounting of experiment and support subsystem modules. Access is required to essentially all areas of the carrier.

The study ground rules include (1) use of the SLA/LEM attach points for carrier mounting with the SLA, (2) positioning of the carrier within the SLA to approximate the LEM docking interface, (3) use of the existing SLA and IU access doors only, (4) minimum modification to existing SLA interior work platforms, and (5) the requirement to maintain access to the carrier until late in the countdown. These restrictions are evaluated in this study to ensure the proposed configuration represents a realistic understanding of all requirements, including those for access. This report provides the analysis defining the degree of accessibility incorporated in the proposed design.

2. SUMMARY

On-pad accessibility to all areas of the carrier while installed within the SLA can be provided for the necessary carrier/experiments installation and servicing until late in the countdown sequence. Late on-pad operations should be minimized, however, since the SLA interval platform set is constructed in sections small enough to pass through the SLA and IU access doors which causes the task of platform removal to consume 6-hours. The existing platforms are at the proper level in the SLA, and with minimum modification will provide all necessary access. Carrier interface with existing platforms is a minor problem. Thermal blanket installation can also be designed for minimum adverse effect on required carrier accessibility.

Figure 1 depicts the Carrier installed within the SLA, with the positioning of the current/proposed work platforms relative to the carrier. Specific component access and heavy component handling will be analyzed in the Maintainability Study Report (PR 29-34).

3. DISCUSSION

3.1 External Access to the SLA access doors will be gained from MST Platform #5 at LC-34. An additional work-stand, provided by facilities, will be used to actually enter the SLA access panels from Level 5 Platform, since Level 5 is approximately 9 1/2 feet below the level of the SLA access doors.

SLA Access Panels = X_A 617.5 to X_A 651.5

MST Level #5 = X_A 502.8

2-SLA Access Panels, 28" X 34" and 34" X 34"

Secondary SLA access could be gained thru the Instrumentation Unit access door (32.5" X 32.89") between X_A 468.75 and X_A 501.25. This access door can be reached from MST Platform #4 at X_A 386.4. Again, a portable work stand will be used to actually enter the I.U. access door from Level #4.

The two SLA access doors provide direct access to SLA internal work platform Level X_A 603.0, while the I.U. access door provides direct access to internal work platforms at Level X_A 441.0. The X_A 441.0 level platforms are provided by Douglas (DAC).

3.2 Internal Access (inside the SLA) will be provided by a set of removable work platforms, supported from the SLA inside walls. The existing work platforms built by North American (NAA) provide access at Levels X_A 525.0, X_A 603.0, and X_A 697.0. Additional partial platforms are located at X_A 660.0, X_A 720.0, and X_A 724.0. This existing platform set also has provisions (ladders and trap-doors) for climbing from one level to another while inside the SLA.

For purposes of this analysis, the "baseline" carrier configuration was the long, pressurized, truncated cone. Two different installations within the SLA were considered - docking ring 115" above the SLA/LEM attachment points and 85" above the SLA/LEM attachment points. Both installations require access to the following areas:

a. Experiment modules mounted within the pressurized compartment on the "Egg-crate" truss;

3.2 (continued)

b. Mission equipment/gear mounted within the pressurized compartment along the walls of the compartment;

c. The docking tunnel for possible equipment installation and final inspection prior to launch;

d. The aft end (exterior) of the carrier for experiments and other equipment mounted in that area;

e. The diagonal support/subsystem module mounting trusses (2);

f. Experiment modules/antennae mounted external to the pressurized compartment.

Access to these areas is required to perform the following general categories of on-pad tasks:

a. Experiment late installation, checkout, calibration, servicing and malfunction correction;

b. Same as "a", except for support subsystem;

c. Docking tunnel debris hatch, display and control panel, and drogue installation;

d. Final visual inspection of complete carrier assembly prior to launch.

3.3 <u>Low Carrier Installation (85")</u>

a. Access to the pressurized compartment interior can be accomplished by bridging between the existing auxiliary platform at Level X_A 660.0 and the carrier docking ring. Since the carrier is better than 10 feet deep, a ladder down into the carrier is required with some type of work surface to stand on while working inside the compartment;

b. Access to the aft end of the carrier exterior can be gained by modifying the existing Level X_A 525.0 platform to provide a dropped section "catwalk" at approximately the Level X_A 503.0;

3.3 (continued)

c. Access to the subsystem support modules mounting trusses can be gained from existing Levels X_A 525.0 and X_A 603.0 platforms. Depending on the final configuration of these two equipment areas, some minor modifications to these two levels of platforms may be beneficial;

d. The carrier upper support arms interface with the Level X_A 603.0 platform in three places. This is easily corrected by making clearance cut-outs in the three affected platform segments.

3.4 <u>High Carrier Installation (115")</u>*

a. Access to the carrier interior could be accomplished thru the docking tunnel, as in the low carrier installation. However, this would be very difficult since the carrier docking ring clears the end of the SPS engine bell by only approximately 30". The alternate, and more desirable method, would be to design the aft bulkhead with a bolted flange thus making the entire bulkhead removable, or to provide a manhole in the aft bulkhead. With either alternate method, the center area of the "egg-crate" truss would be left open to allow personnel entrance. The existing platform at Level X_A 525.0 could be modified to provide support for a workstand approximately 30" high which a technician could stand on, with his body extending thru the center of the "egg-crate" truss, thus not requiring a separate work stand in the interior of the carrier;

b. Access to the aft end of the carrier can be gained by modifying the Level X_A 525.0 platform to provide a "catwalk" at the X_A 525.0 level, from one side of the SLA across to the other. This catwalk could provide the support for the work-stand mentioned in Para. (a);

---

* The docking tunnel was later decreased in length by 8", reducing the dimension from the LEM/SLA attachment points to the docking-ring from 115" to 107", and allowing more clearance between the docking ring and the engine bell.

3.4 (continued)

c. If necessary, access to the docking ring and tunnel could be accomplished by bridging from platform Level X_A 697.0 to the docking ring;

d. Access to the subsystem support modules mounting trusses can be gained from existing platforms at Levels X_A 525.0 and 603.0. A new auxiliary platform at approximately the X_A 639.0 level may be required to reach the higher levels of the trusses;

e. As in the low carrier installation, the carrier upper support arms interfere with the Level X_A 603.0 platform in three places. Again, cutouts in the three affected platform segments would provide the necessary clearance.

Figure 1 shows the experiments carrier installed within the SLA in the high configuration.

4. CONCLUSIONS AND RECOMMENDATIONS

The 1A baseline carrier is considerably smaller than the LEM and also different in overall shape. Since the existing SLA internal work platforms were sized to the LEM, the major consideration in attempting to use the existing platforms for access to the carrier is one of having large enough platforms rather than one of interference between the carrier and existing platforms. Fortunately, the existing platforms are at approximately the right levels for reaching most of the necessary areas of the carrier. Therefore, the recommended solution is to enlarge or bridge the existing levels of platforms, with possibly one additional platform for the emplacement of carrier equipment/experiments.

Access to all areas of the carrier until the last moment before launch would be difficult to provide since removal of the complete modified platform set is estimated at 6-hours. However, some degree of access can be maintained by leaving one segment of the X_A 603 level platform installed just inside each SLA access door. This would provide minimal access to the carrier support subsystems and externally mounted experiments. Late-in-the-count access to internally mounted experiments would be through the carrier docking tunnel, since the carrier aft dome would be installed earlier in the count should the dome installation procedure and integrity checks require an extended time period.

4. (continued)

The requirement to use only available SLA and IU access openings to the SLA interior has been observed. All platforms modifications can be made to observe this requirement, as well as the equipment required for installation/ servicing of carrier experiments/subsystem modules.

The interference between the carrier and the present work platforms is not serious, only affecting three segments of the Level X_A 603 platform. The necessary modifications to the platform segments can be made without affecting the usefulness/integrity of the X_A 603 platform.

The installation of thermal blankets over the carrier structure and subsystem/experiment installations does somewhat inhibit access to those installations. However, this effect can be minimized by constructing and installing the blankets in small, separately removable sections and by requiring blanket installation to be one of the last tasks performed prior to removal of the SLA internal platforms.

DEN 066232-02 3-67

CARRIER/SLA ACCESSIBILITY/INTERFACE

MARTIN MARIETTA CORPORATION

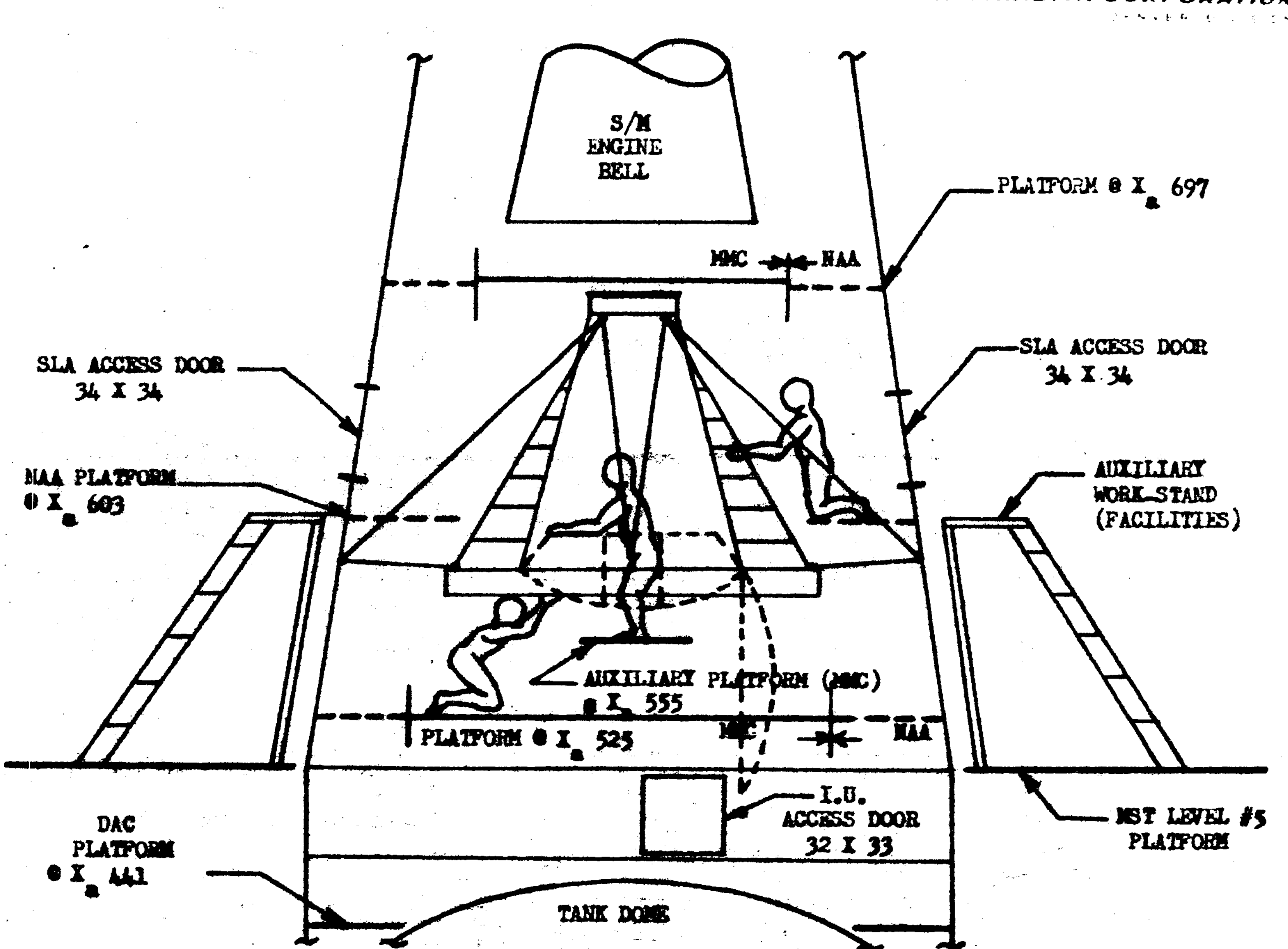

FIGURE 1

PR 29-5

TRADE STUDY REPORT

COOLANT SELECTION

AAP/PIP Early Applications

Contract NAS 8-21004

15 August 1967

Prepared by C. Class CC

Approved by E. Schumacher EAS

Martin Marietta Corporation
Denver Division

I. Functional and Technical Design Requirements

In the design of an active thermal control system that involves a coolant heat transport loop, an optimum coolant must be chosen. The active system considered for this study is a system to remove heat from electronics equipment and experiments and to dissipate it to space through a space radiator. The heat transport loop for a fuel cell system is not a part of this study since it is expected that this will depend a great deal on the design and compatibility considerations of the fuel cells.

If it is found technically advantageous to utilize a toxic coolant a secondary coolant loop may be used within manned areas. Water is the best secondary fluid choice because of its excellent heat transport properties, zero toxicity and compatible temperature ranges. However, hermetically sealed loops within such manned areas should also be given serious consideration in view of the generally low toxicity levels of most of the coolants under consideration. The results of this study can be used for both fuel cell coolant loops and manned systems if the coolant properties are found to be compatible with both systems.

There is never a clear cut method of evaluating coolant candidates for a given design application. The selection must be based on requirements created by the system design. Even when based on firm requirements, coolant selection is difficult since it is hard to evaluate good features of one coolant against good features of another.

It is desirable to select a coolant which gives the lowest overall system weight along with high reliability and low cost. Weight should not only include the weight of all hardware (piping, valves, radiator, heat exchangers, etc.), but should include the weight penalties for electrical power for pumps, controls, valves, etc.

II. Coolant Selection Approaches and Criteria

To minimize the number of coolant candidates, it is possible to screen them against their general properties and then the better of these coolants can be evaluated against their thermodynamic and transport properties.

General properties to judge coolant candidates include:

Freezing point

Critical temperature

Vapor pressure

Toxicity

Flammability

Dielectric strength

Chemical stability

Effects on materials

Cost

Transport properties require evaluation of thermodynamic and physical properties. Properties that need to be evaluated include:

Viscosity

Specific heat

Thermal conductivity

Specific weight

Using these properties, pump power, pressure drop, radiator heat transfer, heat exchanger, heat transfer and relative systems weights can be evaluated and comparisons made. Complexity is introduced into the problem since properties vary with temperature and both laminar and turbulent conditions can exist.

Using the thermodynamic and physical properties, terms have been derived (ref. 1) whereby total system performance and weight can be evaluated. One such term has been entitled, pump power index, ϕ.

laminar flow, $\phi_1 = \frac{\mu}{C_p^2 \rho^2}$

turbulent flow, $\phi_2 = \frac{\mu^{.25}}{C_p^{2.75} \rho^2}$

Another term has been entitled pump power to heat transfer index, Y

laminar flow, $Y_1 = \frac{\mu}{\rho^2 C_p^2 k^{.67}}$

turbulent flow, $Y_2 = \frac{\mu^{.72}}{\rho^2 C_p^{2.28} k^{.67}}$

These terms give a method of evaluating one coolant against another. They assume that heat rejection, tube size and temperatures are the same for each coolant and therefore the lower the term, the lower the pump power or higher the performance for a given weight.

These terms only give a relative index of coolant performance for laminar and turbulent flows individually. A laminar index cannot be compared to a turbulent index. This makes it difficult to compare, say a glycol/water coolant to a Freon since to have reasonable pressure drops with the viscosity differences, the glycol/water will usually flow laminar and the Freons in turbulent. Also, for a given fluid, a system design might have both laminar and turbulent flows. Even with the difficulty of evaluating the indexes because of the flow regions, they are important comparisons terms to judge the performance and system weights.

The pump power to heat transfer index, Y, is based on flow through tubes and therefore applies primarily to a radiator. Since the thermal radiation process from the radiator surface is the major heat transfer resistance and controls the radiator heat rejection capabilities, the coolant heat transfer plays a relatively unimportant role in coolant selection. Therefore, the pump power index is more important than the ratio of pump power to heat transfer index.

In systems containing numerous heat exchangers and cold plates, the coolant heat transfer as well as powes penalties are important. The heat transfer process for compact heat exchangers is a function of Stanton modulus and the Prandtl modulus. For a given heat exchanger

$$j_{max} = \frac{h_m}{C_p G_{max}} \left(\frac{C_p \mu}{k}\right)_f^{2/3}$$

and varies according to Reynolds number

$$j_{max} \approx \frac{N}{R_e^{M}}$$ where N & M are constants.

The slope taken from data shows that m is equal to about 2/3.

For a given heat load and given heat exchanger geometry it turns out that the coolant heat transfer coefficient is proportional to $k^{2/3}$.

$$h \propto k^{2/3}$$

This shows that the coolant thermal conductivity plays an important part in the design and performance of heat exchangers, the higher the value the better.

Although, not completely accurate, the pump power to heat transfer index, Y can be used as an approximation for evaluating compact heat exehangers.

With systems containing radiators and compact heat exchangers, only complete system evaluations can optimize the coolant selection. Full system evaluations would involve the development of a complex computer program to synthesize all factors of the problem. This type of study is beyond the scope of this study. The current coolant evaluation will be made on the basis of a preliminary evaluation of the individual desirable features of the coolant properties.

The following system requirements will be imposed on the coolant general properties.

Freezing Point

The space radiator not only has to be able to dissipate the maximum heat loads but must not freeze up under minimum conditions. The simplest design puts all coolant flow through the radiator and uses a regenerative heat exchanger and a simple vernatherm control valve for regulating the radiator temperature and thus heat rejection capability. The lower the coolant freezing point, the lower the minimum heat load capability.

A bypass around the radiator to lower the coolant flow through the radiator can be used for radiator heat rejection control. This type of system can use a vernatherm type of valve also, but requires no regenerative heat exchanger. This type of radiator and control requires a lower freezing point coolant than a system that uses a regenerative heat exchanger since for low heat loads coolant flow is greatly reduced through the radiator and lower outlet temperatures are obtained.

A selective stagnation radiator system can accommodate higher freezing point coolants. This system controls heat dissipation by valving off radiator tubes and allowing them to freeze. This lowers the radiator effectiveness or can be viewed as decreasing the effective radiator size. This type of radiator is more complex to design since it requires an arrangement to valve off flow tubes and open up bypass lines around the radiator. Even though this type of radiator can use higher freezing point coolants, lower freezing points improve turndown ratios.

A series of examples shows the importance of low freezing point coolants. A coolant that would require a selective stagnation radiator would have to be penalized for costs of development including testing since the design is much more complex.

Example No. 1: Low Earth orbit

coolant ~ Freon -21, 500 lb/hr

area ~ 40 ft^2

tube spacing ~ 5 inches

Fin thickness ~ .040 inches

low earth orbit ~ external heat flux = 22. Btu/hr ft^2

Regenerative H.X. control or bypass control:

inlet temp ~ 60°F
outlet temp ~35°F
heat rejection ~3050 Btu/hr
} Max

inlet temp
outlet temp
} -122°F (equalibrium temp)
heat rejection ~ 0 Btu/hr.
} MIN.

Example No. 2: High Earth orbit

high earth orbit ~ external heat flux
~ 0. Btu/hr ft^2

regenative H.X. control:

inlet temp ~ 60°F
outlet temp ~ 29°F
heat rejection ~ 3830 Btu/hr
} Max

inlet temp ~ -100°F
outlet temp ~ -108°F
heat rejection 997 Btu/hr
} Typical min.

bypass control:

max conditions ~ same as regenerative H.X. control

inlet temp ~ 60°F
outlet temp ~ -186°F
flow 17#/hr
heat rejection 997 Btu/hr
} min. same heat rejection as regenerative H.X. control

As can be seen for example No. 1 for low earth orbits, regenerative H.X. control or bypass control require minimum coolants freezing points $< -122^{o}$ F. For high earth orbits and very low heat rejection rates very low coolants freezing points, possible $< -200^{o}$ F depending on minimum conditions and radiator control are required.

Critical temperature

Critical temperature is the temperature above which a coolant cannot exist in a liquid state. If the critical temperature is too low, then it is possible to form coolant vapor in the system. Since temperatures under extreme orbit conditions might approach 100^{o} F, this will be used as a criteria for selecting candidate coolants.

Vapor pressure

The vapor pressure should be as low as possible to keep the system operating pressure as low as possible. Low system pressures minimizes leakage and lowers weights of tubing, fittings and heat exchangers. Current Apollo CSM heat exchangers have proof pressures of 90 psig and a maximum operating pressure of 60 psig (60 psia in orbit). Therefore, pressures greater than 60 psia for heat exchangers are unacceptable. Vapor pressures will be evaluated at a maximum orbit coolant temperature of 100^{o} F. Those coolants with vapor pressure in excess of 60 psia at 100^{o} F will be eliminated.

Toxicity

Toxicity is an important criteria for evaluating man rated systems. For unmanned systems it is important for the protection of ground crews. Since on the ground, the crews can be provided protection and have adequate fresh air available, toxicity is not an overly important item if the coolant possesses superior heat transport properties. This is not to say that toxicity is unimportant for unmanned systems, since it can add greatly to complexity of designs; tests and usage, but is considered of secondary importance.

Flammability

The problems of using highly flammable coolants is obvious. The problems only occur when tanks or lines leak and/or the fluid comes in contact with an ignition source. The more volatile the coolant, the greater the potential hazard. With proper precautions in the design and use of equipment, the more flammable fluids can be used. If at all possible, the least flammable coolant should be chosen. In manned spacecraft within pressurized areas, flammability is extremely important and flammable fluids must be avoided.

Dielectric strength

High dielectric strength is important to minimize galvanic corrosion. In addition, high dielectric strength coolants can be used in contact with electrical equipment which allows the use of submerged pump motors.

Chemical stability

Coolants must be chemically stable. They must not decompose, separate or have property changes with time, temperature or pressure. They must be stable when in contact with common engineering subsystem materials.

Effects on materials

The coolants must not corrode or degrade potential materials of construction. Highly corrosive coolants to aluminum, iron and copper alloys should be avoided. There should be proven adequate sealing materials and techniques available for subsystem design.

Cost

The lower the cost the better. Cost evaluation is not easily arrived at since it should include: fluid costs, component costs, system costs, development costs and tests influence costs. Generally coolants costs will not vary considerably and the greatest cost will be in the design, development and test associated with choosing a coolant that influences the system design, reliability and design risks.

Coolants that do not involve considerable redesign of components and are compatible with materials of construction are considered more desirable than a coolant that requires no component modifications but require a more complex systems design.

III. Coolant Comparison Analysis

A number of common coolants have been selected for study and comparison. These are listed in Table I. They have been chosen out of the numerous potential coolants because of their general low temperature properties, ready availability, prior usage or high expected performance. From this table a number of coolants have been eliminated because of high freezing points, low critical temperatures and high vapor pressures to the criteria discussed in Section II. The candidates for further study are indicated in Table I. Glycol/water coolant will require a selective stagnation radiator design due to its high freezing point. The coolanols do not have as low a freezing point as the Freons and could be marginal for a system that requires flexibility or growth potential for high earth missions unless they are used in a selective stagnation radiator design.

In evaluating coolants, considerable estimated or extrapolated data was used. Most estimated data was manufactured supplied. Dash portions of the curves show the estimated data. Also, there was some conflicting data for which a choice had to be made.

The candidate coolants were evaluated against pump power indexes, pump power to heat transfer indexes and $k^{2/3}$ vs. temperature and are shown in Figures 1, 2, 3, 4 and 5. Water has been shown for comparison purposes and is obviously the best heat transfer fluid but has a poor freezing point for a radiator design. In a closed loop within a manned spacecraft where temperatures allow, water is an excellent coolant choice.

The pump power index for laminar flow shows that at all temperatures less than 120°F Freon-21 is an excellent choice compared to all other candidate fluids. For turbulent flow, the pump power index shows that the glycol/water coolant is best; Freon-21 and Freon 114 are the next best coolants at temperatures below 50°F.

When the pump power to heat transfer index is examined, Freon-21 is the best coolant below about 80°F in the laminar flow region and is best below about 20°F in the turbulent region.

It is concluded from examination of the pump power indexes and pump power to heat transfer indexes that generally Freon-21 is the best coolant in the radiator operating temperature ranges.

In the design of compact heat exchangers where coolant thermal conductivity is important, glycol/water coolant is the best. The use of the other coolants can make up the difference in thermal conductivity by increasing their flow. Increasing the coolant flows will increase their pressure drop and pump power. Examination of the pump power to heat transfer index curves which takes into account pump power shows that Freon-21 is still a good choice. Table 2 shows a table of candidate coolants pump power indexes. Table 3 shows a table of candidate coolant transport properties.

Taking the three best coolants based on the pump power indexes and the pump power to heat transfer indexes which are: glycol/water (60/40%), Freon-21 and 114; Freon-21 appears to be the best candidate coolant. These three coolants are compared for general properties in Table 4. From this table, Freon 21 appears superior and is the recommended coolant.

IV. Selection of Coolant

Freon-21 is the recommended coolant for this program. It has the following desirable features:

1. Viscosity - low and relative flat vs temperature. Pressure drop for a 3/8 ID tube, 100 feet long and 500 lb/hr at 100°F is 3.3 psi and at -100°F is 3.8 psi;

2. Freezing point - freezing point is the lowest of candidate coolants at -211°F.

3. Vapor pressure - although higher than candidate coolants at 100°F (40 psia) except Freon -114, it is compatible with Apollo CSM hardware which has a maximum operating pressure of 60 psia and LEM hardware which has a maximum operating pressure of 45.

   Pump inlet temperatures will be maintained at about 50 ± 5°F. At 55°F Freon 21 vapor pressure is 17 psia. Maintaining pump inlet pressures greater than 17 psia will prevent cavitation and should allow sufficient pressure rise across the pump and pressure drop through the thermal control system to operate below a maximum system pressure of 45 psia.

4. Critical temperature - critical temperature is 353.3°F which is more than adequate to maintain the system in a liquid state.

5. Toxicity - less toxic than Group 4 and somewhat more toxic than Group 5.

6. Flammability - considered non-flammable.

7. Dielectric strength - very high with a dielectric constant of 5.34.

8. Chemical stability - is stable in the presence of iron, copper and aluminum.

9. Effects on materials - good with iron, copper and aluminum. Good with nylon, polyethylene, teflon TFE, polyvinylidene chloride and phenol formaldehyde.

10. Performance - (indexes) - rates as good or better than most of the candidate coolants. Allows the use of a simplified radiator design such as a single long series system.

Freon-21 will create the following problem areas:

1. All elastomers will have to be changed. Pumps for Apollo Block I, and AAP have been modified and operated on Freon-21. The modification to these pumps included changing of seals. LEM pumps also have been run on Freon-21 for flow rates between 400 and 500 lb/hr.

2. Some of the qualified hardware will require requalification because of changing to a new coolant. Qualification will be necessary for fluid compatibility and performance.

<u>References</u>

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2. DuPont, Technical Report DP-5, "Freon-21" Fluorocarbon
3. DuPont, Bulletin C-30A, Transport Properties of "Freon Fluorocarbons and other Fluorinated Compounds".
4. DuPont, Technical Bulletin B-2, Properties and Applications of the "Freon" Fluorocarbons
5. Minnesota Mining and Manufacturing Company, 3M Brand Inert Fluorochemical Liquids
6. Monsanto, Technical Bulletin, No. AV-3, Dielectric Heat-Transfer Fluids for Electronic Equipment
7. Design Manual for Methods of Cooling Electronic Equipment - U.S Naval Air Development Center NAVWEPS 16-1-532 (Airesearch Report).

Table I

Coolant Properties Comparison

Coolant	Freezing Point (°F)	Critical Temp (°F)	Vapor Pressure (psia) at 100°F	Comments
Glycol/Water 60/40%	-65	>400.	.7	candidate
Water	32.	>100.	1.2	freezes
FC-75	<-80 (pour point)	441.	.05	candidate
Coolanol 15	<-140. (pour point)	>400	<1.	candidate
Coolanol 25	<-120. (pour point)	>400	<1.	candidate
Coolanol 35	<-120 (pour point)	>400	<1.	candidate
Freon 11	-168	388.4	23	candidate
Freon 12	-252.	233.6	130.	vapor press
Freon 13	-294.	83.9	-	crit.temp.
Freon 13B1	-270	152.6	314	vapor press.
Freon 14	-299.	-50.2	-	crit.temp.
Freon 21	-211.	353.3	40.	candidate
Freon 22	-256.	204.8	210.	vapor press.
Freon 23	-247.4	78.6	-	crit.temp.
Freon 112	74.8	532.	1.9	freezes
Freon 113	-31	417.4	10.4	freezes
Freon 114	-137	294.3	46.	candidate
Freon 114B2	-166.8	418.1	10.4	candidate
Freon 115	-159.	175.9	180.	vapor press.
Freon 116	-149.1	75.8	-	crit. temp.
Freon C-318	-42.5	239.6	67.	freezes
Freon 502	<-150	194.1	230.	vapor press.

Table 2

Comparison of Pump Power Indexes

Coolant	Pump Power Index, ϕ_1, Laminar at -40°F	Pump Power Index, ϕ_1, Laminar at 60°F	Pump Power Index, ϕ_2, Turbulent at -40°F	Pump Power Index, ϕ_2 Turbulent at 60°F	Pump Power to Heat Transfer Index, Y_1 - Laminar at -40°F	Pump Power to Heat Transfer Index, Y/1 - Laminar at 60°F	Pump Power to Heat Transfer Index, Y/2 - Turbulent at -40°F	Pump Power to Heat Transfer Index, Y2 - Turbulent at 60°F
Glycol/Water (60/40%)	.1790	.00626	.00303*	.00101*	.477	.0169	.104	.00858*
FC-75	.0278	.00608	.00928	.00573	.1428	.0330	.0949	.0323
Coolanol 15	.0400	.00965	.00815	.00503	.2554	.0611	.1409	.0479
25	.394	.0278	.0159	.00626	2.105	.1551	.6358	.0889
35	1.068	.0453	.0185	.00686	5.483	.2442	1.206	.1207
Freon 11	.00582	.00269	.01070	.00867	.0323	.0169	.0405	.02622
21	.00307*	.00184*	.00672	.00581	.0164*	.0114*	.0220*	.01755
114	.00355	.00184*	.00576	.00515	.0280	.0173	.0335	.0254
114B	.00804	.00386	.01055	.00905	.0769	.0419	.0851	.0576

* Lowest values

Table 3

Coolant Transport Properties

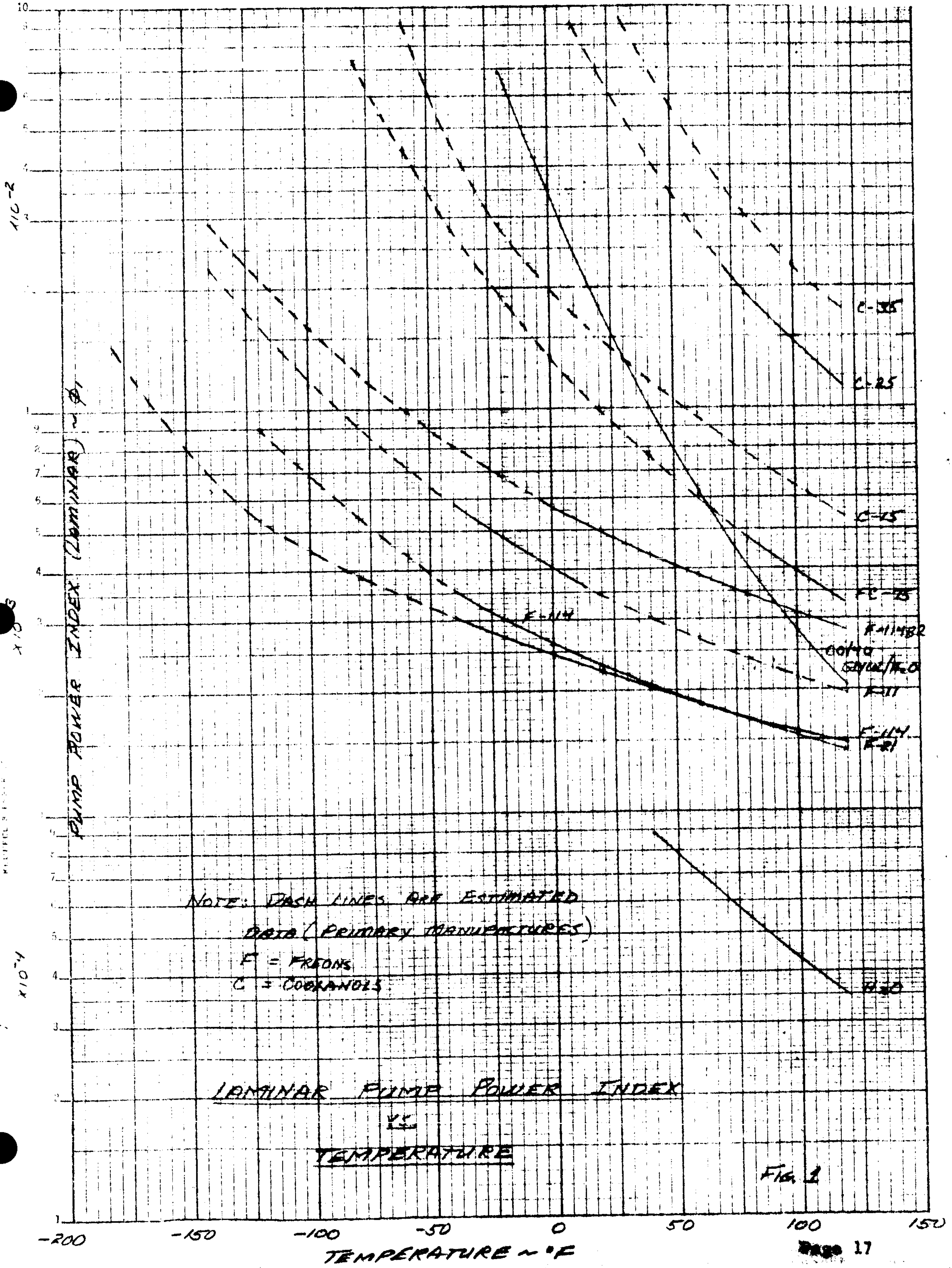
Coolant	Viscosity at -40°F lb/ft-sec	Viscosity at 60°F lb/ft-sec	Density at -40°F lb/ft^3	Density at 60°F lb/ft^3	Cp at -40°F Btu/lb °F	Cp at 60°F Btu/lb °F	k at -40°F Btu/hr ft°F	k at 60°F Btu/hr ft°F	$k^{2/3}$ at -40°F $(Btu/hr\ ft°F)^{2/3}$	$k^{2/3}$ at 60°F $(Btu/hr\ ft°F)^{2/3}$
Glycol/Water (60/40%)	.1000	.0042	69.8	67.1	.641	.737	.232	.227	.376	.370
FC-75	.0054	.0012	120.2	110.7	.221	.244	.087	.080	.194	.184
Coolanol 15	.0060	.0015	59.7	56.2	.388	.428	.063	.064	.157	.158
25	.0534	.0047	59.2	56.6	.374	.434	.082	.077	.187	.179
35	.1572	.0077	58.4	55.8	.394	.444	.087	.081	.195	.186
Freon 11	.0006	.0003	101.3	93.7	.195	.207	.078	.064	.180	.159
21	.0004	.0002	94.5	86.7	.234	.250	.082	.066	.187	.161
114	.0006	.0003	102.2	92.8	.242	.252	.046	.035	.127	.107
114B	.0012	.0005	147.3	136.5	.159	.164	.034	.028	.104	.092

Table 4

Coolant General Properties Comparison

Coolant	Freezing Point °F	Critical Temp. °F	Vapor Press psia @ 100°F	Toxicity * Threshold	Flammability	Dielectric Strength	Chemical Stability	Effects on Materials
Glycol/Water 60/40%	-65 (will require special selective stagnation radiator to utilize	$>$400.	.7	Pure Glycol 200 ppm (8 hr.)	Pure Glycol flash point = 240°F	Conductive	Unknown	Requires inhibitor which is only good for 1000 to 2000 hr. Incompatible for long duration mission
Freon 21	-211	353.3	40.	$<$ Group 4 $>$ Group 5 100,000 ppm 1/2 hr.	Non- (Ignition temp = 1025°F)	Dielectric Constant = 5.34	Excellent	Excellent with alum, steel & copper Poorest Freon with elastomers Good with nylon TFE and others
Freon 114	-137 marginal for flexibility and growth	294.3	46.	Group 6 20% by vol. up to 2 hr do not appear to produce injury	Non-	Dielectric Constant = 2.17	Excellent	Good with Elastomers

* Applies to Sea Level Conditions. Space environmental conditions warrant further investigation

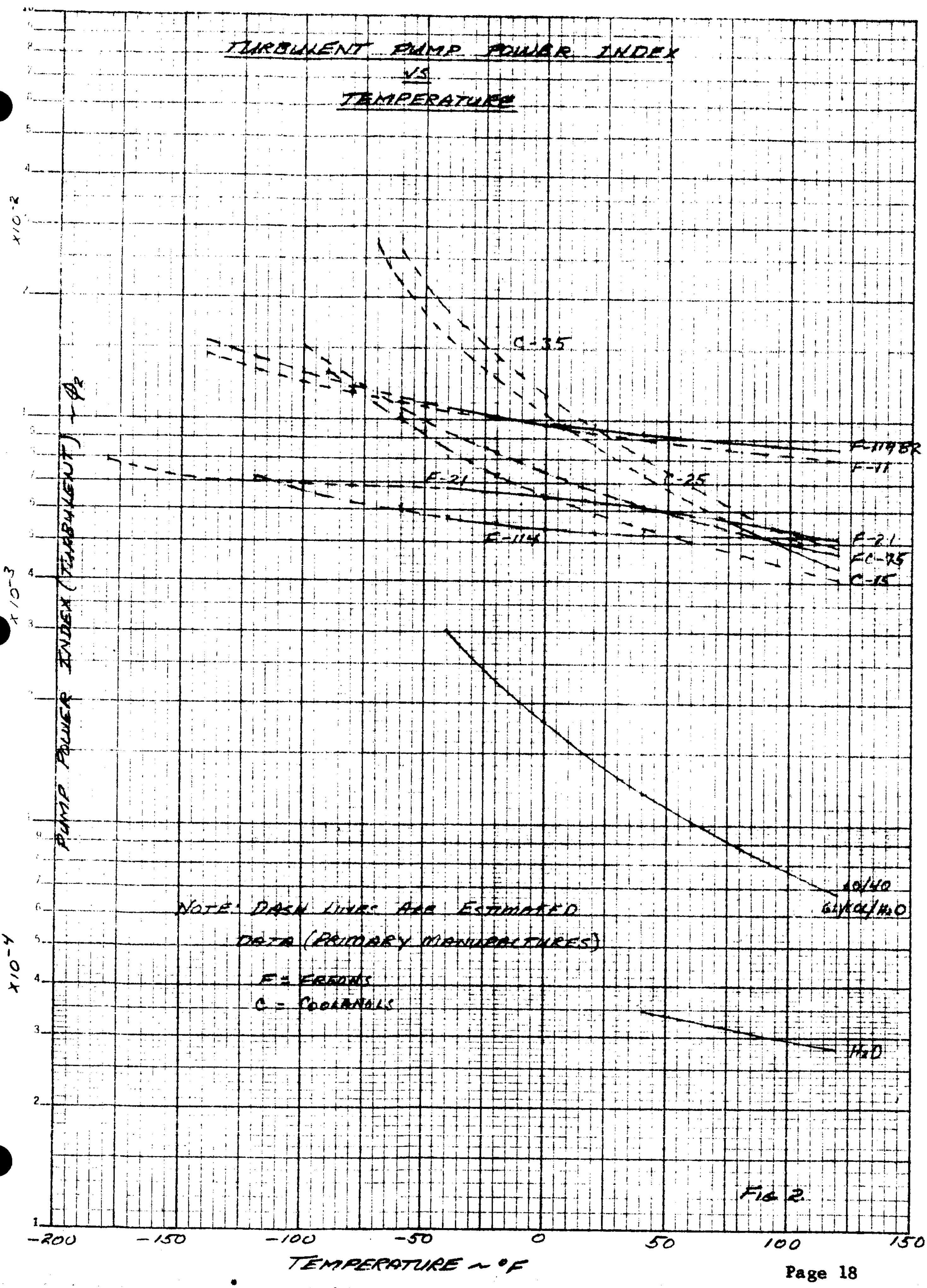


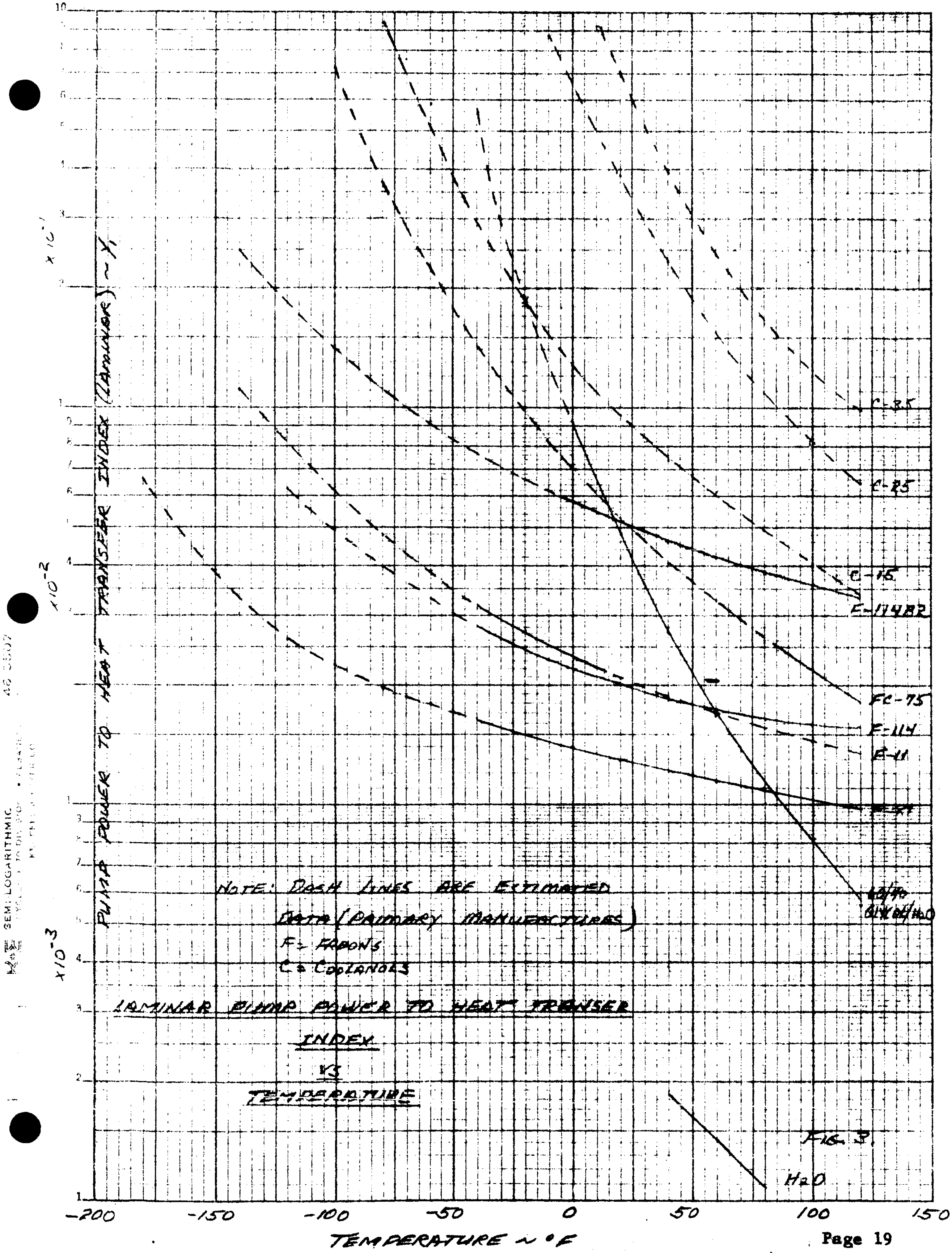
LAMINAR PUMP POWER INDEX

VS

TEMPERATURE

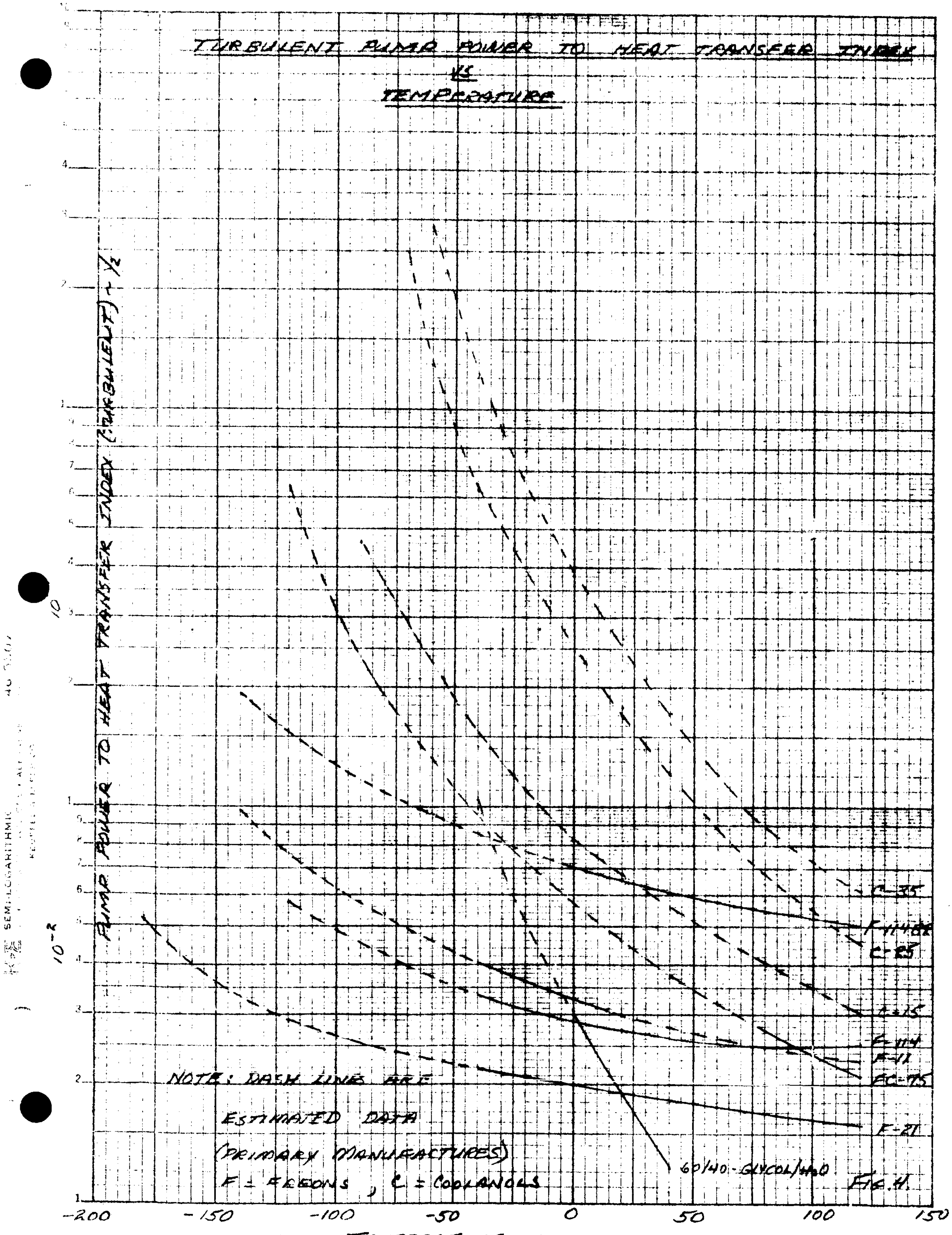
FIG. 1


TURBULENT PUMP POWER INDEX
VS
TEMPERATURE
PUMP POWER INDEX (TURBULENT) ~ ϕ_2
$\times 10^{-2}$
$\times 10^{-3}$
$\times 10^{-4}$
C-35
F-119BR
F-11
F-21
C-25
F-114
F-21
FC-75
C-15
40/40
GLYCOL/H_2O
H_2O
NOTE: DASH LINES ARE ESTIMATED
DATA (PRIMARY MANUFACTURES)
F = FREONS
C = COOLANOLS
FIG 2.
-200
-150
-100
-50
0
50
100
150
TEMPERATURE ~ °F

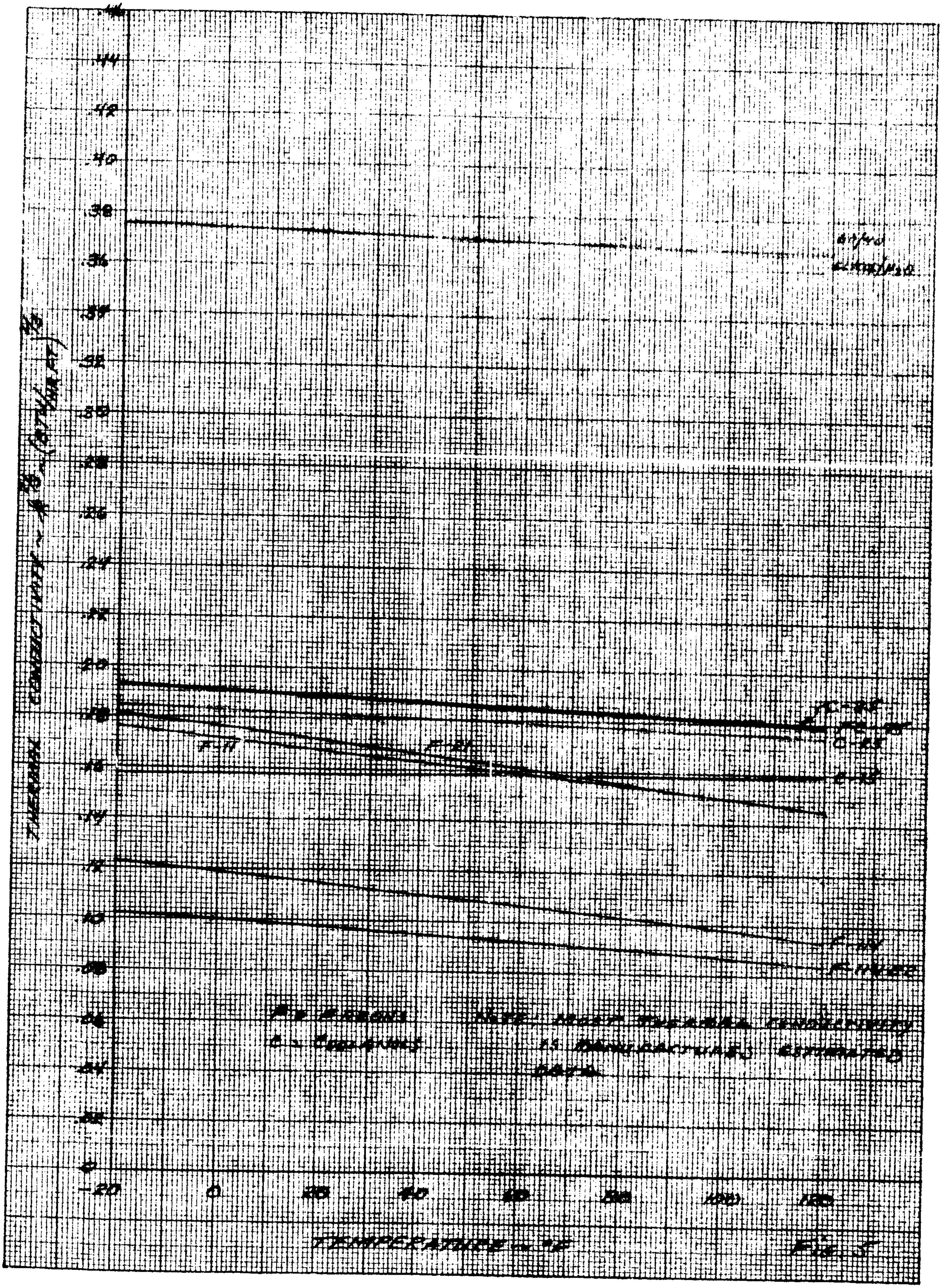


NOTE: DASH LINES ARE ESTIMATED
DATA (PRIMARY MANUFACTURES)
F = FREONS
C = COOLANOLS
LAMINAR PUMP POWER TO HEAT TRANSFER
INDEX
VS
TEMPERATURE
PUMP POWER TO HEAT TRANSFER INDEX (LAMINAR) ~ X_1
TEMPERATURE ~ °F
C-35
C-25
C-15
F-114B2
FC-75
F-114
F-11
60/40 GLY/H2O
H2O

FIG. 3



TURBULENT PUMP POWER TO HEAT TRANSFER INDEX
VS
TEMPERATURE
PUMP POWER TO HEAT TRANSFER INDEX (TURBULENT) ~ 1/2
TEMPERATURE ~ °F
-200
-150
-100
-50
0
50
100
150
10
10^{-2}
C-35
F-114B2
C-25
F-15
F-114
F-12
FC-75
F-21
60/40-GLYCOL/H2O
NOTE: DASH LINE ARE
ESTIMATED DATA
(PRIMARY MANUFACTURES)
F = FREONS , C = COOLANOLS
FIG. 11


.44
.42
.40
.38
.36
.32
.30
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
-20
0
20
40
60
80
100
120
F-11
F-21
Fig. 5

PR 29-6

TRADE STUDY REPORT

Preliminary Thermal Radiator Analysis

AAP/PIP Early Applications

Contract NAS 8-21004

3 August 1967

Prepared by C. Class

Approved by E. Schumacher

Martin Marietta Corporation

Denver Division

PRELIMINARY THERMAL RADIATOR ANALYSIS

Introduction

The experiment carrier for Mission IA will have wide extremes and variable heat loads that the thermal subsystem must control to maintain temperature requirements. The carrier will be earth oriented during experiment operations. During other portions of the mission, the carrier will not be restricted to earth orientation. The orbit altitude for the carrier has been specified as between 120 and 140 n. miles. It is assumed that at the end of the mission, orbit altitudes as low as 100 n. miles might be obtained. Orbit inclinations have been specified at 40 to 50 degrees. With the above information a preliminary radiator evaluation has been performed.

Summary

Initial radiator design evaluations were based on the use of 62.5% glycol/water coolant. One of the better locations for the glycol/water radiator would be on the side which always faces earth in order to prevent freezing problems and to be able to use a simple bypass control system. Since this is the side required for the experiments and the carrier is not restricted to a given earth orientation at all times, a wrap-around radiator is the best choice. This type of radiator would require a regenerative heat exchanger control system but would require a minimum system heat load of about 800 BTU/hr. A wrap-around glycol/water radiator configuration would require about 24 ft^2 of surface for a heat load of 1580 BTU/hr and inlet temperature of 80^{o}F.

Further evaluations showed that Freon-21 coolant using a Block II Apollo pump package, LEM pump package or modified Block II Apollo pump package would produce the most flexible radiator design.

The recommended radiator configuration is a wrap-around configuration using

Freon-21 coolant. A bypass control valve is used to control theheat rejection rate. Maximum inlet radiator temperature of 70°F under normal conditions is recommended. The radiator size will be about 27 - 30 ft^2 for 1580 BTU/hr heat load. Minimum heat load of 200 BTU/hr is recommended as a lower value to keep an ample margin to prevent freezing in the coldest radiator panel.

Further analysis will have to be performed once heat load requirements are firmed up. Additional radiator studies including transient influences along with transient studies of the entire active loop system must still be performed.

Discussion

A. Initial Radiator Analysis - Initial radiator studies were performed to gain an understanding of the problems of integrating a radiator into the carrier configurations being studied. The objective of this early study was to see how a radiator could best be located, its size, and its performance capabilities. The following goals and assumptions were made:

1. Qualified Pump Packages - The Block II Apollo pump package which was chosen has a nominal flow rate (62.5% glycol/water) of 200 lb/hr.
2. Nominal Heat Dissipation Requirement - From a preliminary 155.5 kw/hr battery sizing for a 14-day mission, 1580 BTU/hr average rate was obtained.
3. Maximum Radiator Inlet Temperature - 80°F was chosen as the maximum radiator inlet temperature.
4. Minimum Heat Load - For flexibility, the goal was the lowest minimum heat load requirement without freezing (or excessive Δ P).
5. Minimum Radiator Outlet Temperature - Because of the high viscosity of the glycol/water at low temperatures, 25°F was set as the minimum allowable outlet temperature.
6. Minimum Controlled System Inlet Temperature - The minimum inlet temperature to the system was set at 35°F.

7. Radiator Physical Design - Single long series tube configuration was chosen with a fin thickness of approximately .040 inches and surface properties of α_s = .2 and ϵ = .9. A selective stagnation radiator design was not considered because of the potential development impact on schedule and complexity.

8. Environmental Parameters

   Solar constant = 443 BTU/hr ft^2

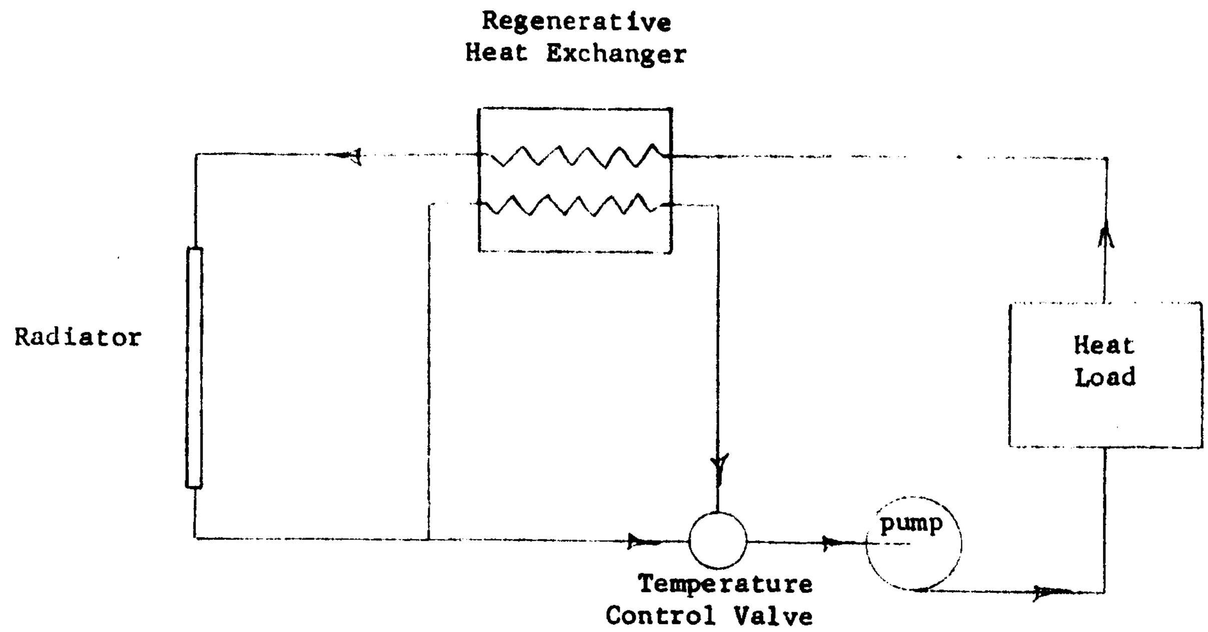
   Earth IR = 73 BTU/hr ft^2

   Albedo = .39

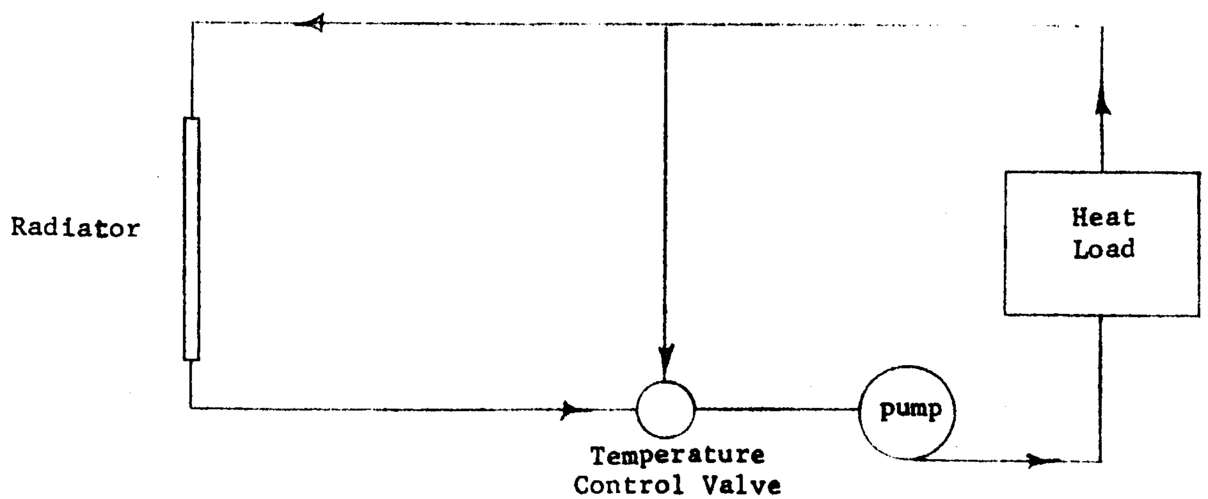
External absorbed radiator heat flux was determined from the environmental parameters, minimum and maximum orbit altitudes and minimum and maximum sun angle positions. The minimum heat loads were based on zero albedo and 140 n. miles. The maximum heat loads were based on 100 n. miles with albedo. The radiator analysis used orbit time averaged steady state heat loads rather than steady state maximums and minimums values.

Under minimum heat dissipation loads, the cold coolant from the radiator must be warmed to minimum allowable system temperatures (35^{o}F). This is accomplished with either a regenerative heat exchanger which reheats the cold radiator coolant by the inlet radiator coolant or by a bypass line around the radiator to mix warm and cold coolant to obtain proper inlet system temperatures. These two control approaches are depicted in Figure 1. Generally, a bypass control scheme will tend to freeze up the radiator faster than the regenerative control method. A regenerative system control has an inherent inefficiency in the regenerative H.X. which requires a minimum heat load to make up for this inefficiency. In the control analysis, maximum regenerative H. X. effectiveness was taken as 0.91. Each radiator configuration must be evaluated for its best control system. The minimum equilibrium temperature that a surface such as the radiator will attain is plotted as a function external absorbed heat flux in Figure 2.

Typical Radiator Control Methods



REGENERATIVE H.X. RADIATOR CONTROL



BYPASS RADIATOR CONTROL

Figure 1

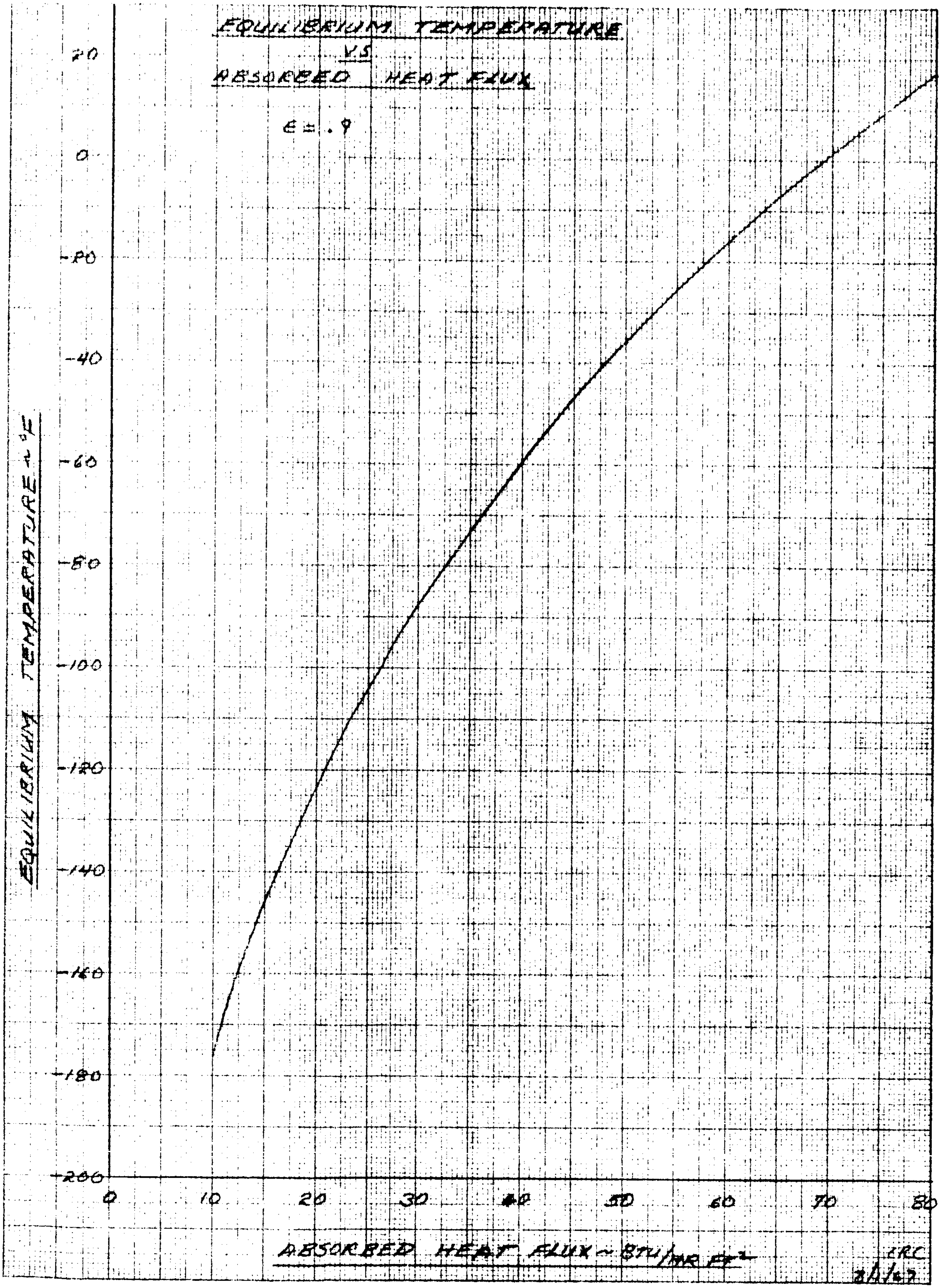

EQUILIBRIUM TEMPERATURE
VS
ABSORBED HEAT FLUX
ε = .9
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
EQUILIBRIUM TEMPERATURE ~ °F
0
10
20
30
40
50
60
70
80
ABSORBED HEAT FLUX ~ BTU/HR FT²

FIGURE 2

Table 1 shows the results of the glycol/water radiator study. The type of control necessary for greatest flexibility is shown. To obtain the greatest heat load flexibility for a glycol/water radiator the only location that the radiator will not freeze is located on the earth side (experiments require this side also). For all other cases examined, a regenerative heat exchanger control system with a minimum system heat load of 800 BTU/hr would be required. An earth side radiator would constrain the radiator to always view earth.

B. Further Analysis - Further study of Freon-21 as a coolant showed great promise. The use of Freon-21 essentially eliminates freeze-up problems at low temperatures and allows the use of a radiator bypass temperature control system. The bypass control allows much higher radiator turn down ratios (maximum heat load/minimum heat load) than can be obtained with a regenerative heat exchanger (because of the regenerative H.X. inefficiency). Coupling the above advantages of Freon-21 with the tests performed on the Block II Apollo and LEM pump package on Freon-21 and Freon-21 low viscosity and low relative pump power index, makes the choice of Freon-21 excellent.

The location of the radiator on any one side places constraints on the system design. See Table 1. The best design approach appeared to be a radiator which would have a panel on each of four sides. With this type of wrap around arrangement, no large penalties are paid for sun exposure since there are always sides of the radiator that can efficiently dissipate heat. Also the wrap-around approach always has external heating no matter the carrier orientation thus minimizing freeze-up problems.

During the evolution of a Freon-21 radiator design the radiator outlet temperature can be allowed to approach the freezing point of the Freon-21 ($-211^{o}F$). Also, the temperature of the returned controlled temperature to the system was lowered from initial studies of $80^{o}F$ maximum to $70^{o}F$ maximum to allow more

Table 1

PRELIMINARY RADIATOR EVALUATION

Radiator Location	At 100 n m Max Est Heat Flux (Ave) BTU/Hr Ft^2	At 140 n m Max Est Heat Flux (Ave) BTU/Hr Ft^2	Radiator Area (Max Heat Flux)	Min Equil Temp	Control with Glycol/ Water	Control with Freon -21	Comments	Pref-erence Glycol/ Water	Pref-erence F-21
1. Earth Side (Bottom)	73	60	35 ft^2	-16°F	Bypass	Bypass	Must provide radiator on side required for experiments	2.	3.
2. Side (Zero sun)	27	22	19	-115°F	Reg H.X = min 800 B/hr	Bypass	Launch time constraint to obtain	5.	5.
3. Side (Full sun)	112	22	~120	-115°F	"	Bypass	Poor candidate	6.	6.
4. Forward End	55	22	28	-115°F	"	Bypass	-	3.	2.
5. Aft End	-	-	-	-	-	-	CSM Blocks radiator	7.	7.
6. Top	28	0	20	-460°F	Reg H.X. Q min = 800 B/hr	Reg H.X.	-	4.	4.
7. Wrap Around (Top, Side, Bottom, Side)	50	33	24	-77°F	"	Bypass	-	1.	1.

Note: Radiator Heat Rejection = 1580 BTU/hr
Max Radiator Inlet Temp = 80°F
Min Radiator Outlet Temp = -25°F
Regenerative H. X. Effectiveness = .91
Coolant - 62.5% glycol/water

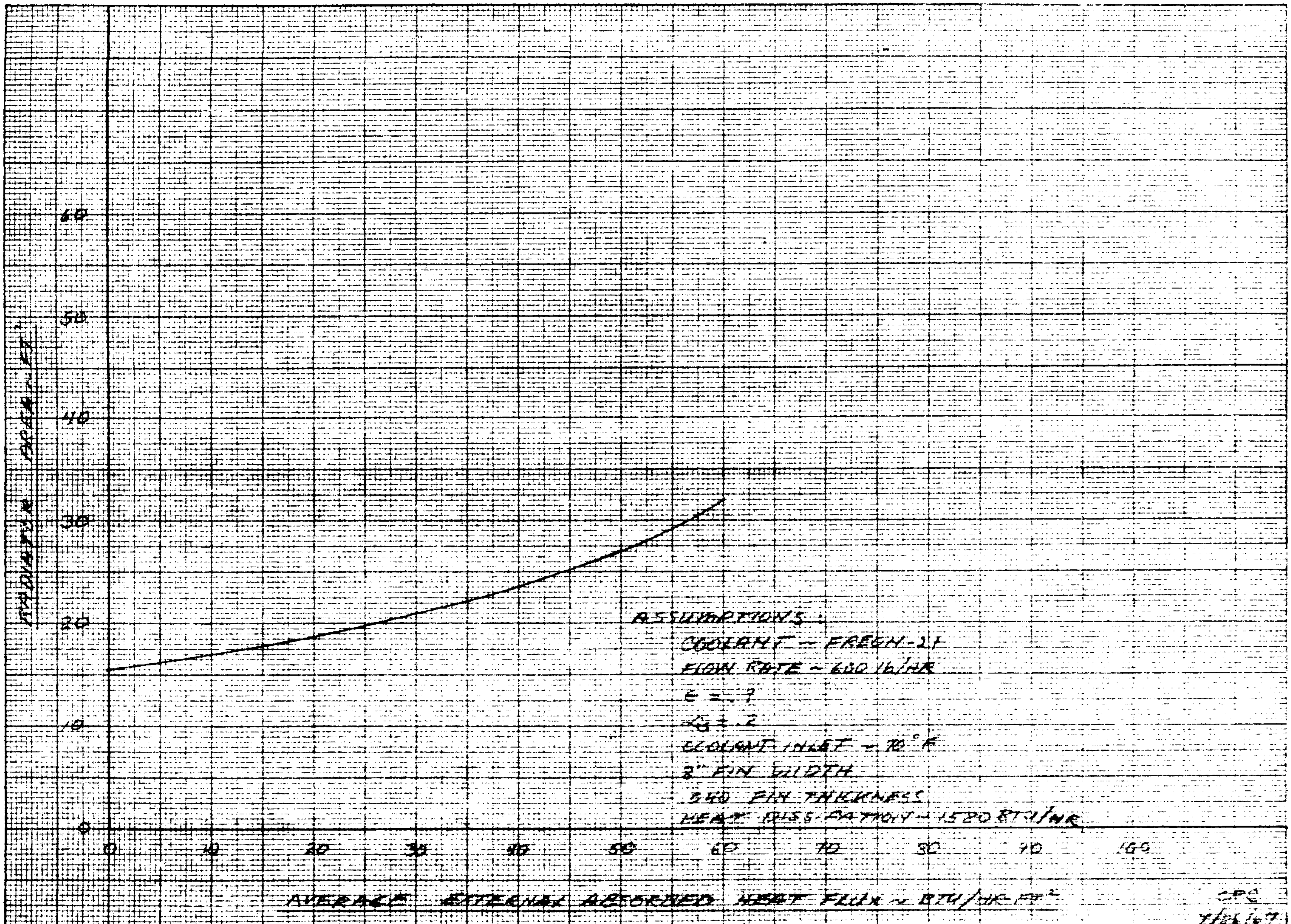
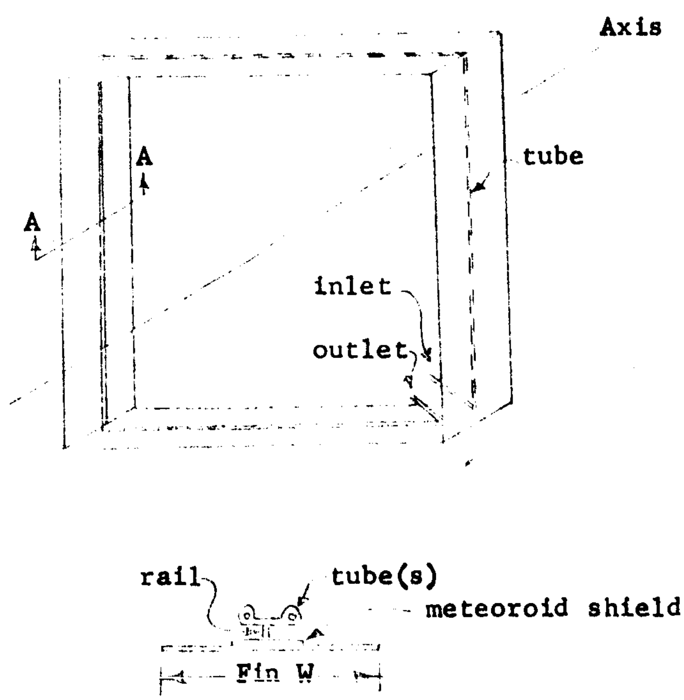

RADIATOR AREA ~ FT²
AVERAGE EXTERNAL ABSORBED HEAT FLUX ~ BTU/HR FT²
0
10
20
30
40
50
60
70
80
90
100
ASSUMPTIONS:
COOLANT ~ FREON-21
FLOW RATE ~ 600 lb/HR
2" FIN WIDTH

FIGURE 3

flexibility for transient heat loads. Lowering the maximum inlet controlled system temperature increases the radiator size only slightly (~10%).

It has been found that the average of the external absorbed heat fluxes by the radiator can be used to evaluate maximum heat loads and preliminary radiator areas. Figure 3 shows a plot of radiator area as a function of average external absorbed heat flux for an average heat dissipation rate of 1580 BTU/hr at a radiator inlet temperature of 70°F. For Freon-21, an average flow rate of 600 lb/hr has been used, which is minimum expected Block II Apollo Freon-21 pump package flow rate.

The radiator design which is considered the simplest approach is a single tube with fins making one pass around the carrier. This eliminates numerous bend required for longer single series systems and eliminates flow distribution problems with parallel tubing. This design approach is shown in Figure 4. Redundant radiator tubes can easily be incorporated as shown.



Section A-A

Figure 4

There are two variations of wrap-around radiator orientations with respect to earth being considered. One orientation has the radiator axis (and carrier) perpendicular to the earth and the other has the axis parallel to the earth. See Figure 5. The maximum and minimum absorbed external fluxes are shown for these two orientations in Table 2.

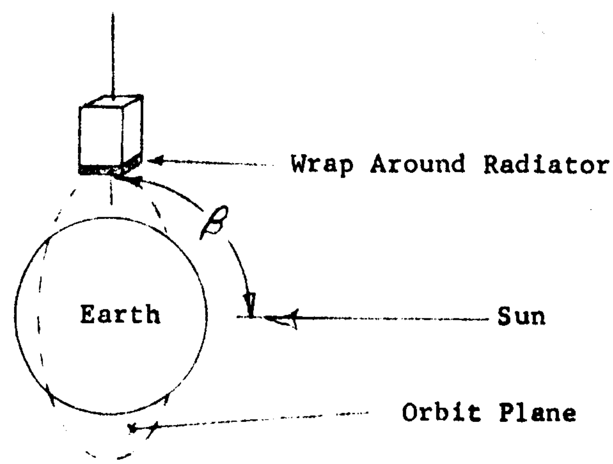
Examination of Table 2 shows that the overall average external heat fluxes for a wrap-around radiator do not vary a great degree. Since attitude will not be frozen, the radiator should be sized for the maximum average external absorbed heat flux of about 50 BTU/hr ft^2. From Figure 2 this corresponds to a radiator of about 27 ft^2 for the total of four sides. Based on the 8 inch total fin width that Figure 3 was derived by, each side length would be 10 feet. If 10 feet is not available, then the fin width can be made wider and thickness slightly greater if need be. Results of previous studies are shown in Figures 6 and 7 for the influences of fin width and fin thickness.

The heat dissipation control and associated temperature control system using a regenerative heat exchanger requires a minimum heat load of about 800 BTU/hr with a regenerative H.X. effectiveness of 0.91. Therefore a bypass control system was analyzed.

The major problem of bypassing flow around the radiator is the potential freeze problem. Pressure drop at reduced flow rates is insignificant due to Freon-21 low viscosity characteristics and the low flow rates.

In evaluating the bypass control of the radiator, the radiator flow varies with heat load. Since one side of the radiator could be exposed to space with zero external heat flux, the coolant can not be allowed to freeze before passing to the next warmer panel. Because of the wide variations of external heat fluxes on the various panels and the significant influence, these heat fluxes can have at low heat loads and associated low flow rates, each panel must be considered separately, that is, not using an overall average heat flux. The flow from the system which is at the hottest temperature should be directed to coldest panel first. Figure 8 is a plot of heat rejection as a function of flow rate through the radiator. Two

Carrier and Radiator Orientations



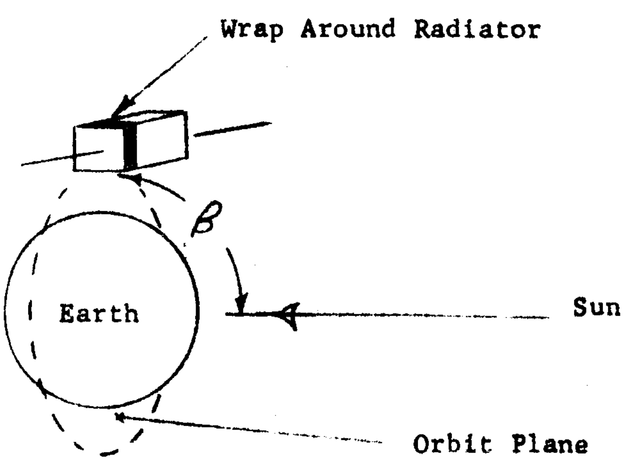


Figure 5

Table 2

Average External Absorbed Heat Flux Wrap Around Radiator

Axis ⊥ to Earth

Side	Ø	100 n m	140 n m
Forward	0°	IR = 23	IR = 22
Aft		IR = 23	IR = 22
Side #1		IR = 23	IR = 22
Side #2		Sun + IR = 112	Sun + IR = 110
		Ave = 45 BTU/hr ft^2	Ave = 44 BTU/hr ft^2
Forward	90°	Sun + Alb + IR = 55	Sun + IR = 50
Aft		Sun + Alb + IR = 55	Sun + IR = 50
Side #1		Alb + IR = 27	IR = 22
Side #2		Alb + IR = 27	IR = 22
		Ave = 41 BTU/hr ft^2	Ave = 38 BTU/hr ft^2

Axis // to Earth

Side	Ø	100 n m	140 n m
Earth	0°	Alb + IR = 73	IR = 60
Space		Sun = 28	Sun = 28
Side #1		Alb + IR = 27	IR = 22
Side #2		Alb + IR = 27	IR = 22
		Ave = 39 BTU/hr ft^2	Ave = 33 BTU/hr ft^2
Earth	90°	IR = 62	IR = 60
Space		0	0
Side #1		IR = 23	IR = 22
Side #2		Sun + IR = 112	Sun + IR = 110
		Ave = 49 BTU/hr ft^2	Ave = 48 BTU/hr ft^2

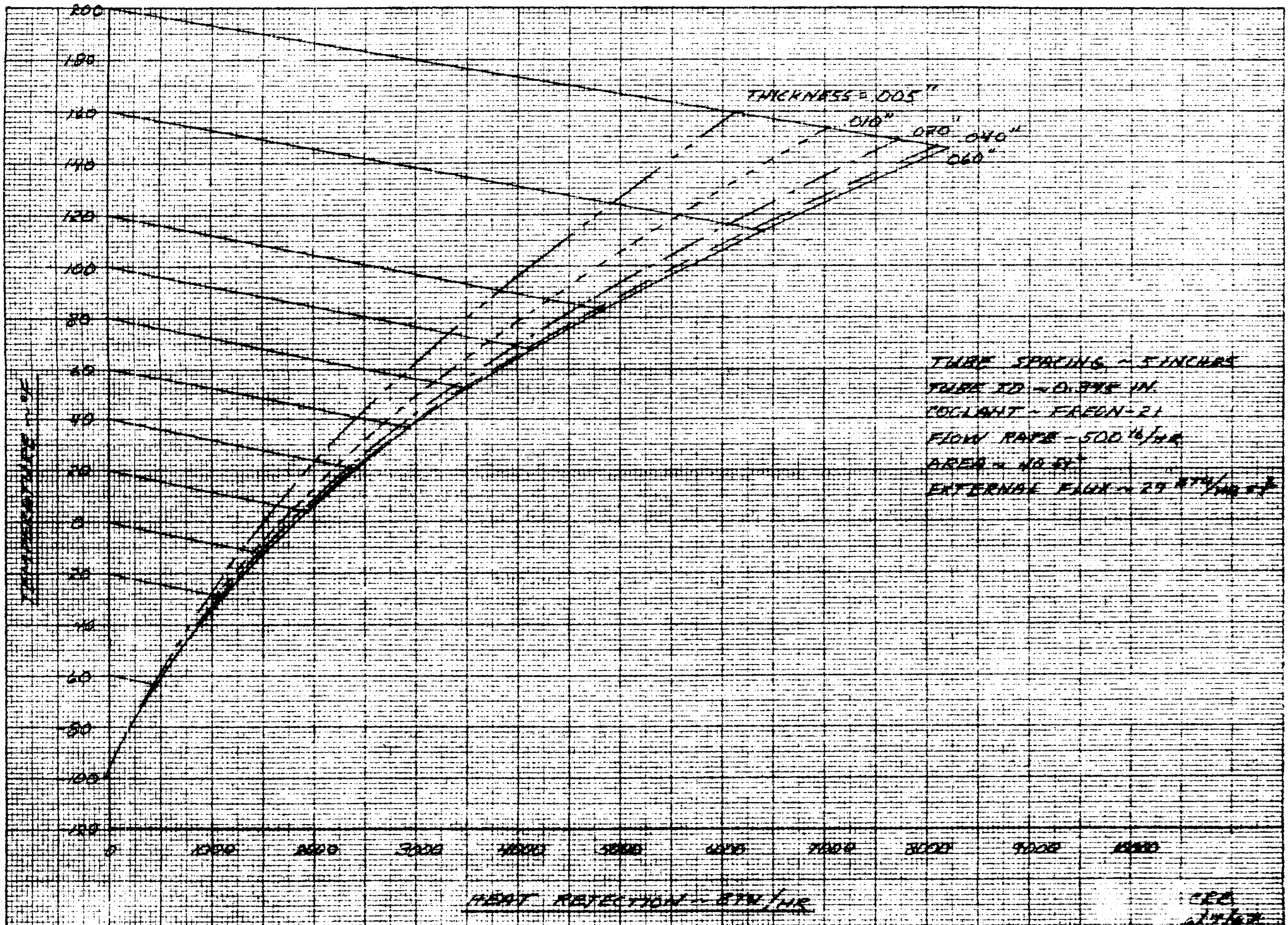

THICKNESS = .005"
.010"
.020"
.040"
.060"
TUBE SPACING ~ 5 INCHES
TUBE ID ~ 0.375 IN.
COOLANT ~ FREON-21
FLOW RATE ~ 500 lb/hr
AREA ~ 40 ft²
EXTERNAL FLUX ~ 29 BTU/hr ft²
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
HEAT REJECTION ~ BTU/HR

FIGURE 6

10 X 10 TO THE CM. 359T-14
KEUFFEL & ESSER CO.
ALBANENE

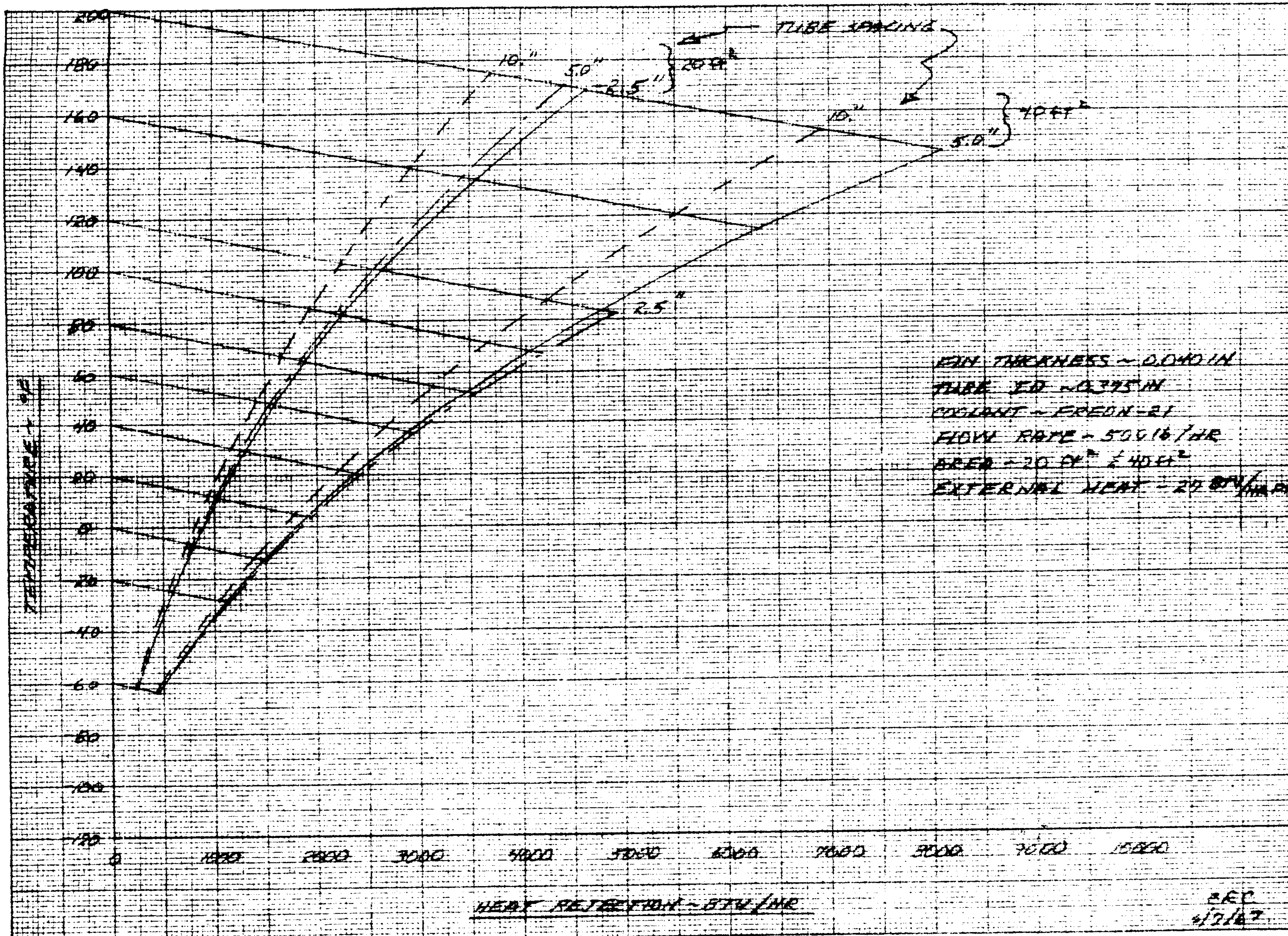


FIGURE 7

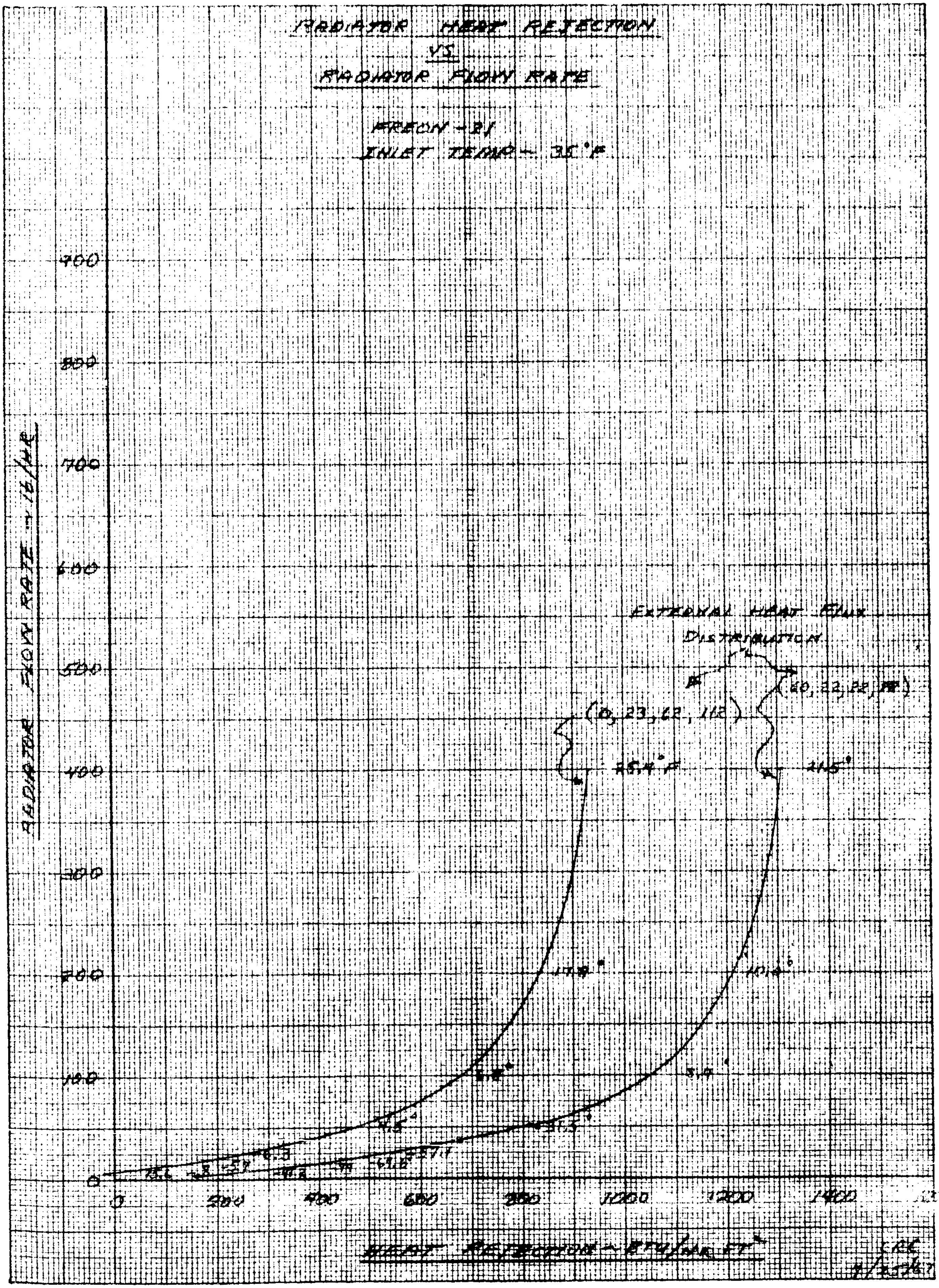

RADIATOR HEAT REJECTION
VS
RADIATOR FLOW RATE
FREON - 21
INLET TEMP - 35°F
EXTERNAL HEAT FLUX
DISTRIBUTION
(0, 23, 22, 112)
(20, 22, 22, 77)
RADIATOR FLOW RATE ~ lb/HR
HEAT REJECTION ~ BTU/HR FT²
0
200
400
600
800
1000
1200
1400
100
200
300
400
500
600
700
800
900

FIGURE 8

external heat flux distributions are shown in Figure 8. Outlet temperatures from the last panel are indicated on the curve. Figure 9 shows plots for the same two external absorbed heat flux distributions as for Figure 8 but shows radiator outlet temperature as a function of flow rate. The heat rejection values are indicated on these curves. Figure 10 is a plot of outlet temperature of the first coldest panel as a function of flow rate. A minimum flow rate of about 20 lb/hr which corresponds to a minimum heat rejection rate of about 200 BTU/hr is recommended to keep the control valve from having to control mixing of warmer coolant at lower flow rates as seen by the knee of the curve in Figure 9 and to provide margin against freezing.

The evaluation of the radiator thus far has been based on the Block II Apollo pump with a flow rate of 600 lb/hr. This pump draws 52 watts AC power and with inverter losses raises this to about 70 watts D.C. This 70 watts is equal to 23.5 kw/hrs which requires about 2 batteries (11.1 kw/hr per battery) weighing about 280 lb. Because of this high weight penalty, the LEM pump package has been briefly investigated. The LEM pump package has been tested on Freon-21 and will put out 400 lb/hr. This pump draws 27 watts at this flow rate which, for 14 days is 9.1 kw/hrs. The use of this pump would save one battery weight of 140 pounds. For the same heat dissipation of 1580 BTU/hr, 400 lb/hr flow rate would have a ΔT through the system of about 15.5°F compared to 10.3°F for a flow rate of 600 lb/hr. The radiator area would therefore increase about 10% giving a total radiator area requirement of about 30 ft^2.

A modified Block II Apollo pump which has been tested on Freon-21 is another strong pump candidate. This pump has a brushless DC motor and produces a flow rate from 400 to 500 lb/hr for a power of about 43 watts DC power. This is equivalent to about 14 kw/hrs.

Based on the analysis thus far performed, it appears that any of the

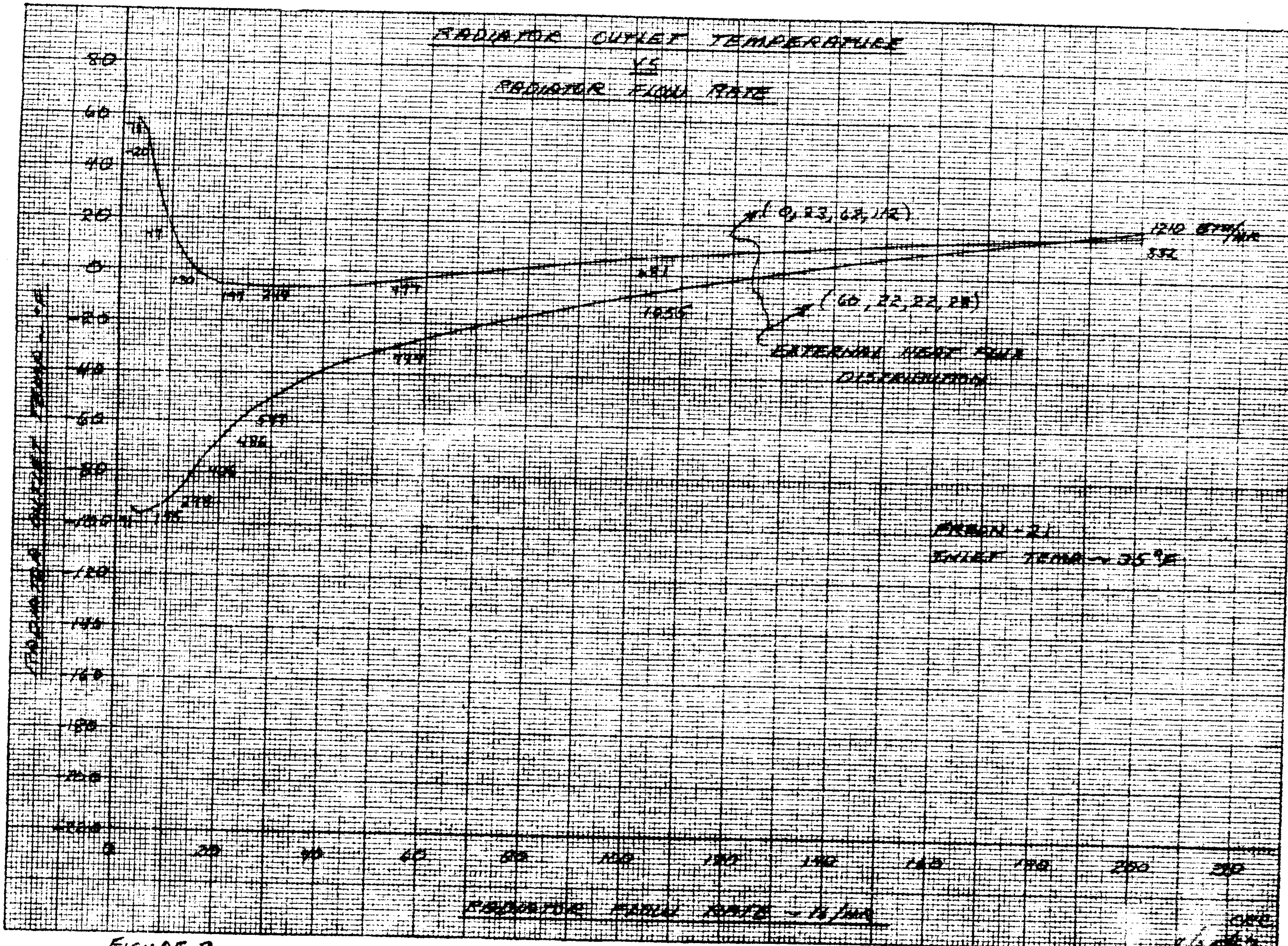

RADIATOR OUTLET TEMPERATURE
VS
RADIATOR FLOW RATE
(0, 23, 63, 112)
1210 BTU/HR
(60, 22, 22, 28)
EXTERNAL HEAT FLUX
DISTRIBUTION
FREON - 21
INLET TEMP ~ 35°F
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
0
20
40
60
80
100
120
140
160
180
200
220

FIGURE 9

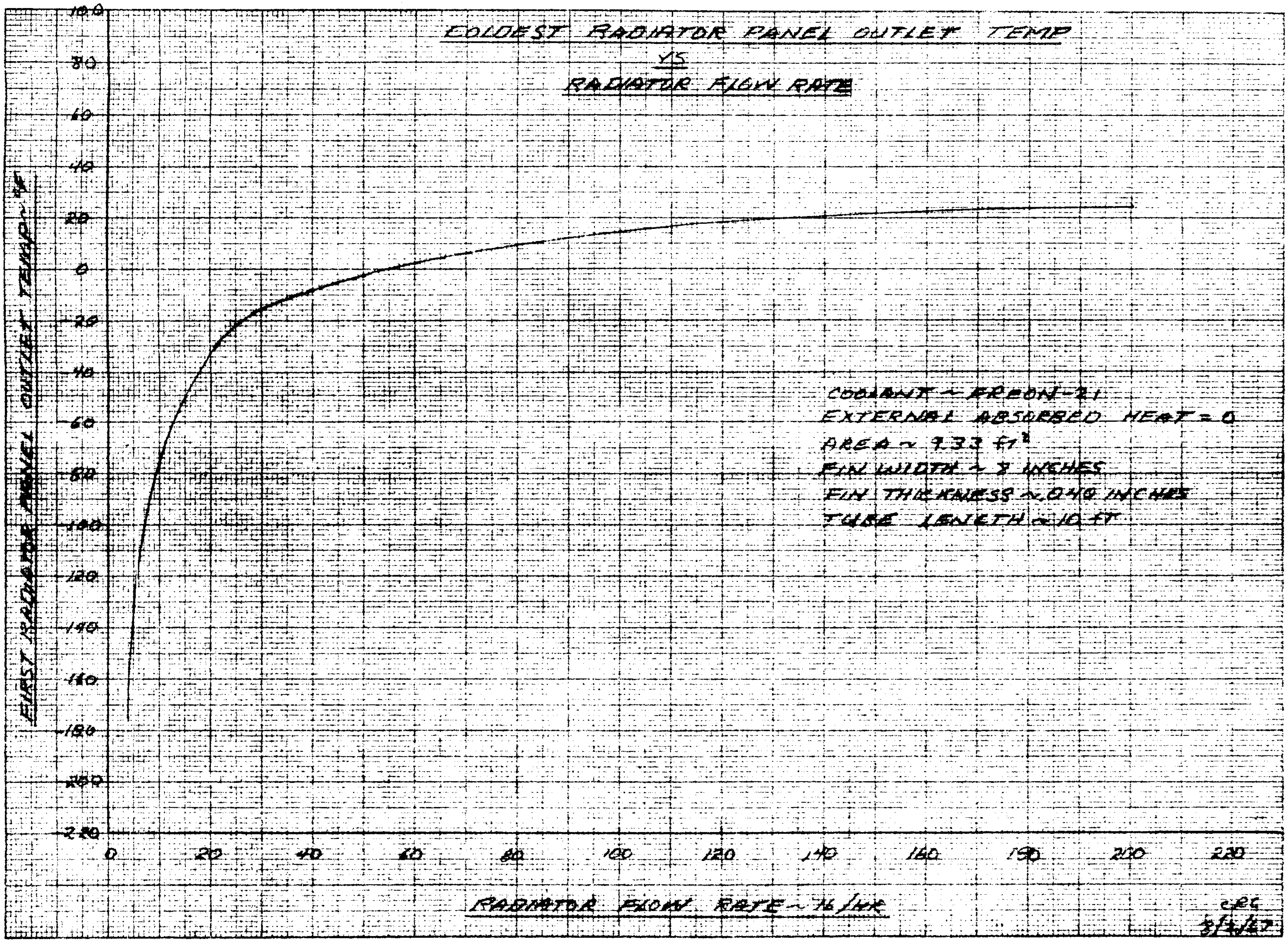

COLDEST RADIATOR PANEL OUTLET TEMP
VS
RADIATOR FLOW RATE
COOLANT ~ FREON-21
EXTERNAL ABSORBED HEAT = 0
AREA ~ 733 ft^2
FIN WIDTH ~ 8 INCHES
FIN THICKNESS ~ .040 INCHES
TUBE LENGTH ~ 10 FT
FIRST RADIATOR PANEL OUTLET TEMP ~ °F
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
0
20
40
60
80
100
120
140
160
180
200
220
RADIATOR FLOW RATE ~ lb/hr

FIGURE 10

above mentioned pumps can be used if heat load requirements do not exceed the current design value of 1580 BTU/hr. Once the heat load requirements become more firmly established, a complete reevaluation of the radiator system is necessary along with a complete study of the total active loop subsystem including transient analyses.

PR 29-7

TRADE STUDY REPORT

CARRIER CONFIGURATION

TRADE STUDY

AAP/PIP Early Applications

Contract NAS 8-21004

23 August 1967

Prepared by: K. Kohlenberg

J. Noland

R. Hurley

Approved by: W. Paulson

MARTIN MARIETTA CORPORATION
DENVER DIVISION

TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to document the results of a trade study evaluating several alternate approaches to a carrier structural configuration.

1.2 Objectives - Two alternate orbital attitudes and three pressurization options are considered. The orbital attitudes are:

a. Axial viewing - sensors oriented with earth-viewing axes parallel to the CSM centerline, causing a relatively high drag orbital configuration.

b. Side viewing - sensors oriented with earth-viewing axes normal to the CSM centerline, resulting in a minimum drag orbital configuration.

The pressurization options include:

a. No pressurization

b. Intermittent pressurization

c. Continuous pressurization

It is not the objective of this study to select a pressurization mode, since this decision must consider several system considerations in addition to structural optimization. Rather, a best structural configuration is selected for each of the three pressurization options. These candidate carriers are, in turn, carried into the pressurization study (Ref PR 29-8) which considers all systems aspects of the pressurization mode selection.

2. SUMMARY

The carrier configuration selected for the unpressurized option is an axial viewing, box-shaped truss structure, permitting full entry of the astronaut for IVA activities.

One pressurized configuration has been selected for both the intermittent and continuous pressurization modes. This configuration also is axial viewing, and consists of a conical pressurized section with a shallow spherical segment bulkhead with sensor viewing windows. Only those experiments requiring crew access are located within the pressure chamber; other sensors and subsystems are located on externally located racks on either side of the pressure chamber.

3. DISCUSSION

3.1 <u>Ground Rules and Design Criteria (all configurations)</u> - The following ground rules and design criteria were applied to the configurations developed during the trade study.

3.1.1 The Mission 1A Carrier, including experiments and carrier subsystems, shall be designed for independent operation when hard docked to the CSM.

3.1.2 Liftoff weight of the carrier including experiments and carrier subsystems, whether located in the CM or in the carrier, shall not exceed 5000 lbs.

3.1.3 Data retrieval from carrier mounted experiments shall be accomplished by crew IVA.

3.1.4 The carrier shall be supported in the SLA on the four LM attach points, and must provide lateral support for the SLA structure at these points during boost flight.

3.1.5 The carrier/SLA structural interface shall be identical to the present four-point LM/SLA interface.

3.1.6 The carrier shall be designed so that the desired experiment fields of view and physical orientation requirements can be achieved.

3.1.7 The Saturn S-IB will be used as the Mission 1A booster.

3.1.8 Experiment and support subsystem components shall be accessible for maintenance at any time prior to pad evacuation.

3.1.9 For pressurized carriers, only those components requiring direct crew access shall be located in the pressurized compartment; all other components shall be placed on racks external to the pressurized chamber.

3.1.10 In light of the short development and production time dictated by Flight 1A launch schedule, simplicity of design and use of state-of-art material and fabrication methods are considered paramount in the design of the carrier.

3.2 CONFIGURATION DESCRIPTION

Several carrier concepts were studied to develop a set of candidate configurations. Six configurations were selected for further study, and are included in this trade study report. Of these six, three configurations are axial viewing pressurized, one is side viewing pressurized, one is side viewing unpressurized, and the last is axial viewing unpressurized. More than one axial viewing pressurized configuration is included, since in this group, shortened configurations, providing partial (head and shoulders) crew entry appeared to have some merit. For side viewing experiments, a pressurized container having sufficient side-looking sensor mounting surface inherently provided full crew entry, precluding partial entry configurations.

The pressurized configurations presented are considered applicable to either continuous or short term, intermittent pressurization. The only structural difference expected between these two modes of operation may be in the area of acceptable leakage rates, which could be greater for the intermittent pressurization mode.

The following paragraphs describe the six candidate configurations.

3.2.1 Configuration 1 - Axial Viewing, Pressurized, Conical - This carrier configuration, shown in Figure 1 mounts the experiment sensors in an axial viewing attitude. The pressurizeable portion of the carrier is in the shape of a truncated circular cone expanding from the docking tunnel diameter to an 84 inch diameter at the spherical segment aft closure. Adequate volume is provided for crew IVA and for stowage of various items of equipment in the carrier during launch and subsequent orbital activities. Four truss assemblies support the carrier in the SLA.

Only those experiment components which require data retrieval or direct crew access are located within the pressurizeable structure. The balance of the experiment sensors are mounted on earth facing platforms located on opposite sides of the spherical aft closure, or are supported from these structures in the cases of the radar scatterometer and the microwave radiometer. Experiment sensor supporting equipment such as electronic packages are appropriately mounted near their sensors.

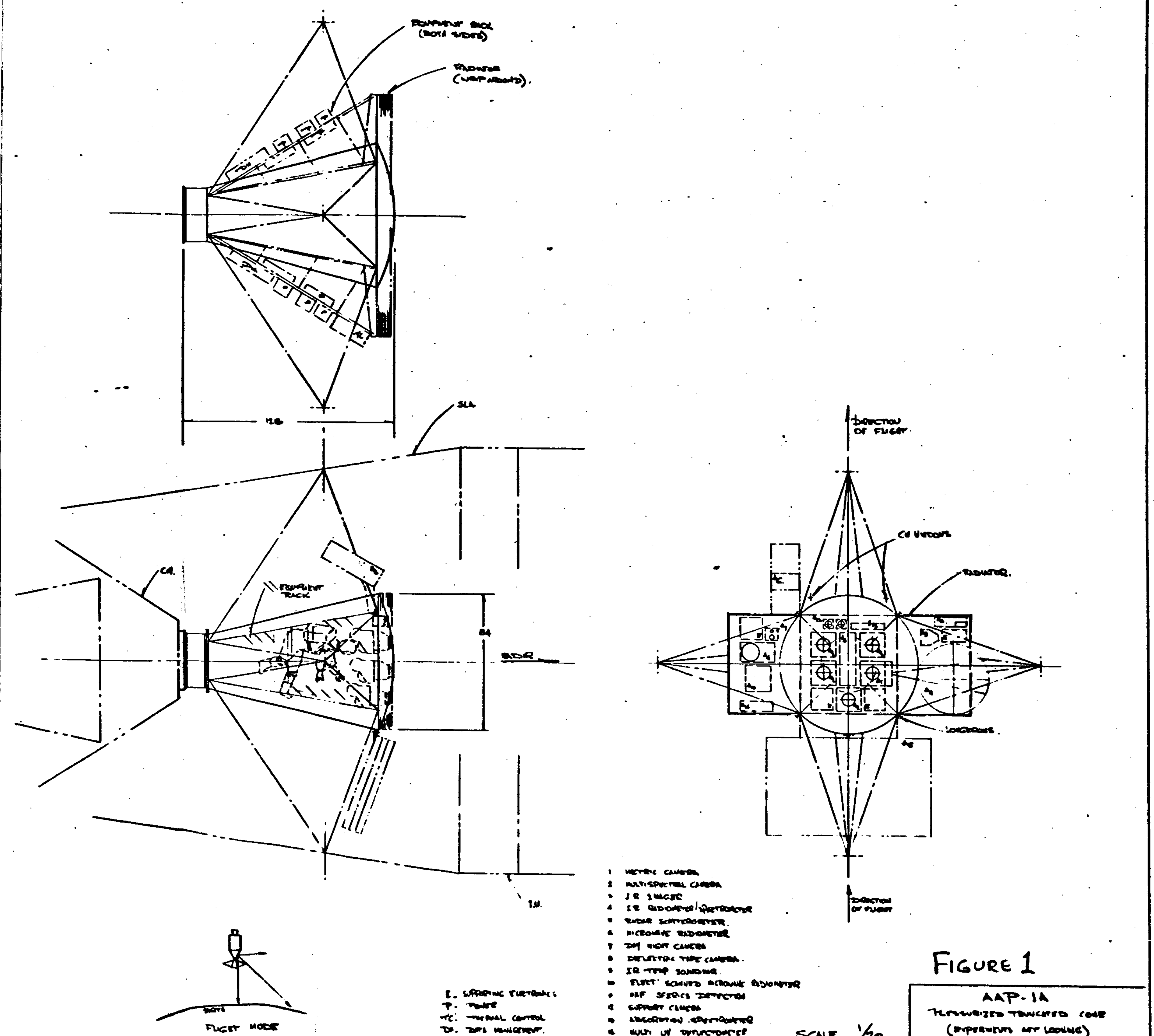


FIGURE 1

AAP-1A
PRESSURIZED TRUNCATED CONE
(EXPERIMENTS AFT LOOKING)

3.2.1 Configuration 1 (Continued)

Support subsystem components are mounted on two equipment racks each supported by longerons and two experiment platform support members. The thermal control radiator is supported from the experiment platforms and the ring frame at the juncture of the cone-spherical closure.

Location and grouping of the experiments and subsystems in these unpressurized areas facilitates access for maintenance activities, and thermal and meteoroid shield design is simplified.

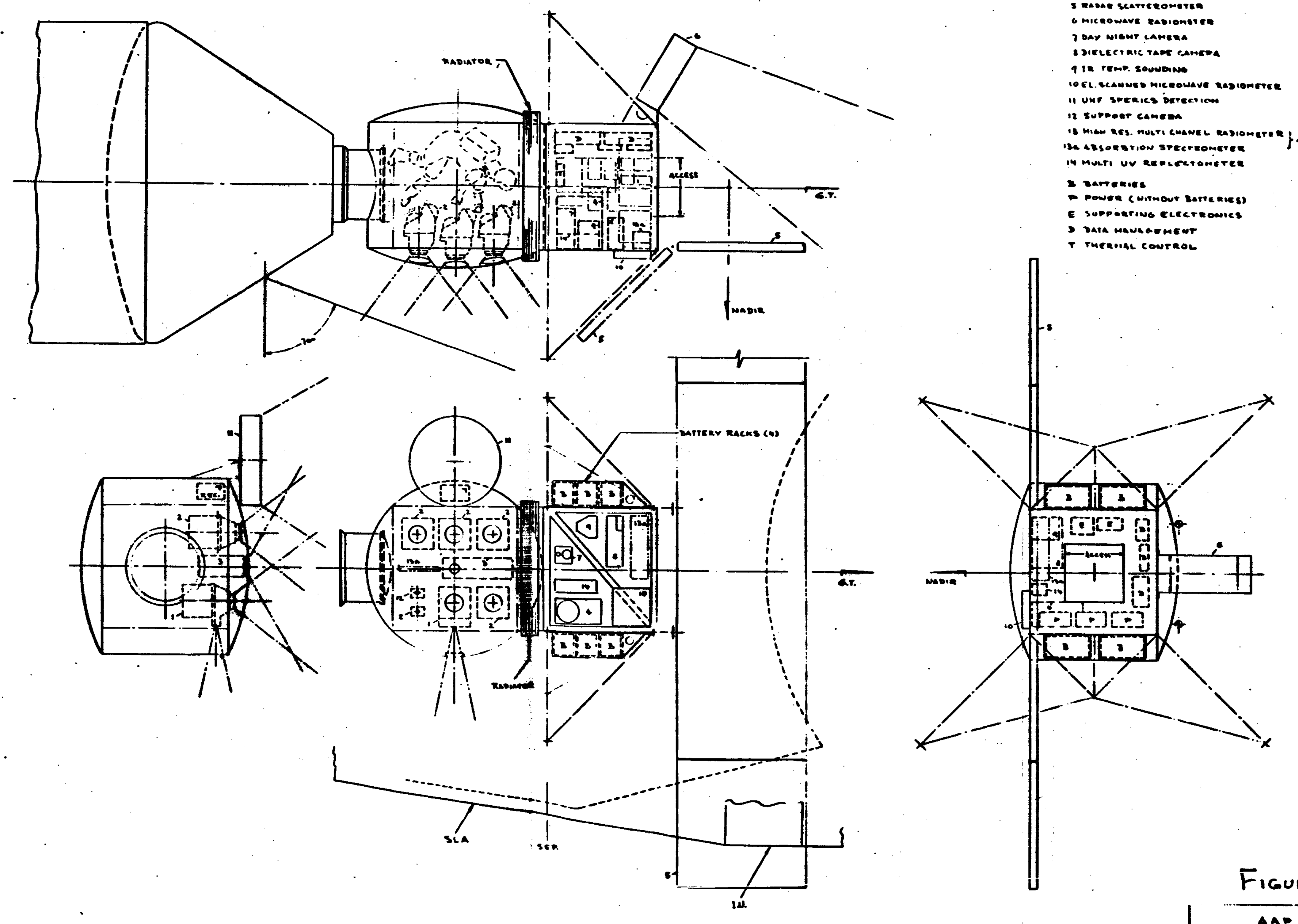
3.2.2 Configuration 2 - Side Viewing Pressurized, Cylindrical - This concept, shown in Figure 2, consists of a pressurizeable cylinder mounted above a rack which is supported in the SLA by four truss assemblies. Experiment sensors are mounted in a side viewing attitude with only those experiment components which require data retrieval or crew access being located in the pressurizeable cylinder. The size of the cylinder provides adequate room for crew IVA and stowage of various items of equipment.

The unpressurized rack accommodates the unpressurized experiments and houses the support subsystems.

3.2.3 Configuration 3 - Axial Viewing, Pressurized, Shortened Conical - This configuration, as shown in Figure 3, is very similar to Configuration 1 except that the pressurizeable truncated cone is considerably shorter than that of Configuration 1. Only enough volume is provided for partial entry of the crewmen performing IVA in the carrier.

3.2.4 Configuration 4 - Axial Viewing, Pressurized, Cylindrical - Major features of this configuration, shown in Figure 4, are similar to those of Configuration 1. The shape of the pressurizeable portion of the carrier is a combination of a cylinder and a truncated cone while the truss configuration has been tailored to accommodate this shape.

3.2.5 Configuration 5 - Side Viewing, Unpressurized - This configuration, shown in Figure 5, features an unpressurized box frame with the side looking experiment sensors arrayed on one side of the carrier and support subsystems mounted to the other faces of the carrier.



1 METRIC CAMERA
2 MULTISPECTRAL CAMERA
3 IR IMAGER
4 IR RADIOMETER/SPECTROMETER
5 RADAR SCATTEROMETER
6 MICROWAVE RADIOMETER
7 DAY NIGHT CAMERA
8 DIELECTRIC TAPE CAMERA
9 IR TEMP. SOUNDING
10 EL. SCANNED MICROWAVE RADIOMETER
11 UHF SFERICS DETECTION
12 SUPPORT CAMERA
13 HIGH RES. MULTI CHANEL RADIOMETER } ALT.
13a ABSORBTION SPECTROMETER
14 MULTI UV REFLECTOMETER

B BATTERIES
P POWER (WITHOUT BATTERIES)
E SUPPORTING ELECTRONICS
D DATA MANAGEMENT
T THERMAL CONTROL

FIGURE 2

AAP - 1A
PRESSURIZED - SIDE LOOKING

SCALE 1/20 8.1.67

FOLDOUT FRAME FOLDOUT FRAME 1 FOLDOUT FRAME FOLDOUT FRAME 2

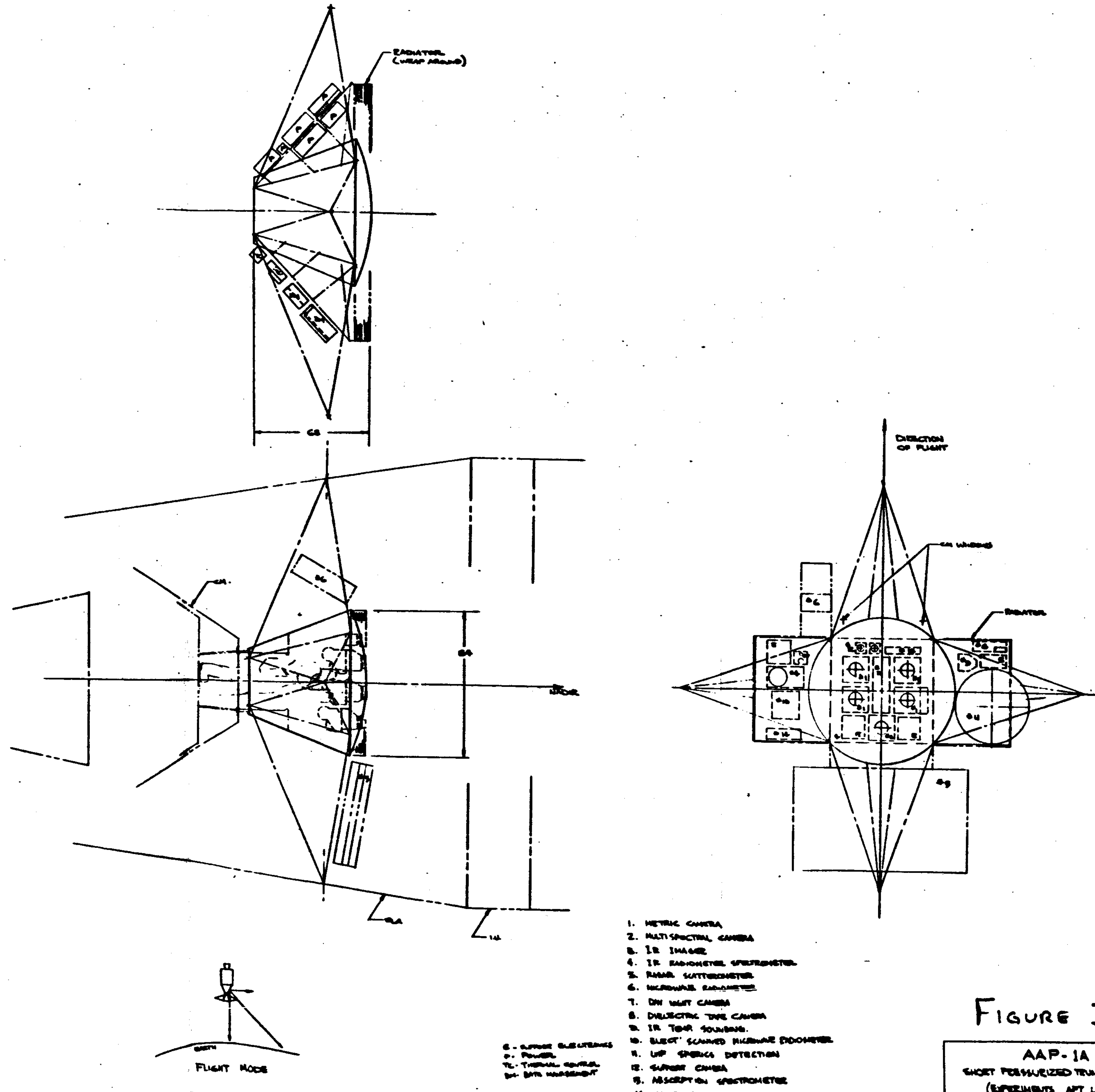


FIGURE 3

AAP-1A
SHORT PRESSURIZED TRUNCATED CONE
(EXPERIMENTS AFT LOOKING)

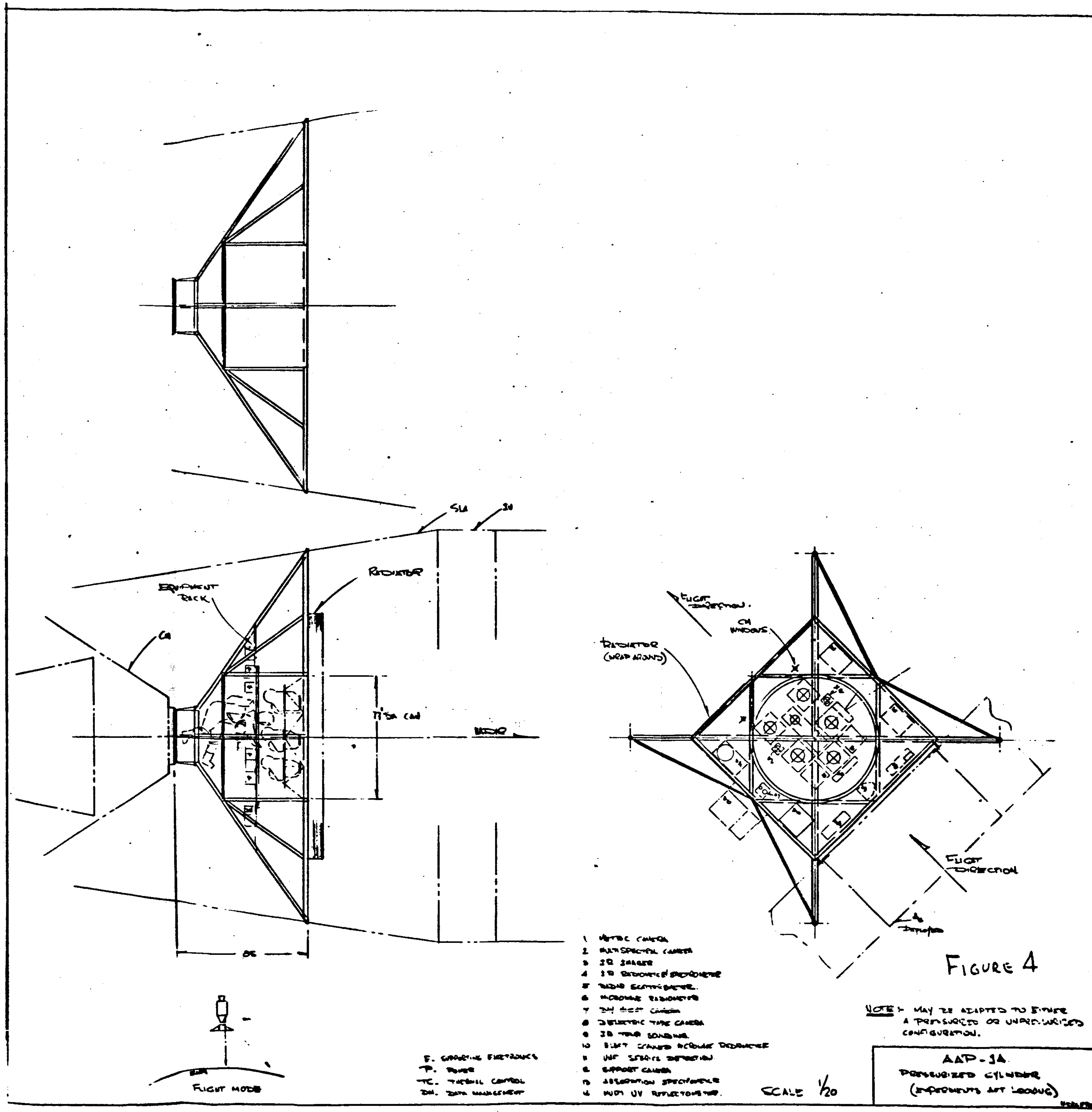


FIGURE 4

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME

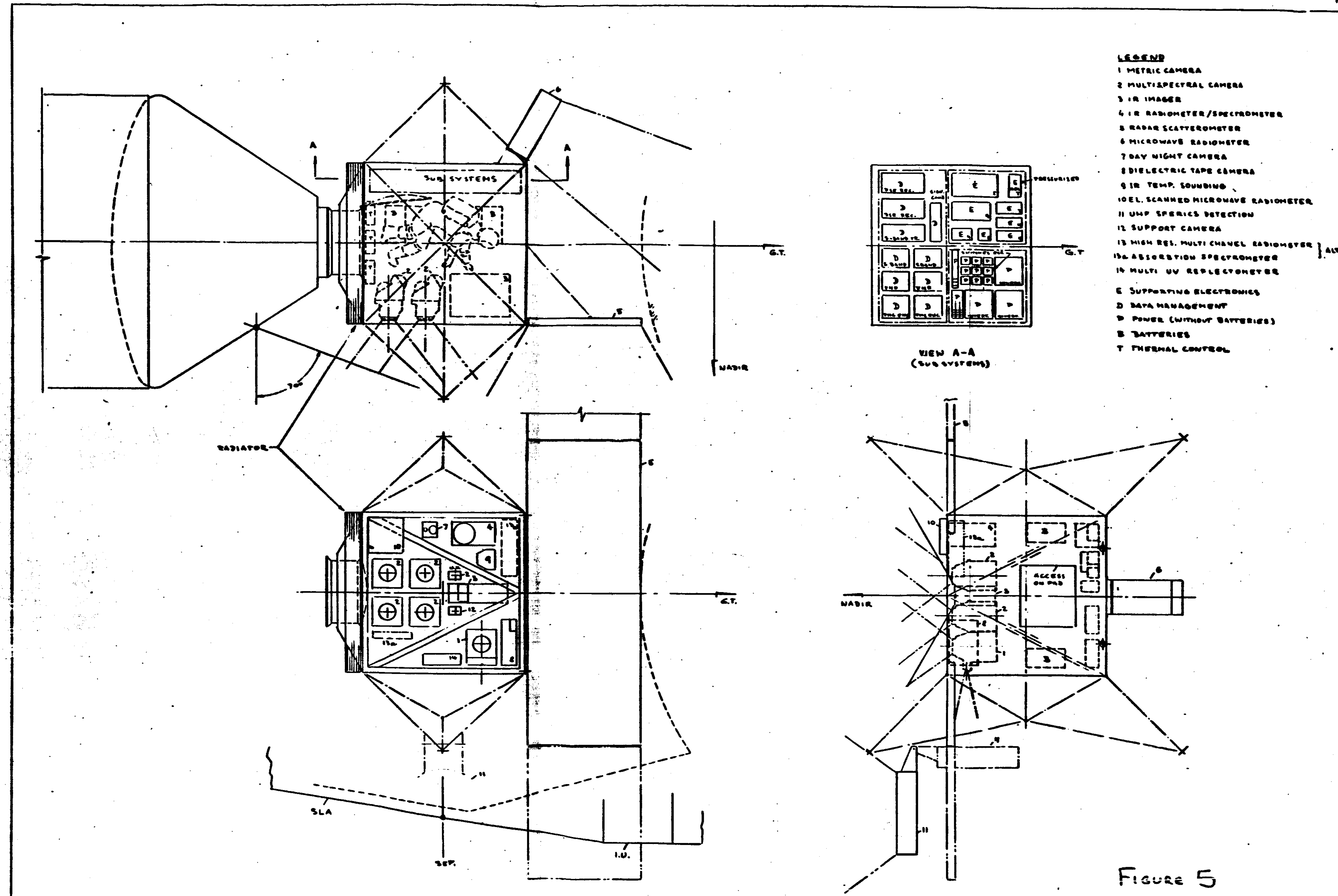


Figure 5

AAP-1A
UNPRESSURIZED - SIDE LOOKING
SCALE 1/50
8.4.67
SCHOPPEL

FOLDOUT FRAME 1
FOLDOUT FRAME
FOLDOUT FRAME 2

3.2.5 Configuration 5 (Continued)

Four truss assemblies support the carrier in the SLA.

3.2.6 Configuration 6 - Axial Viewing, Unpressurized - The basic features of this configuration are similar to those of Configuration 5, however, the experiments are located in an axial viewing attitude with the support subsystems located on the other faces of the carrier. Because of its extreme similarity to Figure 5, an additional figure has not been shown for this configuration.

3.3 STRESS ANALYSIS SUMMARY

3.3.1 Analysis - The structural analysis performed on each of the candidate carrier concepts is representative of the level of detail and degree of sophistication necessary to establish preliminary weight values and to assure that the concepts are inherently structurally sound. The main effort, in each case, focuses on primary structure with the objective of establishing relatively efficient load paths while providing the desired functional characteristics.

3.3.2 Load Conditions - The basic loading conditions for the carriers are:

1) Ground Handling
2) Boost Phase
3) Operation in Orbit

For the trade study the following specific load conditions were considered:

1) Stage I Burn Out
   N_x = -5.76 g's limit, -8.05 g's ult
   $N_{y,z}$ = 0 limit

2) Post Release
   N_x = -3 g's limit, -4.2 g's ult
   $N_{y,z}$ = 2.5 g's limit, 3.5 g's ult

3) Command Module Design Pressures
   5.2 psi Operating
   9.5 psi Proof
   12.9 psi Ultimate

4) Lateral stiffness requirements of 50,000 lb/in.

These values represent the best available data at present. Future loads work will yield accurate values for this particular application. Based on a survey of reports and other documents concerning the Saturn booster and associated spacecraft, the above values appear to be suitable for preliminary design. The values above include a 1.25 dynamic amplification factor.

3.3.3 Materials - The basic structural material for the carrier is 2219-T87. It was selected because of its favorable welding and strength characteristics. Other higher strength materials, e.g., stainless steel, titanium, were considered, but stability, handling and manufacturing considerations indicate that the thicker aluminum gages are more practical.

3.3.4 Stress Summary - Sketches delineating the basic structure of each of the concepts studied and a stress summary of the basic structure of each are presented in Figures 6 through 10 and Tables 1 through 5. Although not presented here, analysis was done on various secondary structure, e.g., experiment mounting, subsystem mounting, to provide a reasonable basis for weight calculations. The basic trusswork was sized as square tubing three inches on a side, the pressure hull as sheet aluminum, and ring frames, longerons, caps, etc. as open extruded or formed sections. In the tables the structural type refers to the types described above and are numbered:

(1) square tubing 3" on a side
(2) sheet aluminum
(3) open sections

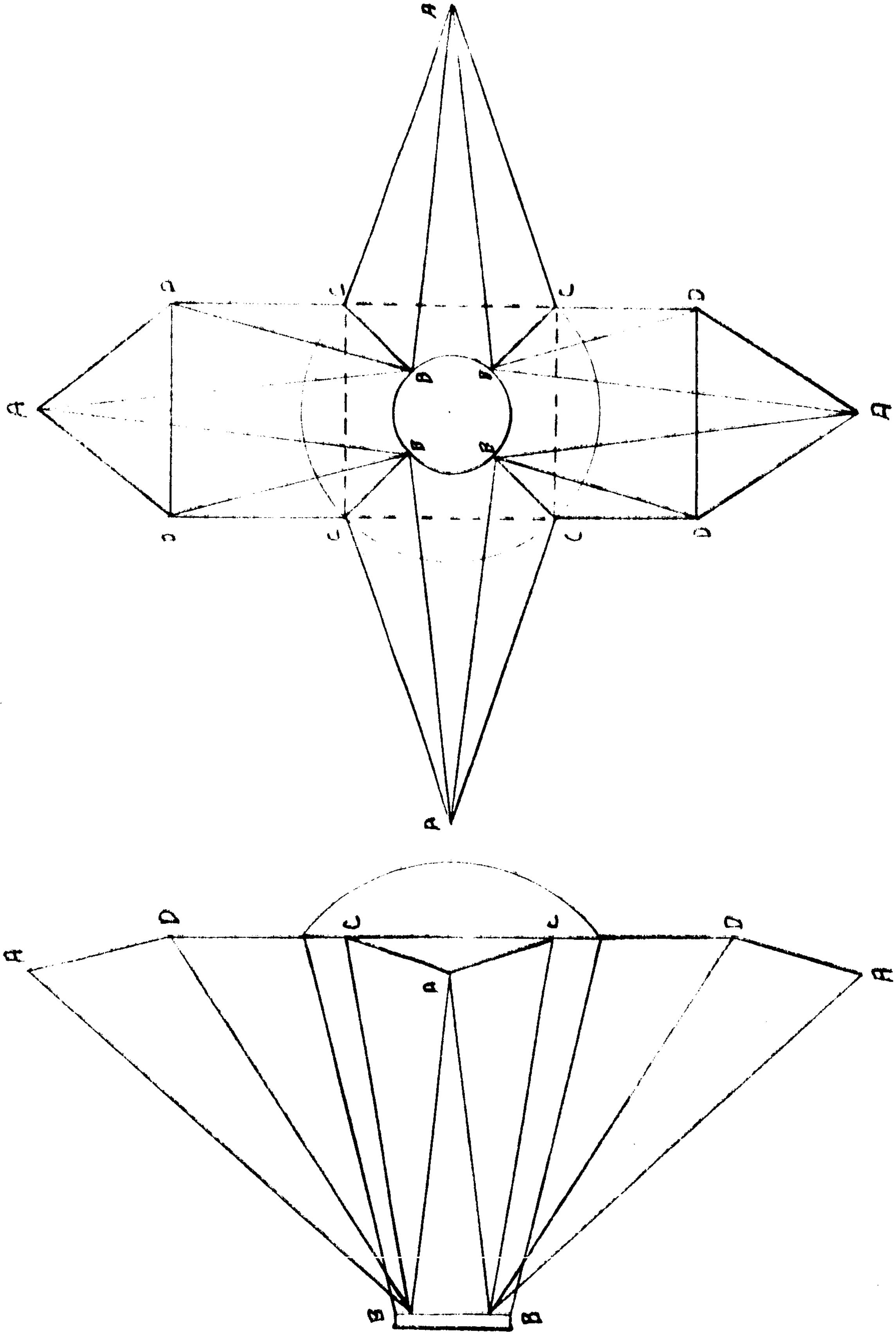


FIGURE 6 CONFIGURATION 1 BASIC STRUCTURE

ELEMENT	CRITICAL CONDITION	TYPE	AREA/THICKNESS	LOAD STRESS (ULTIMATE)	MARGIN OF SAFETY
AC	2	1	1.05 in^2	17400# C	.04
AB	1	1	.934 in^2	6210# C	.05
AD	2	1	.59 in^2	11000# C	.01
DC	2	1	.706 in^2	15950# C	.04
DD	2	1	.59 in^2	5500# C	.50
CC	2	1	.821 in^2	15950# C	.19
Docking Collar-to-Cone Ring Frame	1	3	.40 in^2	51200 psi F	.21
Cone-to-Spherical Cap Ring Frame	3	3	1.0 in^2	55000 psi C	.08
Spherical Cap	3	2	.04 in^2	10750 psi T	Large
Cone	3	2	.04 in^2	13900 psi T	Large
BC	1	3	.50 in^2	18050 psi C	Large
BD	1	3	.10 in^2	5750# F	.06
Camera Support Truss	3			35000 psi F	0

Code: C = Compression
T = Tension
F = Flexure

TABLE 1
STRESS SUMMARY
CONFIGURATION 1

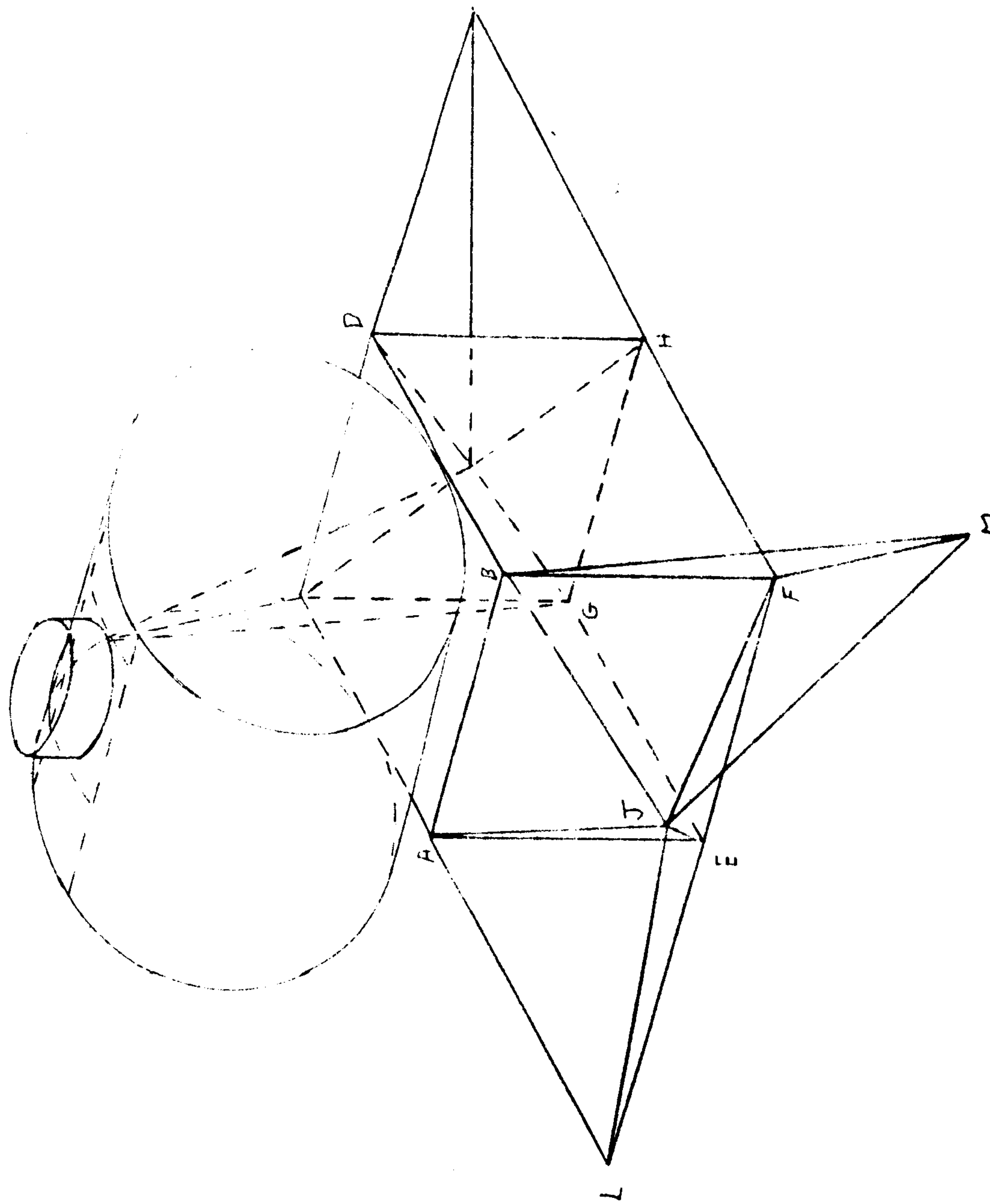


FIGURE 7 CONFIGURATION 2 BASIC STRUCTURE

ELEMENT	CRITICAL CONDITION	TYPE	AREA/THICKNESS	LOAD/STRESS (ULTIMATE)	MARGIN OF SAFETY
*BD	1	1	.4543 in^2	9210# C	.40
*BM	2	1	1.95 in^2	18030# C	.41
*JM	2	1	1.761 in^2	5320# C	Large
*JA	2	1	.867 in^2	3900# C	Large
*BF	1	1	1.0 in^2	3125#	.60
Panel ABEF	2	2	.035 in^2	1140 psi shear	0
Sperical Caps	3	2	.040	15500 psi T	Large
Cylinder	3	2	.040 in	13500 T	Large
**Cylinder Cap Ring	3	3	.947	46000 psi C	.34
Docking Collar Support Beams	Docking	3	.42	27800 psi F	.80
Camera Support Truss	3			36000 psi F	0

* Designed by Lateral Stiffness Requirement
** Designed by Stability Requirements

TABLE 2
STRESS SUMMARY
CONFIGURATION 2

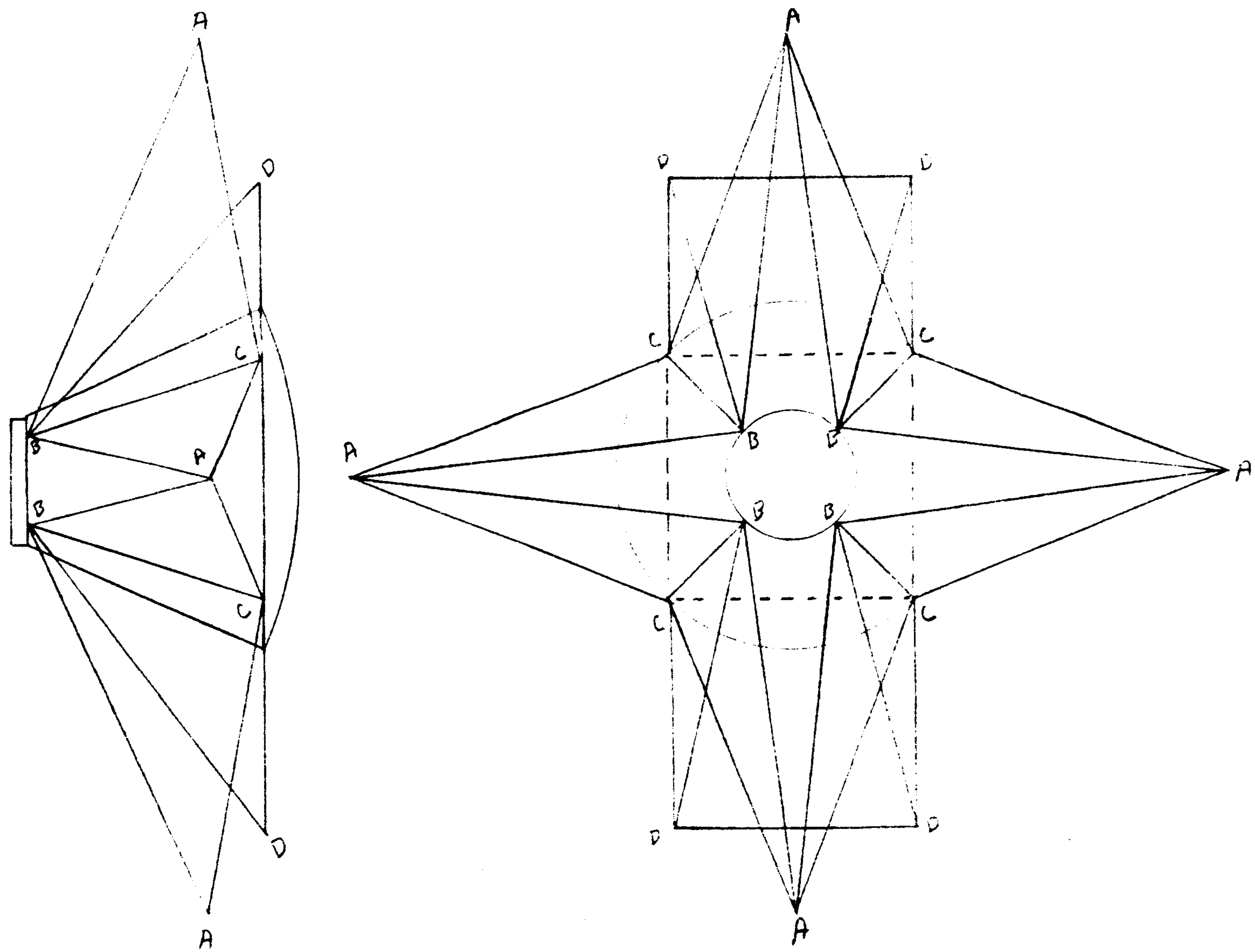


FIGURE 8 CONFIGURATION 3 BASIC STRUCTURE

ELEMENT	CRITICAL CONDITION	TYPE	AREA/THICKNESS	LOAD STRESS (ULTIMATE)	MARGIN OF SAFETY
AB	1	1	.821 in^2	7250# C	.31
AC	2	1	.821 in^2	8700# C	.54
BC	1	3	.50 in^2	18120 psi C	Large
BD	1	3	.10 in^2	5150# T	.08
CC	2	1	.59 in^2	8000# C	.39
Docking Collar-to-Cone Ring Frame	1	3	.45 in^2	61000 psi F	.02
Cone-to-Spherical Cap Ring Frame	3	3	1.0 in^2	55000 psi C	.08
Spherical Cap	3	2	.04 in	10750 psi T	Large
Cone	3	2	.04 in	13900 psi T	Large
Camera Support Truss	3			35000 psi F	0

TABLE 3
STRESS SUMMARY
CONFIGURATION 3

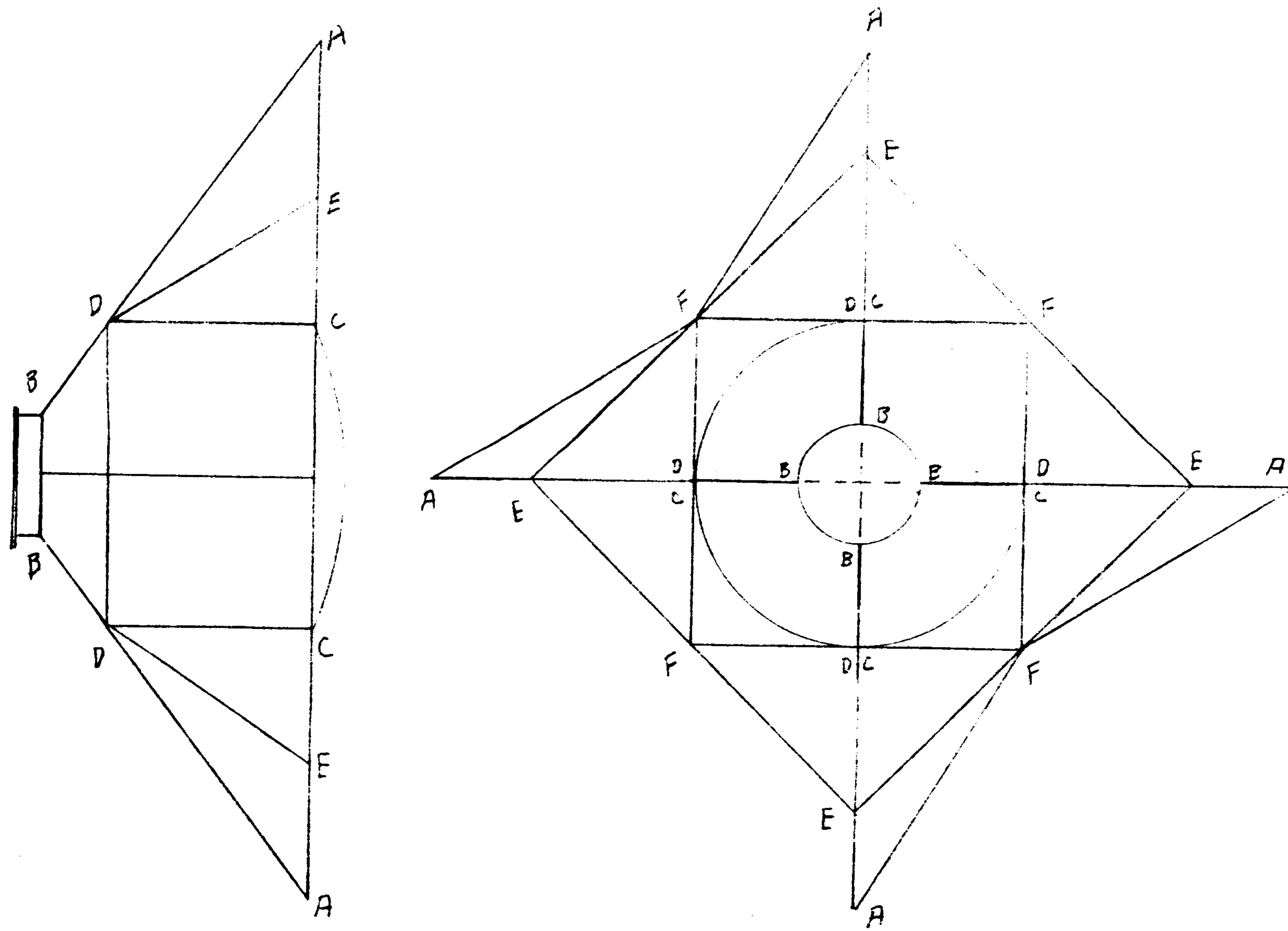


FIGURE 9 CONFIGURATION 4 BASIC STRUCTURE

ELEMENT	CRITICAL CONDITION	TYPE	AREA/THICKNESS	LOAD/STRESS (ULTIMATE)	MARGIN OF SAFETY
AA	Lateral Stiffness	1	.75	14800# C	Large
AB	1	1	1.0 in	15650# C	.06
AF	2	1	1.0 in	16800# C	.10
CF	2	1	0.5 in	8750# C	.05
EFE	1	3	0.40 in	52800 psi F	.175
DE	1	3	0.20 in	5930 psi T	Large
Cone-to-Docking Collar Ring Frame	1	3	0.60 in	47000 psi F	.31
Cylinder-to-Spherical Cap Ring Frame	3	3	0.80 in	49800 psi C	.24
Spherical Cap	3	2	.040 in	10750 psi T	Large
Cylinder	3	2	.040 in	12400 psi T	Large
Camera Support Truss	3			35000 psi F	0

TABLE 4
STRESS SUMMARY
CONFIGURATION 4

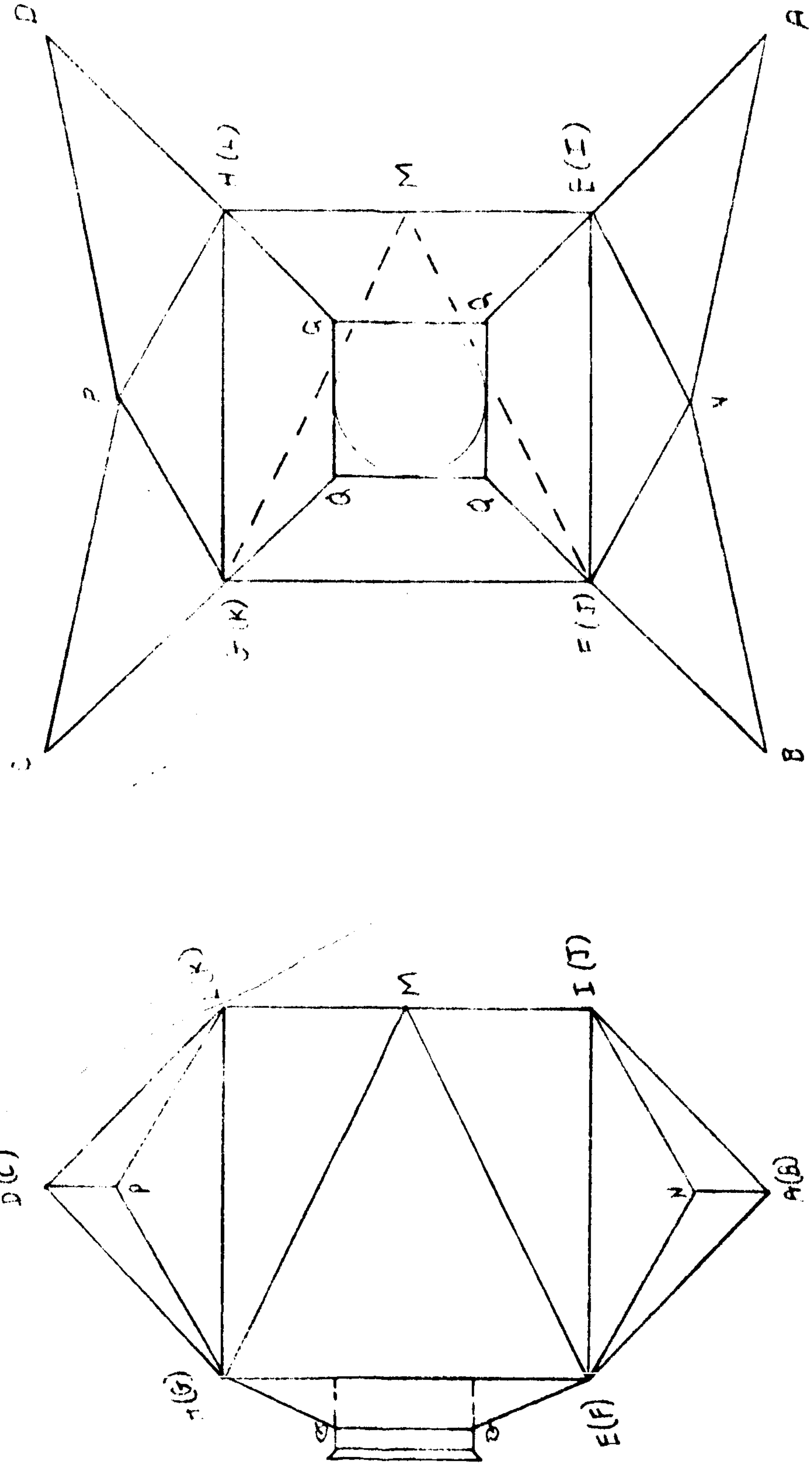


FIGURE 10 CONFIGURATION 5/6 BASIC STRUCTURE

ELEMENT	CRITICAL CONDITION	TYPE	AREA/THICKNESS	LOAD STRESS (ULTIMATE)	MARGIN OF SAFETY
AE	2	1	.706	12750# C	.08
AN	2	1	.934	16000# C	.13
AI	4	1	.706	3650# C	Large
NF	2	1	.59	10500# C	.04
FG	4	1	.675	4375# C	Large
EF	4	1	.675	4375# C	Large
EI	4	1	.675	4375# T	Large
EM	4	1	.675	9800# T	Large
EQ	Docking	3	1.0	60000 psi F	.03
Camera Support Truss	2 - Concept 5 1 - Concept 6	3	.3 (Concept 5) .5 (Concept 6)	20000 psi F	.50

TABLE 5 CONFIGURATION

STRESS SUMMARY
CONFIGURATION 5, 6

3.4 Weights Analysis Summary

A summary of the weight breakdown of each of six candidate mission 1A carrier configurations is presented in Table 6. The weight of each configuration is apportioned according to seven basic classifications:

a) Pressure Chamber - All structural elements forming an integral part of the pressure hull, e.g., ring frames, longerons, spherical cap with windows, conical or cylindrical shell, etc.

b) Carrier Support Truss - All space frame members comprising the primary load carrying structure plus the required end fittings. This structure also provides lateral stiffness for the SLA during boost.

c) Equipment Support - All structure directly utilized for the mounting and support of experiments and experiment subsystems.

d) Docking Port - Basic docking port plus a hatch in the tunnel which serves as a pressure hatch for the unpressurized carrier during transportation docking, and a contamination control cover for the pressurized version.

e) Drogue Assembly

f) Meteoroid Protection - Meteoroid protection consists of 100 ft^2 of paneling plus the pressure hull for the four pressurized configurations. Additional panel area is required for the unpressurized configurations.

g) Sensor Contamination Covers - The covers plus their operating mechanisms are included in this category.

	CONFIGURATION				
	1	2	3	4	5/6
a. PRESSURE CHAMBER	297	309	230	246	-
b. CARRIER SUPPORT TRUSS	293	437	269	210	313
c. AUXILIARY EQUIPMENT RACKS	181	150	135	155	168
d. DOCKING PORT	70	70	70	70	133
e. DROGUE ASSEMBLY	75	75	75	75	75
f. METEOROID PROTECTION	64	64	64	64	96
g. SENSOR CONTAMINATION COVERS	75	75	75	75	75
SUB TOTAL	1055	1180	918	895	860
CONTINGENCY (20%)	211	236	184	169	172
TOTAL	1266	1416	1102	1064	1032

TABLE 6 WEIGHT BREAKDOWN

	MAX RATING	PRESSURIZED				UNPRESSURIZED	
		1 AXIAL VIEW CONICAL	2 SIDE VIEW CYLINDRI-CAL	3 AXIAL VIEW SHORT CONICAL	4 AXIAL VIEW SHORT CYLINDRICAL	5 SIDE VIEW TRUSS	6 AXIAL VIEW TRUSS
STRUCTURAL WEIGHT (lb)	-	1266	1416	1102	1064	1032	1032
WEIGHT RATING	10	8	6	9	10	10	10
CREW ACCESSIBILITY	10	10	10	7	8	10	10
GROUND VIEWING FROM CM	10	9	1	9	9	1	10
CSM DOCKING	5	5	5	3	3	4	4
DESIGN FLEXIBILITY	5	4	4	3	3	5	5
ORBITAL DECAY	5	2	5	3	3	5	2
MAINTAINABILITY	5	3	3	3	3	5	5
PRODUCIBILITY	5	4	2	4	3	5	5
TOTALS	55	45	36	41	42	45	51

TABLE 7 CONFIGURATION EVALUATION

3.5 CONFIGURATION EVALUATION AND SELECTION

3.5.1 Evaluation Method - This comparative evaluation of the candidate carriers selects two configurations, one pressurized version applicable for either intermittent or continuous pressurization, and one unpressurized. These two, in turn, are evaluated in a broader sense, considering all systems aspects, in the pressurization study, PR 29-8.

The parameters evaluated in this carrier selection study include carrier structural weight, crew accessability in the carrier, ground viewing characteristics from the CM, CSM docking, design flexibility and growth capability, orbital drag and decay characteristics, prelaunch maintainability, and producibility. Carriers in each of the two groups (pressurized and unpressurized) are ranked on each of these parameters.

3.5.2 Configuration Evaluation - A summary of the ranking of the candidate configuration in each evaluation parameter, along with preliminary estimates of structural weights, is presented in Table 7. Those parameters of primary importance have been assigned a maximum weighted rating of ten points, while those of lesser importance have been assigned a maximum of five points. It is recognized that this type of comparison tends to be somewhat arbitrary, but with an attempt at impartial evaluation, credible conclusions may be drawn.

The following comments are presented in justification of the gradings shown on Table 7.

3.5.2.1 Weight - This rating assigns ten points to those configurations having the lightest weight. The ratings decrease correspondingly as the carrier weights increase.

3.5.2.2 Crew Accessibility in Carrier - This parameter considers the internal carrier maneuvering space and arrangement, and the astronaut's ability to gain access to those installations requiring service. It does not consider effects of pressure differentials across the astronaut's suit; this is covered in the pressurization study.

3.5.2.2 (Continued)

Crew Accessibility ratings are highest for those configurations permitting full astronaut entry and turn-around capability, as well as ability to work in the carrier in a natural body position. The short, partial entry configurations are down-graded since they require an over-the-head working position.

3.5.2.3 Ground Viewing Characteristics - This parameter considers the ground track viewing capability of the crew from the CM crew station. Ability to see forward along ground track as well as cross track is highly advantageous, especially for targets of opportunity. Near-nadir viewing and concurrent view of ground track approaching nadir is also of great value. Ground viewing capability from the CM is markedly superior in the axial viewing mode of operation with the CSM center line along nadir. Reference TM 29-10 for further discussion of spacecraft orientation.

3.5.2.4 CSM Docking - This parameter considers the degree of CSM "fly-in" required into the restricted SLA panel areas of the SIV B stage to perform carrier docking, release, and extraction. A docking interface located near the existing LM docking station is considered ideal; a docking station further aft is less desireable.

3.5.2.5 Design Flexibility and Growth: For Mission 1A, sufficient flexibility and growth capability must be provided to allow for revisions or modest additions to the complement of sensors and their supporting subsystems. Design flexibility is greatest for the unpressurized carriers. Of the pressurized versions, the larger configurations have more flexibility than the shortened versions.

3.5.2.6 Orbital Decay Characteristics - This is of secondary importance, only because both the "high-drag" and "low-drag" attitudes have sufficiently low orbital decay characteristics to not require station keeping for the 14-day mission. However, some advantage exists for having a minimum variation in orbital altitude for the mission duration. Ratings vary directly with drag characteristics.

3.5.2.7 Prelaunch Maintainability - This parameter considers the ease of sensor/subsystem installation, alignment and check-out prior to SLA integration and access capability during the prelaunch period in the SLA section for late sensor installation and component maintenance and replacement. Maintainability characteristics are graded highest for the unpressurized, open rack carrier concepts.

3.5.2.8 Producibility - This parameter evaluates the simplicity of the carrier design concept and use of state-of-the-art materials and fabrication techniques. These are particularly important in view of the short Mission 1A production time span. Producibility ratings are highest for the unpressurized carriers. The pressurized carriers are down-graded according to complexity of design details.

3.5.3 Unpressurized Carrier Selection - Configuration 6, the axial viewing carrier, is selected as the unpressurized carrier candidate. The primary reason for the choice of this configuration over the side viewing Configuration 5, was its greatly superior rating in the crew ground viewing category. Although the orbital decay characteristics are less desireable than those of Configuration 5, this feature is far outweighed by the more favorable ground viewing characteristics. The two configurations were rated at the same level for all other parameters.

3.5.4 Pressurized Carrier Selection - Configuration 1, the axial viewing conical carrier, is selected as the pressurized carrier candidate, based on the ratings tabulated in Table 7. This choice is based on favorable comparative ratings over Configurations 3 and 4 for several parameters. These include crew accessibility, ground viewing, CSM docking, design flexibility, and producibility. Slightly lower ratings for the weight and orbital decay parameters do not balance the high scores achieved in the above categories. Configuration 2, the side viewing cylinder, scored particularly low in the weight and ground viewing categories.

PR 29-8

TRADE STUDY REPORT

CARRIER PRESSURIZATION STUDY

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

31 August 1967

Prepared by: [signature]

Approved by: [signature]

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

1.1 Purpose - This report summarizes the results of a trade study on pressurization mode of operation for the Mission 1A Early Applications Carrier.

1.2 Objectives - Two candidate carriers, representing one pressurized and one unpressurized configuration, are studied. The pressurized configuration is applicable to either continuous or intermittent pressurization. Parameters considered in this trade study include crew and experiment aspects of pressurization, as well as oxygen utilization and system weight comparisons.

2.0 SUMMARY

A pressurized and an unpressurized carrier configuration are compared in terms of experiment considerations and crew aspects at pressurization, oxygen utilization, and configuration weight. The pressurized carrier is selected for Mission 1A, with continuous pressurization mode. Intermittent mode option is available if warranted by results of experiment O_2 compatibility study currently in progress.

3.0 DISCUSSION

3.1 Experiment Considerations - The twenty three experiments, plus the support camera, were classified according to the influence of pressurization mode on their operational requirements. Four groups became apparent in this evaluation, as listed below:

Group 1 - This group includes all experiments that require no crew access during the course of the 1A Mission. This group consequently has no impact on the selection of the pressurization mode, since they will be located in an unpressurized portion of the carrier in either case. Experiments included in this group are S039, S040, S043, S044A, S048, S017, D017, T004, E06-9A, E06-9B, and E06-11.

3.1 Experiment Considerations - (Continued)

Group 2 - This group includes those experiments performed in the CM. Five experiments fall in this category: S015, T003, D008, D009, and T002. Of these, S015, T003, and D008 are stowed, used, and returned in the CM, so are of no further concern in this study. The remaining two will likely be stowed in the carrier during boost and retrieved after docking to minimize abort condition CM chute weight. For ease of retrieval in the unpressurized carrier configuration, these two experiments would be stowed with the drogue in the short, pressurized docking tunnel. This pressurized docking tunnel is required to enable transposition docking and SIVB separation without depressurizing the CM. It is concluded that the experiments in this group are not affected by the selection of pressurization mode.

Group 3 - This group includes those experiments to be used with the NAA scientific airlock. To minimize EVA, the airlock is located in the CM for the unpressurized carrier. However, the CM location for this airlock requires significant redesign and requalification in the CM hatch and airlock ablative cover, because of a single point failure possibility in the ablative cover. This failure mode does not apply to a carrier-mounted scientific airlock, so the NAA designed airlock is used without modifications in the pressurized carrier. Experiments in this category include S016, S018, S019, and S020.

Group 4 - This last group includes those components located in the carrier that require crew access for sensor adjustment, film changes, or film retrieval. Experiments in this group include E06-1, E06-4, and E06-7, as well as the support camera.

Of these four groups, only the last two influence the selection of pressurization mode.

Group 3 experiments prefer a pressurized carrier airlock location, so that the NAA scientific airlock ablator and

3.1 Experiment Considerations - (Continued)

CM hatch redesign/requalification is not required. An additional advantage in carrier location is the capability of using two airlocks, providing experiment operation versatility. These experiments have been designed for CM operation, so no O_2 compatibility (flammability) problems are expected.

The Group 4 experiments need individual consideration in terms of vacuum or oxygen environments, and flammability requirements. In general, however, the O_2 compatibility in terms of flammability requirements has not yet been assessed; a continuing study must evaluate each component in accordance with current flammability criteria.

The E06-1 metric camera (Fairchild) is an aircraft unit, with added stellar camera, and may require modification for either vacuum or O_2 operation. The E06-4 multi-spectral cameras (Hasselblad) are currently neither designed nor qualified for continuous, long-term vacuum operation; they are compatible with O_2 atmosphere operation. For the 1A Mission, two film changes are required for the current Hasselblad cameras. If an unpressurized carrier is used, a redesign to increase film capacity, and avoid film reload EVA's, is recommended. For both E06-1 and E06-4, the use of windows for lens viewing through the carrier pressure wall is acceptable.

The E06-7 IR Imager experiment will be a modified aircraft unit. The film removal door on the experiment is too small to permit retrieval by a gloved astronaut; redesign is required for either vacuum or pressurized mode. No window material is acceptable for sensor viewing. The pressurized carrier concept locates this experiment outside the pressurized section, with a film transport system through the wall into a film return cannister. At experiment completion, a film cutter will also seal the pressure wall penetration, permitting film canister removal without pressure loss.

The Hycon support camera is a sealed unit, and as such is likely compatible with either vacuum or O_2 atmosphere operation.

3.2 Crew Considerations - The primary crew consideration in the pressurization mode selection is that of unpressurized EVA vs pressurized IVA. It is readily apparent that the pressurized IVA is the preferred mode for the crew. In either case, the astronaut is suited; however, the soft suit configuration (no Δp across the suit) provides greatly enhanced mobility and manual dexterity. Also, pressurization redundance provided by a pressurized carrier enhances crew safety.

3.3 Oxygen Utilization - For the unpressurized carrier configuration, two EVA's are assumed, requiring 6 lb. of O_2 for each CM repressurization. This requires a total of 12 lb. of oxygen.

Oxygen requirements for the continuously pressurized carrier are based on the following assumptions:

a) Continuous pressurization for 12.5 days,
b) Pressure level is 5.0 psia (nominal),
c) Leakage of docking adapter interface is 2.4 lb/day,
d) Leakage of carrier (through windows and seals) is 1.0 lb/day,
e) Leakage of NAA scientific airlock is not included.

These conditions result in an oxygen requirement of 50 lb.

For intermittent pressurization, the following baseline was established:

a) A total of ten pressurizations, with venting between, is required for the 1A Mission. Refer to Table 1 for details of these pressurizations.

b) Pressure level is 5.0 psia (nominal).

c) A total of 40 hours pressurization is provided, with leakage rates as used for the continuous pressurization case.

This data provides a requirement for 58 lb of oxygen for the intermittent pressurization/vent configuration.

It is assumed that carrier pressurization will be accomplished by oxygen supplied from the CM. In the event the CM cannot provide the required gas supply, an independent carrier pressurization system will be required. This system, with weights, is shown in Figure 1 and Table 2.

TABLE 1 NUMBER OF ENTRIES FOR PRESSURIZED CARRIER

1. DOCK AND PLUG IN SLA ELECTRIC CONNECTOR - 1ST DAY.

2. STOW PROBE AND DROGUE, TRANSFER D&C TO CM, INSTALL S016 IN DOME AIRLOCK AND EXTEND, DISCONNECT SLA PLUG, CONNECT D&C ELECTRIC PLUGS, TURN D&C CIRCUIT BREAKER ON - 1ST DAY.

3.* INSTALL S020 IN WALL AIRLOCK AND OPERATE, REMOVE S020 AND INSTALL S019 - 2ND DAY.

4. CHANGE FILM ON 6 E06-4 CAMERAS - 4TH DAY.

5.* BORESIGHT S019 WITH G&N SEXTANT AND OPERATE, REMOVE S019, AND INSTALL S018 - 6TH DAY.

6. CHANGE FILM ON 6 E06-4 CAMERAS, REMOVE S018, TRANSFER T002 AND D009 TO CM - 8TH DAY.

7.* TRANSFER T002 AND D009 TO CARRIER, TRANSFER EMULSIONS, FILM, AND S019 AND S020 TO CM, STOW D&C PANELS (INCL. S017 AND FROG), PROBE AND DROGUE, AND CM EXPENDABLES (i.e., LiOH CANISTERS) IN CARRIER, OPEN D&C CIRCUIT BREAKER AND DISCONNECT PLUGS AT TUNNEL - 9TH DAY.

* WILL REQUIRE 2 ENTRIES - 1 MORNING, 1 AFTERNOON.

TOTAL ENTRIES = 10

FIGURE 1

OXYGEN SUPPLY SYSTEM FOR PRESSURIZATION

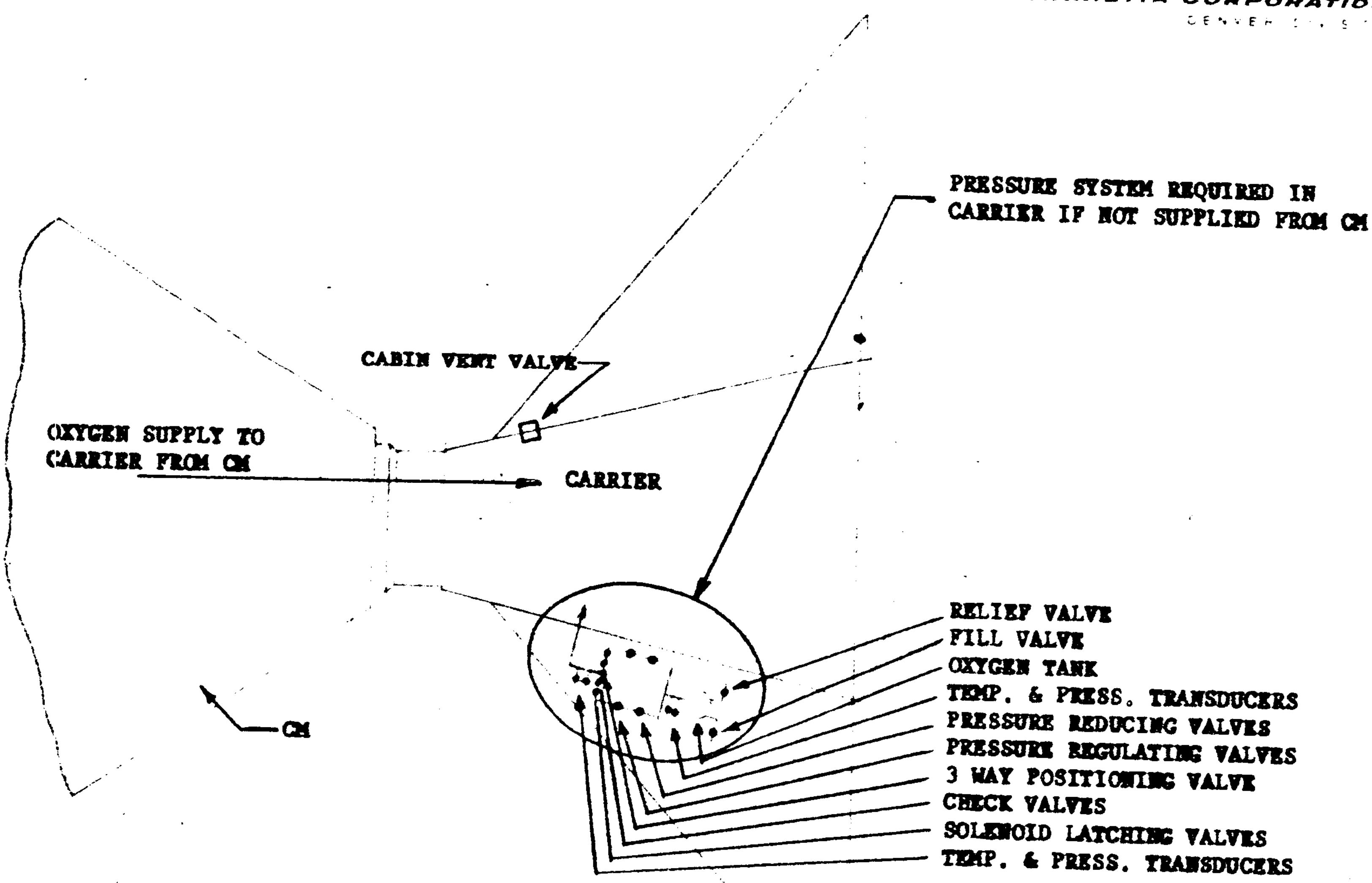


TABLE 2 INDEPENDENT OXYGEN PRESSURIZATION REQUIREMENTS

OXYGEN WEIGHT	
CONTINUOUS PRESSURIZATION FOR 12.5 DAYS	50.0 LBS
INTERMITTENT PRESSURIZATION (10 PRESSURIZATIONS PLUS 40 HRS FOR EXPERIMENTS & DATA RETRIEVAL)	58.0 LBS
HARDWARE WEIGHT	
RELIEF VALVE	
FILL VALVE	
OXYGEN TANK	
PRESSURE TRANSDUCER (TANK)	
TEMPERATURE TRANSDUCER (TANK)	
PRESSURE REDUCING VALVES	
PRESSURE REGULATING VALVES	
SOLENOID LATCHING VALVES	
CHECK VALVES	
3 WAY HAND POSITIONING VALVE	
PRESSURE TRANSDUCER (CARRIER)	
TEMPERATURE TRANSDUCER (CARRIER)	
VENT RELIEF VALVE (CARRIER CABIN VENT VALVE)	
TOTAL WEIGHT FOR HARDWARE	61.0 LBS
STRUCTURAL MOUNTS LINES AND FITTINGS	25.0 LBS
TOTAL WEIGHT	
CONTINUOUS PRESSURIZATION SYSTEM	136.0 LBS
INTERMITTENT PRESSURIZATION SYSTEM	144.0 LBS

3.4 Weight Comparison - Two carrier configurations, one for pressurized mode, and one for unpressurized modes were selected in PR 29-7, "Carrier Configuration Trade Study". These two concepts are presented in Figures 2 and 3 respectively; for more detail refer to PR 29-7.

The pressurized carrier predicted structural weight is approximately 200 lb heavier than the unpressurized version. Other subystem weights are unaffected by the pressurization mode, assuming that all oxygen is provided by the CM oxygen system. If a separate O_2 system must be provided, an additional 136 lb and 144 lb of pressurization system must be added for the continuous and intermittent pressurization modes, respectively, as discussed in Section 3.3 above.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions - Table 3 summarizes those pressurization considerations discussed in Section 3. From these considerations, the following conclusions may be drawn.

Scientific airlock and crew aspect advantages of the pressurized concept far outweigh the disadvantage of higher structural weight. Oxygen usage is approximately the same for either intermittent or continuous mode of pressurization. Selection of intermittent vs continuous pressurization mode should be contingent upon O_2 compatibility of experiments during operative periods; venting the carrier between crew entries will permit minimum redesign/requalification for those components which may prove to be incompatible with O_2 during operational periods.

4.2 Recommendations - The pressurized carrier, using a continuous pressurization mode, is selected. Intermittent mode option is available if warranted by experiment oxygen compatibility study results.

FIGURE 2 PRESSURIZED CARRIER CONFIGURATION

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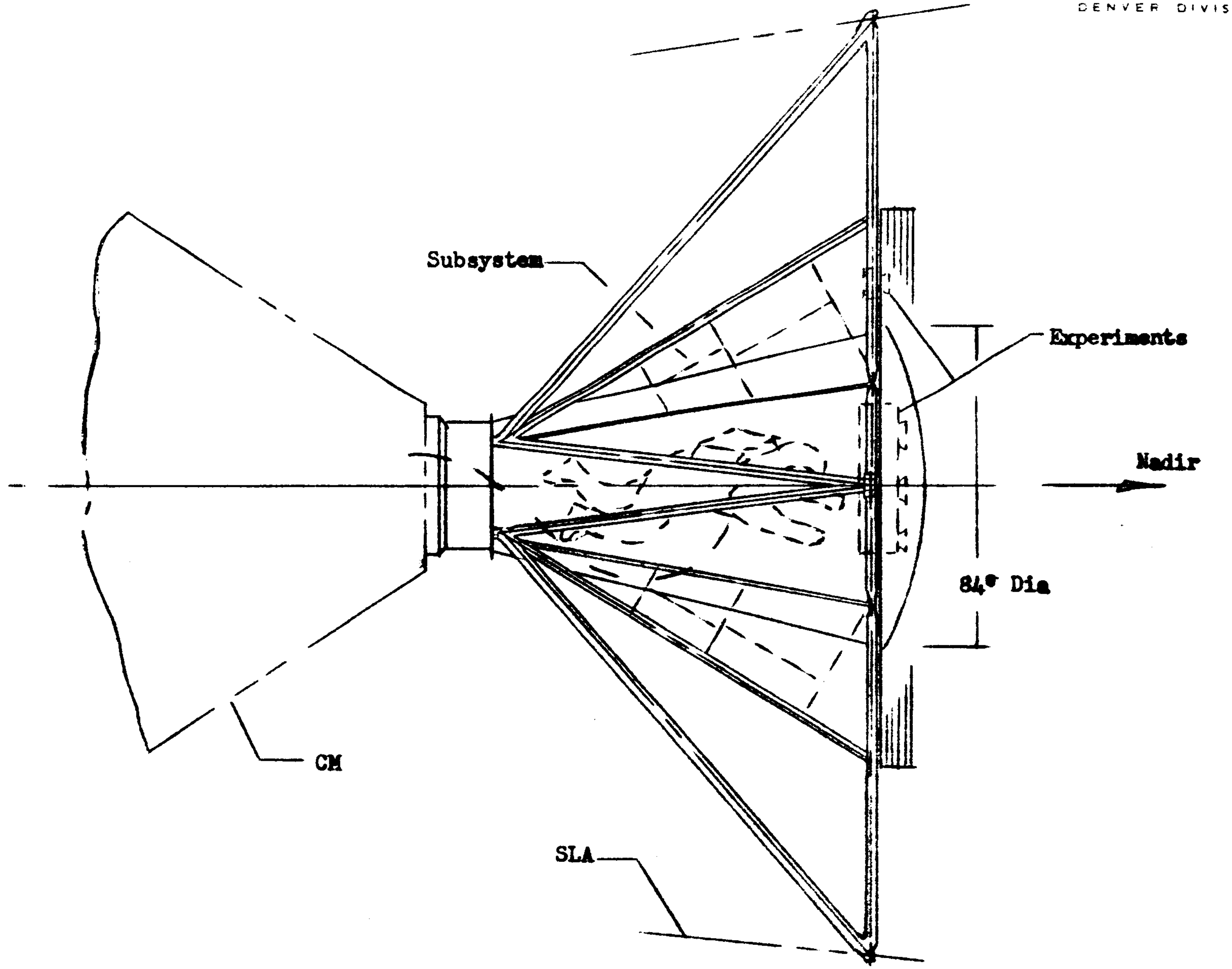

DEN 066232-02 (3-67)

FIGURE 3 UNPRESSURIZED CARRIER CONFIGURATION

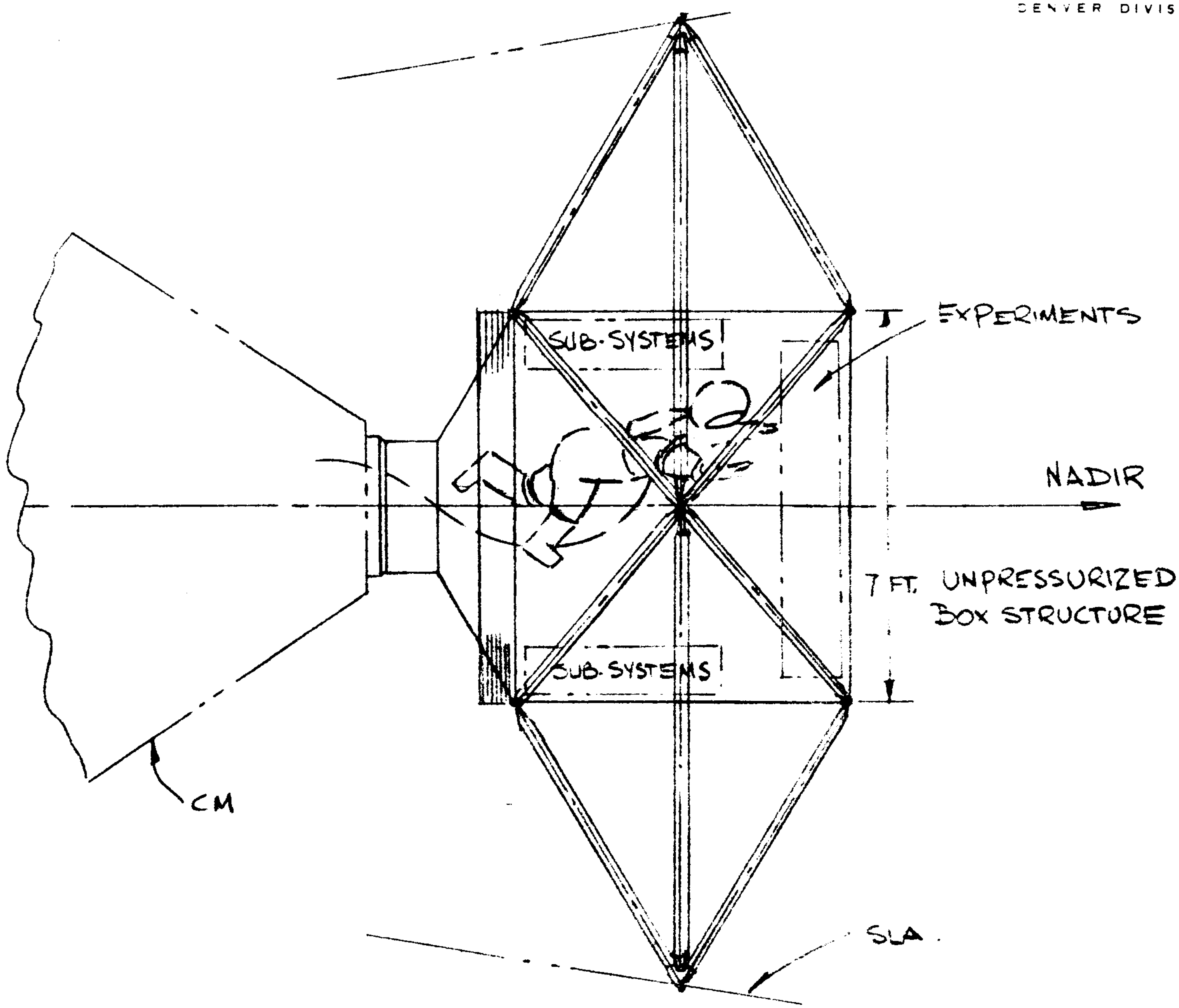

TABLE 3 CARRIER PRESSURIZATION CONSIDERATIONS - SUMMARY

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CONSIDERATIONS	UNPRESSURIZED	PRESSURIZED
SCIENTIFIC AIRLOCK	LOCATE IN CM; REQUIRES ABLATIVE COVER & HATCH REDESIGN	LOCATE IN CARRIER; AIRLOCK CURRENTLY QUALIFIED.
E06-1 METRIC CAMERA	MODIFY FOR SPACE OPERATION	MODIFY FOR SPACE OPERATION*
E06-4 MULTISPECTRAL CAMERA	MODIFY FOR VACUUM OPERATION; INCREASE FILM CAPACITY TO MINIMIZE EVA.	NO CHANGE REQUIRED,* RE-LOAD FILM DURING IVA.
E06-7 IR IMAGER	EVA FOR FILM RETRIEVAL; REDESIGN FILM CASSETTE FOR ACCESSIBILITY.	NO SENSOR WINDOW ACCEPTABLE; LOCATE OUTSIDE PRESSURIZED SECTION, PROVIDE FILM TRANSPORT THROUGH PRESSURE WALL FOR IVA RETRIEVAL.
SUPPORT CAMERA	EVA FOR FILM RETRIEVAL	IVA FOR FILM RETRIEVAL
O_2 REQUIREMENTS	12 LB (2 EVA'S)	50 LB. (CONTINUOUS)
CARRIER Δ WT.	-	APPROXIMATELY +200 LBS.
CREW SAFETY	EVA REQUIRED	PRESSURIZATION REDUNDANCY PROVIDED BY IVA
CREW MOBILITY	MOBILITY IMPAIRED BY HARD SUIT	GOOD MOBILITY, SOFT SUIT
FLAMMABILITY	EXPECT NO IMPACT	O_2 COMPATIBILITY FOR INTERNAL EXPERIMENTS*

*STUDY BEING CONDUCTED ON NON-METALS O_2 COMPATIBILITY

PR-29-9

TRADE STUDY REPORT

NON-METALLIC MATERIAL SELECTION CRITERIA AND GUIDELINES

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

24 August 1967

Prepared by R. Ritz

Approved by J. T. Keeley

MARTIN MARIETTA CORPORATION

DENVER DIVISION

1.0 INTRODUCTION

The flight 1A Mission Experiment Carrier will be maintained in a pressurized mode at 5 psia O_2 from the initial post docking pressurization until depressurization prior to CM-Carrier separation at mission completion. Although the great majority of mission time will be flown with the CM pressure/thermal hatch in a closed position, there will be occasions when it will be necessary for a crewman to perform carrier ingress for purposes of data collection or experiment operation. During these periods the carrier becomes part of total crew habitation with the attenuate concern for fire potential, toxic offgassing and odor.

2.0 SUMMARY

Non-metallic materials for the 1A mission will be selected in general accordance with ASPO-RQTD-D67-5A "Non-Metallic Materials Selection Guidelines" and MSC-A-D-66-3 Revision A "Procedures and Requirements for the Evaluations of Spacecraft Non-Metallic Materials".

To review candidate materials, a Non-Metallic Material Selection Review Board will be established at Martin. Board membership will include representatives from Crew/Systems Safety, Reliability and Test under the chairmanship of Materials Engineering. Any requests for deviation from the selection criteria will be processed through the Selection Review Board and submitted to a designated NASA-MSC board for approval.

3.0 DISCUSSION

3.1 Design Goal & Approach - It will be a design goal to select materials that have demonstrated test compliance with MSC-AD-66-3. Apollo and Gemini program components and/or assemblies will be used whenever possible.

Close communication will be maintained with the Non-Metallic Materials Information Center at MSC. The non-metallic flammability test data provided in the Characteristics of Non-Metallic Materials (COMAT) Listing prepared by this information center will be used as one of the basis of material selection. Additionally, data relative to Apollo

3.1 (continued)

Command Module components that have been requalified or on which waivers have been obtained, will be reviewed.

Whether or not full scale, full volume Crew Bay Configuration Flammability Verification Tests (Test II in MSC-A-D-66-3) will be recommended remains open. A preliminary review of the CFE non-metallics anticipated for the carrier would indicate that this test may not be required. Until GFP Experiments, including both those in inventory and those to be procured, are evaluated, however, such determination cannot be made.

3.2 Non-Metallic Material Selection Review Board - A Non-Metallic Material Selection Review Board will be established at Martin to review candidate materials. This board will be chaired by Materials Engineering and will have a representative from Crew Safety, Reliability and Test.

Should any request for deviation on any non-metallic be considered advisable, such requests will be processed through this board and submitted to the NASA-MSC board for approval.

3.3 Government Furnished Property - GFP items, including experiments, are considered to be provided by the Government as qualified system elements verified to conform to the non-metallic material selection criteria. The Contractor is responsible to analyze the experiments and their installation placement and inter-relationships to assure that system hazards and mission degradation cannot result from experiment inter-reaction.

PR-29-10

SPACECRAFT ORIENTATION STUDY

AAP/PIP EARLY APPLICATIONS

MISSION 1A

CONTRACT NAS 8-21004

13 September 1967

J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

This study summarizes the parameters considered in selection of the flight orientation for the Mission 1A spacecraft to accomplish the low earth orbit experiments in meteorology, earth resources, solar and stellar investigations, and corollary scientific experiments.

2.0 SUMMARY

Evaluation indicates the preferred spacecraft orientation for the body mounted experiments required for earth resources sensing is a CSM nose down attitude with the +X axis on the local earth vertical and the crewmen in the CM couches, heads forward along the flight path. The experiments are rigidly mounted in the end of the pressurized conical carrier which is also boresighted to the local vertical.

3.0 DISCUSSION

3.1 Orientation Requirements

The primary mission orientation requirements for the orbital experiments identified for Mission 1A fall into the following categories:

a) Earth orientation about the nadir (local vertical) within 1.4 degrees to 1.5 degrees in all axes is required to permit passive remote sensing of the earth surface by body mounted cameras, IR radiometers, altimeters and other devices operating in the optical and electromagnetic spectra. Meteorological observation experiments impose similar requirements.

b) An inertially oriented spacecraft is required for conduct of solar and stellar/galactic observations. Optical and electromagnetic spectra from essentially point sources are of interest, thereby necessitating target acquisition by direct viewing and through display/control panel sensor readouts, and precise pointing and stabilization during experiment operations.

c) Free drift mode is required for low gravity evaluation of biological specimens, and RCS propellant conservation.

d) Miscellaneous experiments require pointing or orientation to selected targets for short periods to permit experiments, including handheld cameras, to be completed.

The detailed pointing and orientation requirements for all experiments, and resulting impact on CSM/carrier operations are described in PR 29-43, Pointing and Stability Studies.

3.2 Crew Visibility

Crewmen must be able to view the earth targets ahead on the ground track as well as on nadir, to prepare for and operate the experiment/subsystems and to make any required target acquisition attitude corrections. Trade Study PR-29-12, Window Visibility Study, describes the viewing areas and limitations for all CM windows and the G & N scopes. Other considerations, as described in PR 29-11, Crew Worksite Considerations, indicated that the carrier would not be utilized as a primary viewing station. The preferred crew visibility location was then determined as a "heads forward" position permitting both the command pilot and the pilot in the left and right couches respectively to view either "forward" on track or "down" on the local vertical by moving their individual head positions relative to the couches.

The main hatch window viewing area has not been considered since use of the center couch for viewing would conflict with the selected experiment/D & C Panel mounting area. That window may also be pre-empted by the scientific airlock, should NASA require a CM installation in addition to the carrier installed airlocks.

An auxiliary pointing and tracking aid such as the prototype Kollsmann unit would facilitate forward viewing by enlarging the field of view, and reducing required head movements to cover window look angle requirement.

3.3 Carrier Weight

A decision to utilize a rigid pressurizable carrier to eliminate mission dependent EVA was reached early in the

3.3 (continued)

study and is documented in PR 29-8, Pressurization Study. Additional analyses of various carrier configurations for both nose down and streamlined configurations are detailed in PR 29-7 carrier configuration. The results of both studies indicated that the nose down vehicle configuration would provide the lightest weight rigid structure, with the least interior volume, and consequent oxygen consumption for internal pressurization and leakage makeup. Also, equipment mounted within the pressure vessel would require lower mounting weight since direct axial mounting instead of cantilever approaches could be used. The nose down configuration then was 150 lbs. lighter and provided a preferred design.

3.4 Orbital Decay

Preliminary MMC estimates of orbital decay for the candidate configurations were updated and refined by an MSC-MPAD computer run. Total decay from 140 nm over 14 days was determined to be 8.5 nm for the nose-down configuration and 2.5 nm for the streamlined configuration. Both configurations were judged capable of meeting mission objectives.

3.5 Sensor Contamination

Lens contamination and adverse heating problems associated with RCS plume impingement were also reviewed. Selective RCS forward nozzle inhibiting was considered undesirable as a solution because of resulting difficulties in RCS propellant management. Potential lead time to program the CMC for nozzle inhibit was also deemed a disadvantage. The nose down conical configuration provided the only design which inherently would deflect RCS plume away from the sensors.

The side airlock used for S019 and S020 may, however, require selective inhibiting or a localized deflector during the two days currently planned for use of that airlock.

CSM waste dump control may be required if it is determined that ice particles will be ejected into the path of sensors. A Block I control valve system in place of the demand dump would correct this problem.

3.6 RCS Propellant Usage

RCS propellant allowances dictate a minimum maneuvering orbital mission. During most of the earth oriented flight, the spacecraft will be maintained on-track with local vertical sensing in the coarse attitude mode. Fine mode attitude control will be utilized only during target (USA) overpasses. The results of PR 29-43, Pointing and Stability Studies, define minimum RCS usage for the streamlined configuration, considering only local vertical stabilization and cross track maneuvers. That study also indicates, using available NAA Mission Modular Data Book information, that adequate orientation, stabilization and control can be provided for all experiments in the baseline mission timeline with the nose-down configuration. It should be noted that the selected configuration incorporates a side airlock oriented 30° off of the + Z axis for the S019 and S020 stellar and solar experiments. Streamlined considerations apply to those two experiments.

3.7 Disturbing Torques

Aerodynamic torques on the symmetrical, streamlined configuration are low, whereas for the nose-down configuration that torque tends to pitch the spacecraft toward the - Z axis (or forward along the ground track). This is within the capabilities afforded by the RCS budget. Gravity gradient torques are minimal for both configurations.

3.8 Configuration Summary

3.8.1 Selection Criteria

Orientation selection and configurations were based upon the following:

(1) Maximizing crew viewing from the CSM based upon PR 29-43, Window Visibility Consideration,

(2) Minimizing carrier pressure vessel and overall structural weight based on the pressurization PR 29-7 and the specific carrier configurations evaluated in PR29-8,

(3) Determining that no other known constraints impacted the decision based exclusively on visibility and weight.

The nose-down configuration was selected and the summary rationale is given below.

3.8.2 Nose Down Configuration

The "nose-down" configuration, with a heads forward crew position (-Z) axis, provides a forward, on track visibility of up to 200 nm continuously, interrupted only by carrier truss protuberances. The auxiliary pointing device is a desirable option to increase the 36 sec. advance time available to the crew before overflying nadir targets. A minimum weight of the rigid carrier pressure vessel is achieved since the cone structure is also the adapter to the CM docking collar. An orbital decay of 8.5 nm for the 14 day time period is well within the altitude tolerances of the sensors and does not require orbit maintenance by SPS firings.

Experiment contamination is minimized during data collecting operations which require active control by the SM-RCS thrusters. The flared carrier cone and end mounted experiments provide a natural RCS deflector to minimize contamination and exhaust particle clouds either over the sensor ports or in close proximity to the spacecraft between sensors and the target. In addition the CSM vents and dumps are oriented in different directions and should not effect the primary nadir oriented experimentation. The side airlock mounted experiments S017, 18, 19 and 20, however, are in the path of one RCS forward pointing nozzle and will require selective nozzle inhibit or perhaps a truss mounted deflection plate.

RCS propellant utilization for the on-track earth sensing experiments will be low assuming modification of the G & N computer program to provide local vertical and optimized RCS operation in fine mode.

3.8.2 (continued)

Aerodynamic torques tending to move the X axis centerline forward along the ground track are minimal but do require RCS corrections to maintain the X axis on nadir.

3.8.3 Streamlined Configuration

The "streamlined" configuration shown in Fig. 1 provides a very good forward view (+ X) on track, but no visibility at all on the nadir (+Z) with the crew in the heads down position. The auxiliary pointing and tracking scope is essential in this configuration. Heads up crew position requires use of the sextant scope as the sole means of viewing the target area. This limits a single crewman to viewing either forward or on nadir during target passes since no other windows are located on the +Z side of the CM.

Carrier pressure vessel weight is higher than the nose-down configuration due to a separate transition cone from the primary experiment pressure vessel to the docking collar. The Δ weight is approximately 150 lbs.

Sensor contamination from the RCS forward nozzles will require inhibiting up to 3 nozzles during data collection. In addition, the waste water dump and SM vents may require exhaust reorientation to minimize vapor clouds or ice particles in the sensor field of view.

RCS propellant usage in the G & N automatic mode is low due to the low vehicle inertia in roll. This flight mode has been previously evaluated during the LM & SS program to meet rigid requirements.

Disturbing torques are minimal since aerodynamic drag acts symmetrically on the CSM/carrier combination and gravity gradient torques are essentially zero although the configuration is not stable, as the restoring torques of gravity will tend to pull it to a nose-down or nose-up position.

3.8.4 Oblique Configuration

Although previous discussions in this report have been limited to two configurations, streamlined and nose-down, an oblique intermediate orientation, see Figure 1, was originally considered as a compromise alternative. Due to the fact that it included all of the disadvantages of the other two without improving the advantages of either, it was deleted in the detailed studies. An overall summary of aspects of the oblique orientation configuration is included in this report for completion purposes.

The "oblique" configuration identifies a spacecraft with experiments oriented in the 70° region from 10° off +X to 10° off + Z axis in the CSM. The heads down position has forward view limited by the carrier envelope, but presents a direct nadir view without vision aids. A "carrier forward" orientation is shown in Fig. 1 with heads-down attitude. The flight path could be reversed to have a carrier aft configuration and improve the forward visibility; however, the auxiliary tracking scope would still be required to provide adequate forward visibility on the flight path. Carrier weight becomes a compromise between the streamlined and nose-down configurations but was not studied in detail.

RCS impingement varies with sensor orientation, i.e., the closer to the spacecraft X axis the lower the contamination. RCS propellant usage and attitude maneuvers were considered the most negative factors since the sensors would not be aligned on any basic spacecraft axis and would require combination firings of X, Y and Z thrusters for all maneuvers (the pitch, yaw and roll axis of the sensors are displaced from those of the CSM thrusters, thereby making manual control most difficult and increasing RCS propellant usage.)

Aerodynamic torques are between the nose-down and streamlined; however, gravity gradient is greatest for the oblique orientation.

1A SPACECRAFT ORIENTATION

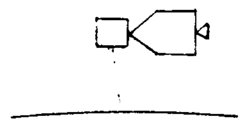
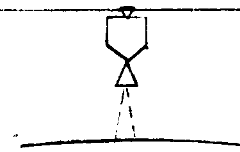
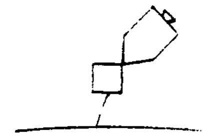
CONSIDERATIONS / EARTH ORIENTATION	 STREAMLINED	 NOSE DOWN	 OBLIQUE
• CREW VISIBILITY			
ORIENTATION	HEADS DOWN	HEADS FORWARD	HEADS DOWN
FORWARD VIEW	VERY GOOD	VERY GOOD	LIMITED
NADIR VIEW	PRISM REQ'D	VERY GOOD	VERY GOOD
• CARRIER WEIGHT			
PRESSURE VESSEL	HIGH	LOW	MEDIUM
• NOMINAL ORBITAL DECAY (14 DAYS)	2.5 NM	8.5 NM	5.0 NM
• SENSOR CONTAMINATION (RCS)	INHIBIT FORWARD POINTING NOZZLES	MINIMAL WITHOUT NOZZLE INHIBIT	POSSIBLE WITH FORWARD NOZZLES
• RCS PROPELLANT USAGE ON TRACK OPERATIONS			
G & N AUTOMATIC MODE	LOW	POTENTIALLY LOW	POTENTIALLY LOW
MANUAL/SCS	MEDIUM	HIGH	MEDIUM
CROSSTRACK MANEUVERS	HIGH	MEDIUM	HIGH
• DISTURBING TORQUES			
AERODYNAMIC	LOW	HIGH	MEDIUM
GRAVITY GRADIENT	LOW	LOW	HIGH

FIGURE 1

PR-29-11

CREW WORKSITE STUDY

AAP/PIP EARLY APPLICATIONS

MISSION 1A

Contract NAS 8-21004

14 September 1967

J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

This study summarizes the selection of the CM and Carrier worksites for the 1A mission, primarily the operating location of the experiment carrier display and control panel, the spacecraft flight control and guidance and navigation stations, experiments requiring data retrieval and the scientific airlock locations.

2.0 SUMMARY

The experimental mission considerations, crew station design factors and configuration characteristics of the Block II Command Module were evaluated for the 1A mission. The recommended crew work stations include primary experiment control from the pilot's couch (right seat) using a portable display and control panel carrier in the carrier during boost and relocated to temporary mounting brackets in the lower cutout area above the center couch during orbital flight. This D & C panel may also be monitored and controlled by the Command Pilot (left seat).

The right and left forward docking windows provides direct viewing on the line of sight of the carrier mounted experiments. Spacecraft flight and attitude control is provided by the Command Pilot who also utilizes the left docking window for viewing oncoming sensor target areas.

Any auxiliary experiment pointing station is provided by the G & N station in the Lower Equipment Bay which is used for pointing and tracking X-ray targets for the side airlock mounted experiments primarily S017 and S019.

Preliminary evaluation of these stations has been made by checking the locations and positions in CM mockups at both MSC and NAA.

3.0 DISCUSSION

3.1 Crew Station Locations

Spacecraft control experiment operating, and data retrieval requirements were considered in two categories; first - crew activities for specific pieces of body mounted equipment for which local access, work space

3.1 (continued)

and work site restraints must be provided; secondly, crew activities requiring visibility, spacecraft control, experiment operations, CM and Carrier displays and controls, windows and viewing devices and auxiliary portable equipment unique to Mission 1A.
The first category includes cameras, scientific airlocks, docking umbilicals, etc., and the approach is defined in PR 29-14 Crew Equipment and Illumination Requirements. The second category covering flight control and experiment work stations is covered in this report.

3.2 Experiment Operating Requirements

The baseline experiment grouping was evaluated for crew station requirements, emphasizing those in the pointing, tracking and stabilization area. These requirements analyzed in PR 29-43 Pointing and Stabilization Studies, and summarized in Fig. 3.2-1 identify the specific types of experiment targets desired, pointing and attitude control requirements imposed on the crew and the Command Service Module (CSM) Stabilization Control System (SCS) and the Reaction Control System (RCS). A number of experiments require local vertical attitude hold over the Continental U.S.A. for synoptic mapping of earth resources and meteorological phenomena. This mode of flight is achieved either by a crewman manually controlling the vehicle from an IR horizon scanning system readout display or through a local vertical computer program fed directly into the SCS for automatic control. This same computer program may be utilized by a crewman viewing the Flight Director Attitude Indicator (FDAI) visual display and manual controlling the RCS. The X-Ray Galactic (S017) experiment requires crew control from a light matrix mounted on the T004/S019 panel with manual control provided by the crewman. X-Ray Stellar Photography (S019) will use either the experiment mounted calibrated optic or the CM scanning telescope with manual flight control during experiment operation.

Initially the S019 optical viewer and the CM sextant would be boresighted by alignment with a known starfield. The sextant would then provide the visual reference for vehicle attitude control during S019 operation by a

FIGURE 3.2-1

EXPERIMENT 1A POINTING, STABILIZATION AND CREW REQUIREMENTS

Experiment	Experiment Location	PGNS Requirement
D008 Radiation	CM	None
D009 Simple Navigation	CM	Pointing at Stellar fields; manual (fine mode) tracking during observations
D017 CO_2 Reduction	CM	None
E06-1 Metric Camera	Carrier Dome	Orient to local vertical $\pm 1.0^\circ$ for operation; calibrate to starfield
E06-4 Multispectral Camera	Carrier Dome	Orient to local vertical $\pm 1.0^\circ$ for operation
E06-7 IR Imager	Carrier Wall (airlock)	Orient to local vertical $\pm 1.0^\circ$ for operation
E06-9 IR Radiometer/ Spectrometer	Carrier Dome	Orient to local vertical $\pm 1.0^\circ$ for operation; Roll once thru 90° at 1°/sec; Acquire moon once with experiment F.O.V.
E06-11 Multifrequency Microwave Radiometer	Carrier Dome	Orient to local vertical $\pm 1.0^\circ$ for operation; Roll to space once during each day experiment operated
S015 0-g Single Human Cell	Carrier Truss	Orient to local vertical $\pm 10^\circ$
S016 Trapped Particle Asymmetry	Carrier Dome (airlock)	Orient within cycle limits of G & N fine mode hold to local vertical thru the South Atlantic anomaly.
S017 X-Ray Astronomy	Carrier Truss	Orient to $\pm 0.5^\circ$ of X-ray sources with fine mode dead band about all axis.

FIGURE 3.2-1 (continued)

Experiment	Experiment Location	PGMS Requirement
S018 Micrometeorite Collection	Carrier Wall (airlock)	Orient to deep space periodically
S019 UV Stellar Astronomy	Carrier Wall (airlock) (see Fig. 13)	Acquire stars within ± 2°; Hold on star ± 1/4°
S020 UV X-Ray Solar Astronomy	Carrier Wall (airlock) (see Fig. 13)	Orient to sun within ± 1/5° in pitch and yaw; Roll-N/A
S039 Day-Night Camera	Carrier Truss	Orient to local vertical ± 10°
S040 Dielectric Tape Camera	Carrier Truss	Orient to local vertical ± 10°
S043 IR Temperature Sounder	Carrier Truss	Orient to local vertical earth opportunity targets ± 5°
S044A Scanned Microwave Radiometer	Carrier Truss	Orient to local vertical ± 5°
S048 UHF Sferics Detection	Carrier Truss	Orient to local vertical ± 5°
T002 Manual Navigation	CM	Orient to starfields ± 0.5° Fine mode or - 5.0° coarse mode
T003 In-flight Nephelometer	CM	None
T004 Frog Otolith Function	Carrier Truss	None

3.2 (continued)

crewman in the CM Lower Equipment Bay. Other techniques were considered for S020 X-Ray Solar Photography including the method just described for S019. A light filter would be required on the sextant and viewfinder eye pieces. An alternate approach would utilize a sun sensor boresighted in the lab to the S020 sensor. The 1A Mission D & C panel would then incorporate a visual display indicator to maintain spacecraft control for precise sun alignment.

3.3 Flight Control and Experiment Operating Crew Stations

Six basic locations were evaluated in the Command Module as well as two in the carrier for the primary flight and experiment/subsystem control station and are identified in Fig. 3.3-1 depicted in Fig. 3.3-2. Primary emphasis was placed on selecting a location capable of providing: comfortable target visibility, shirt sleeve operation, capability for both spacecraft and experiment monitoring during watch, and provisions for utilization by more than one crewman at a time.

CREW STATION LOCATIONS - OPERATING

	Avail. D & C Locations	Outside View
1. Main D & C Panel		
a. Right Seat-Pilot	-2 Locations	Right Window Right Docking
b. Center Seat-Sen.Pilot	-2 Locations	Main Hatch
c. Left Seat -Com.Pilot	-2 Locations	Left Docking
d. Overhead-Any	-4 Locations	Left Window
2. Lower Equipment Bay		
a. Rock Boxes	-2 Locations	Scopes -2
b. Above G&N Station	-2 Locations	Scopes -2
c. Docking Tunnel Base	-6 Locations	Scopes -2
3. Upper Equipment Bay		
a. Main Hatch Window	2 - Locations	Main Hatch Window
4. Right & Left Hand Eqpt Bays		
a. Stow Couches	4 - Locations	Right Window Left Window- Limited View
5. Carrier Pressure Vessel		
a. Dome End View	As Needed	New Carrier Window
b. Side Wall View		New Carrier Window

FIG. 3.3-1

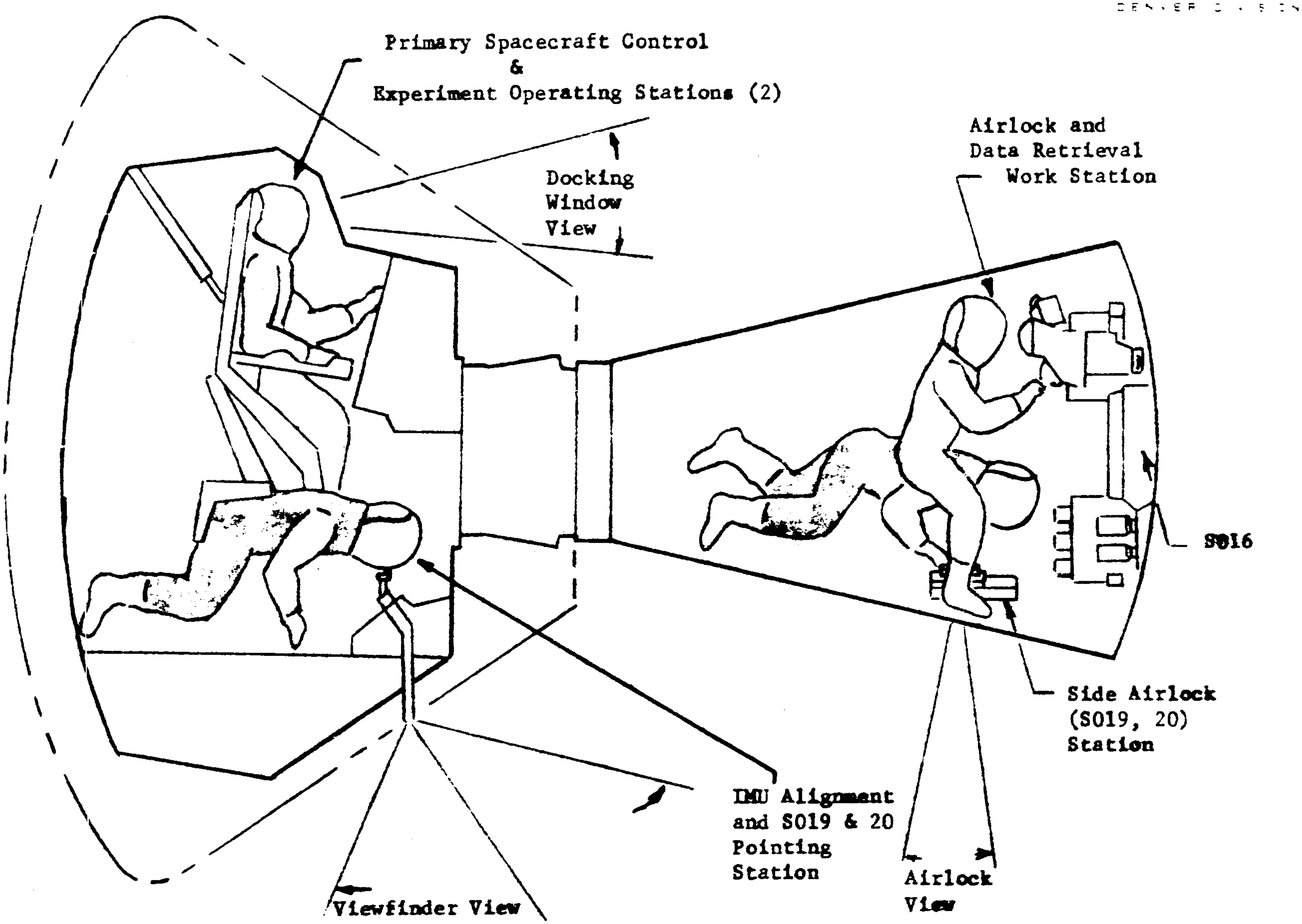


FIGURE 3.3-2 CREW WORK STATIONS

3.3.1 CM Main D & C Panel Areas

3.3.1.1 The command pilot position (left couch) provides two candidate panel locations, a limited space overhead above the main panel cutout area below the main D & C shown in Fig. 3.3-3. Since this is the primary flight control station including the Flight Director Attitude Indicator (FDAI) it was considered most adaptable as the secondary experiment control station, but primary for spacecraft attitude control, pointing and tracking. Two exterior viewing windows are available, the left side landing and left forward docking windows.

3.3.1.2 The senior pilot position (center couch) provides two panel locations, both overhead unless the auxiliary panels are located in front of the middle portion of the main panel which was considered inadvisable without additional study and evaluation by MSC. Should the scientific airlock be installed in the main hatch for this mission, protuberances into the CM would be in the same area as the senior pilot's head, and the Block I airlock requirement for all crewmen to be soft suited would make experiment operations somewhat difficult. The center couch provides an exterior view only through the main hatch window (if the airlock is not installed there) or through the docking windows by awkward body motions over to the right or left couches. This position was considered unsuitable as a work station.

3.3.1.3 Pilot position (right seat) provides an opposite orientation to the left seat described above, has two basic locations available, and differs from the command pilot station primarily in being the Command Module system engineering and

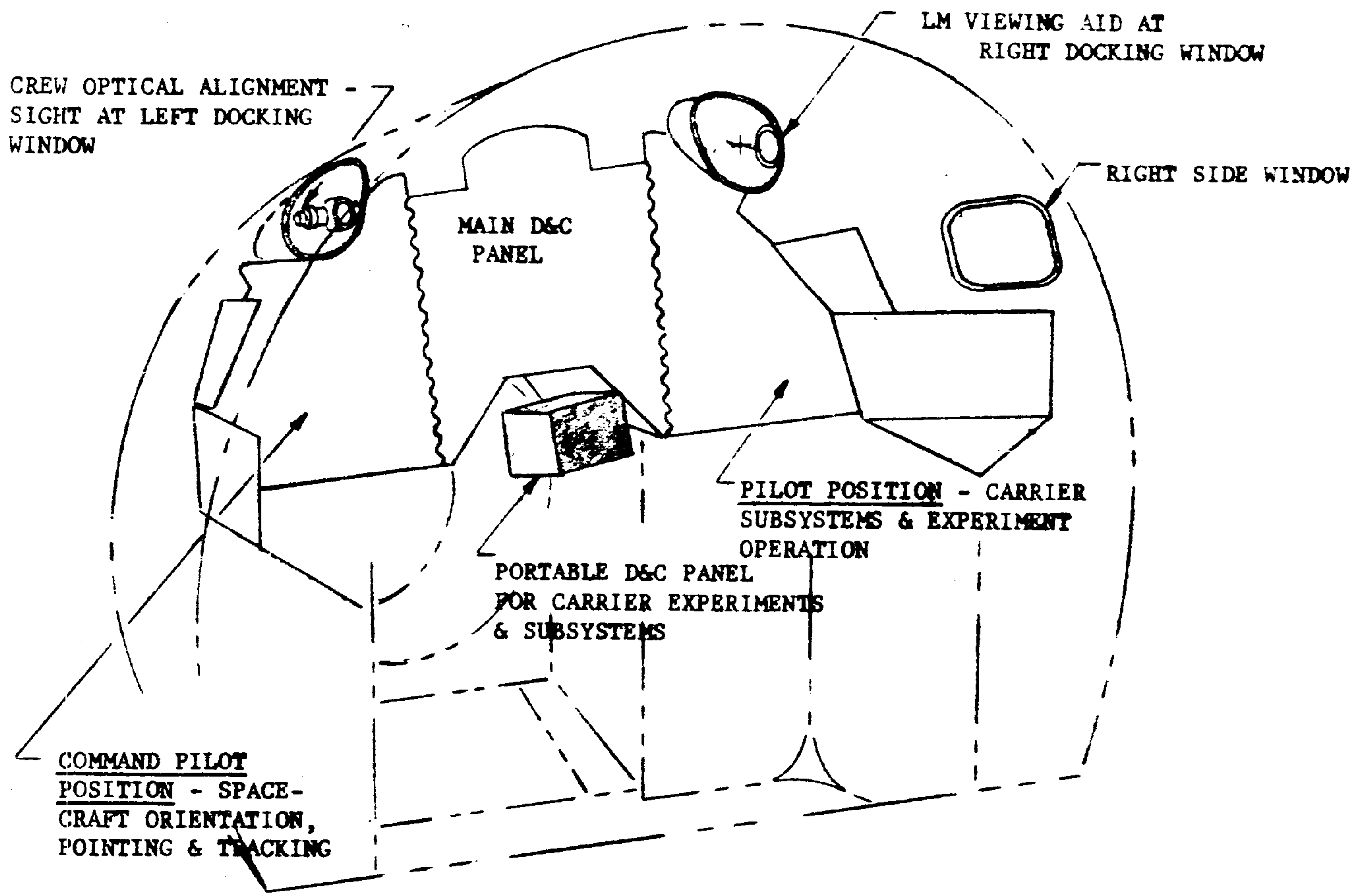


Figure 3.3-3 PRIMARY CM WORK STATION

3.3.1.3 (continued)

communications control area and is normally the watch station. A single crewman at this position may perform CM systems monitoring and housekeeping, control and monitor the carrier and experiments, and control the spacecraft using the portable side arm controller. His visibility forward is similar to the left seat for sensor pointing and tracking. This position shown in Fig. 3.3-3 was selected as the primary experiment/carrier subsystem work station for the baseline configuration. Visibility considerations are covered under PR 29-12 Window Visibility Study.

3.3.4 <u>CM Lower Equipment Bay Area</u>

3.3.4.1 Lunar Sample Containers (Rock Boxes) Figure 5, located at approximately knee height for the crewman restrained on the center couch lower section were primary contenders for D & C location considering ease of access to the G & C sextant viewing scopes (1 & 60 power), minimum impulse controller and the Computer Keyboard (DSKY). Since suit donning is required in this same area as well as access to the carrier docking tunnel, operational interferences during preparation and completion of carrier visitations would be expected. Even though the surface is greater than any available in the main panel area, only one crewman can view through the scope at a time, and simultaneous pointing and tracking and experiment D & C operation by a single astronaut overloads the crewman, also no other CM Window permits a view of the area covered by the scopes so that extensive inter-communication of the observer and the experiment operator would be necessary. This station was

3.3.4.1 (Continued)

desireable only for the carrier side airlock pointing and tracking operations.

3.4.2 Above the G&N scopes there is a potential location in the LEB which provides the space for a D&C panel at arms length above the crewman's eye level. The available space is less than any other location evaluated, and offers potential only for an auxiliary tracking display after primary target acquisition with the G&N computer/scope. It is not suitable for the entire complement of 1A carrier/equipment controls and displays.

3.4.3 Docking Tunnel Areas

Several locations were checked just inside the CM pressure vessel adjacent to the docking tunnel for wall mounted D&C panels. These require a standing posture in the LEB and offer no direct exterior visibility, but do provide direct viewing into the carrier when the hatch is open. This area is of no immediate interest.

3.5 CM Upper Equipment Bay (Main Access Hatch)

Two locations were checked. One for a D&C panel mounted on the inside of the hatch, is not desireable in the Block II configuration because of the exposed operating mechanism. The other location, just above the rapid repressurization system (RRS) at the head end of the senior pilot's couch was considered unacceptable because of poor crew access.

3.6 CM Right and Left Hand Equipment Bays

The two locations considered for each bay, required stowage of the new Weber folding couches for D&C placement below the right or left landing window to provide direct visibility during control operations. The location is awkward, requires the new couches, presents no advantage over other position and was discarded.

3.7 Carrier Pressure Vessel Areas

The carrier pressure vessel was not selected as the prime flight control and experiment D&C location for several reasons. The simplest carrier configuration consistent with minimum spacecraft modifications uses a pressurized conical chamber to permit soft suited crew entry and limited operating time on the extended CM suit umbilicals. Communication and biomedical instrumentation are also provided in the cobra umbilical so no new CM interfaces are required. Attitude control by the CM sidearm controller extended into the carrier would undoubtedly require a backup crewman at the RCS circuit breakers for safety. In addition, outfitting a complete crew work station with an overall restraint system, D&C panel, viewing window, hard wired communication, biomedical instrumentation, direct CM RCS control, and long duration atmospheric and thermal control, all this would be required in addition to the crew equipment, restraints and tether discussed in PR 29-14, Crew Equipment and Illumination Requirements.

3.7.1 Carrier Dome End

Location of an operating station other than the scientific airlock for S016 in the area of the experiment mounting frame would not provide an astronaut eye position as close to an end mounted window as is now possible in the CM. Consequently, the viewing angles would be smaller for similar windows. In addition, stowage of equipment on the truss would be difficult, as would camera cassette operations. Carrier diameter would have to be enlarged preferably by a cone-cylinder pressure vessel with the planned 84 inch diameter to accommodate a crew station with display and control still provide access to the experiment truss frame, cameras and the scientific airlock.

3.7.2 Carrier Side Wall View

A side location for a crew station could only be provided in the general area of the side airlock since no nadir visibility is possible. The airlock station is now utilized for S017, 18, 19 and 20, with both 19 and 20 having internal pointing devices and requiring manual operations during data taking.

4.0 CONCLUSIONS

Considering all factors in selection of the experiment worksites, the preferred location is in the CM couches preferably the left and right sides for flight control and experiment operations respectively. The carrier stations are intended for intermittent manual activities and not for continuous occupation.

PR 29-12

CM WINDOW VISIBILITY & VIEWFINDER STUDY

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

September 6, 1967

Prepared by: W. D. Carmean

Approved by: J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

The primary objectives for the 1A mission are centered on the acquisition of earth resources data from a variety of passive sensors. These experiments require crew visibility, not only of the nadir target areas where data is being taken, but forward along the ground track to permit minor spacecraft maneuvering for target acquisition prior to overpass. The baseline configuration for the carrier/CM placed the primary crew observation station inside the CM and this study presents the viewing areas projected on the earth surface available from the CM forward and side windows and scanning telescope. Direct earth viewing by a crewman in either the left or right couch was emphasized without auxiliary systems to enhance the field of view.

2. SUMMARY

The fields of view for the CM left docking (forward) and left side windows were plotted on an earth projection using the baseline mission 1A altitude of 140 nautical miles. Two flight orientations were considered: nose down with the CM X axis aligned with local vertical and the heads of the crewmen directed forward toward the velocity vector, and streamlined with the CM windows facing forward along the flight path, the X axis aligned with the velocity vector and the heads of the crewmen directed toward the earth. Viewing envelopes thru the forward docking window were evaluated with the eyes of the crewmen located in two positions, determined by the couch adjustments. These were the boost and reentry, and docking modes. A 50th percentile crewman was assumed as the test subject.

It is readily apparent upon review of the earth projections that only the nose down orientation provides pilot viewing thru the docking window of nadir as well as forward target areas without auxiliary viewing devices. The plots shown herein assume the crewman to be in a normal, restrained couch position. Additional study and testing will be conducted to determine the maximum viewing envelope available when the pilot is allowed to translate his head and upper torso in all directions about the vehicle's X axis. Viewing augmentation by the incorporation of mirrors will also be investigated.

NAA data utilized for the CM window fields of view and crew positioning relative to the windows was obtained from test report No. CSU-402076, entitled, "Evaluation of Command Module (CM) Docking and Side Window Field of View" dated 31 May 1966. Window locations were obtained from NAA Block II drawings for spacecraft 101. The viewfinder study encompasses a brief review of the existing PGNS and a survey of candidate systems which Martin Marietta has evaluated during this study effort. Report No. PR29-43, Pointing and Stabilization Study contains a more detailed analysis of the candidate hardware and spacecraft interface.

3. CM WINDOW VISIBILITY STUDY

3.1 Configuration - The CM windows were evaluated for the field of view projected on the earth's surface. Data were obtained using a 140 nautical mile altitude with the CSM/carrier flying two attitude orientations. These were nose down with the crewmen oriented heads forward with respect to the velocity vector, and streamlined (CSM X axis aligned with velocity vector) with the heads of the crewmen directed toward the earth.

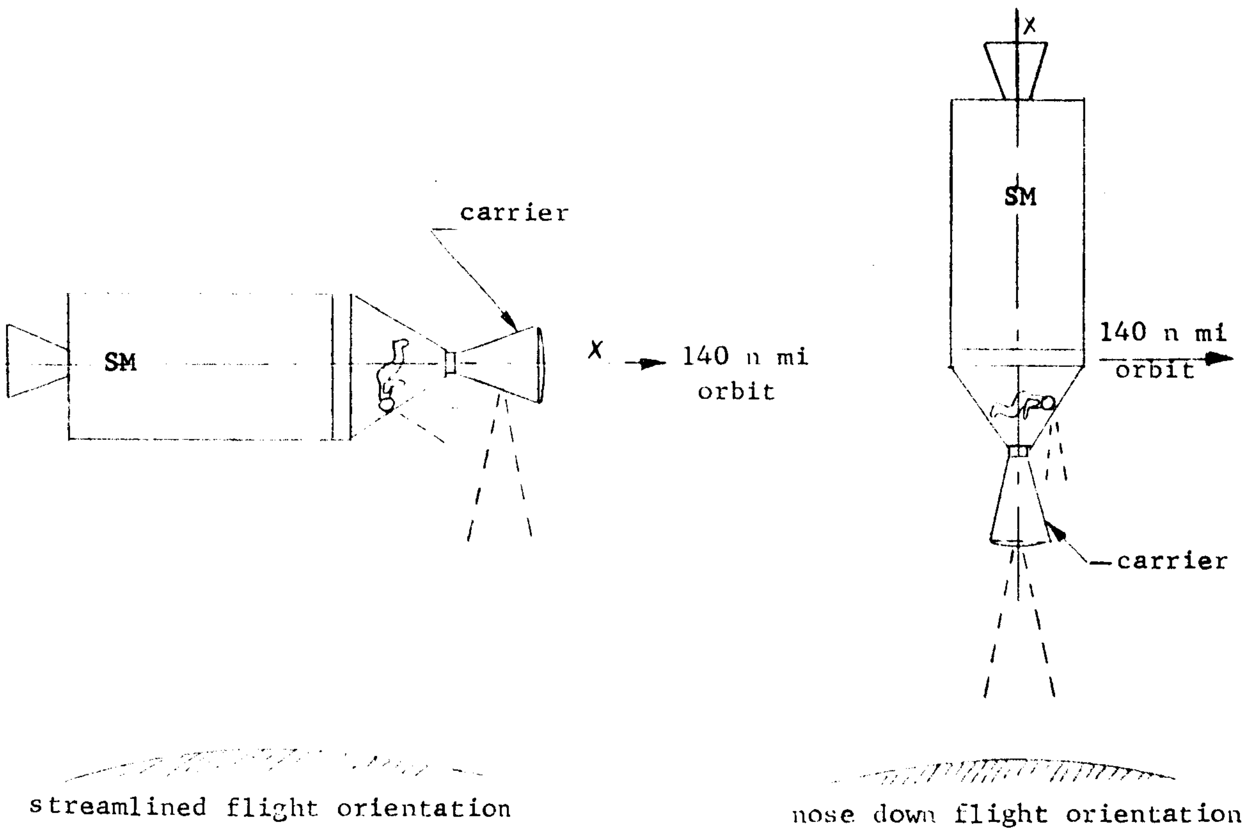


Figure 1 Flight Orientations

In either of these orientations, the windows affording an earth view are the left and right-hand forward (docking) windows, the left and right-hand side windows and the main access hatch window. The locations of these windows are shown in Figure 2. No data were available on the hatch window because of the current hatch modification program which includes a round instead of an oblong window change.

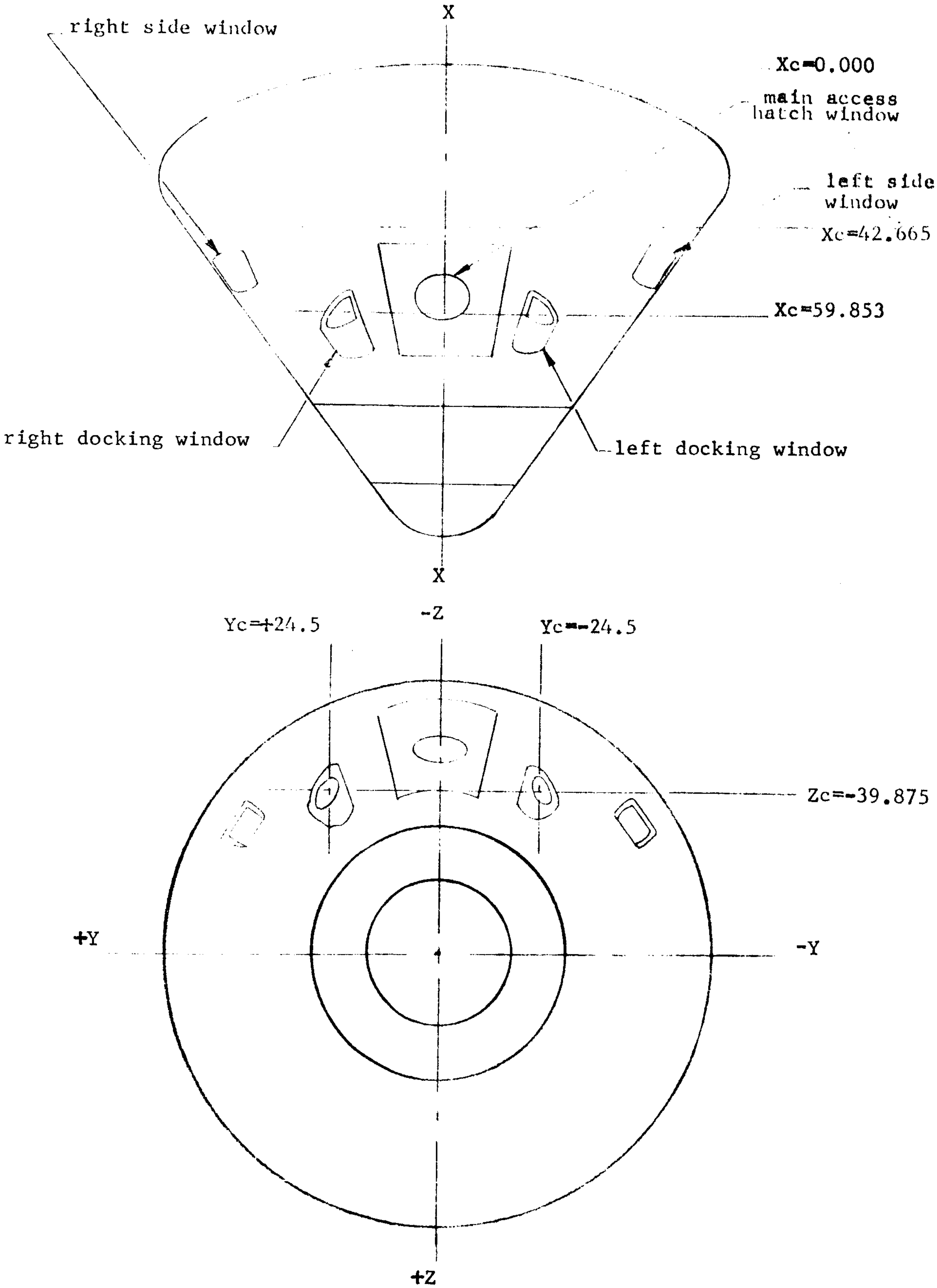


Figure 2 Block II CM Window Locations

For the forward windows, viewing projections were obtained for the two crew couch positions - boost and reentry, and docking. Figure 3 depicts the relative crew forward window locations for these two modes.

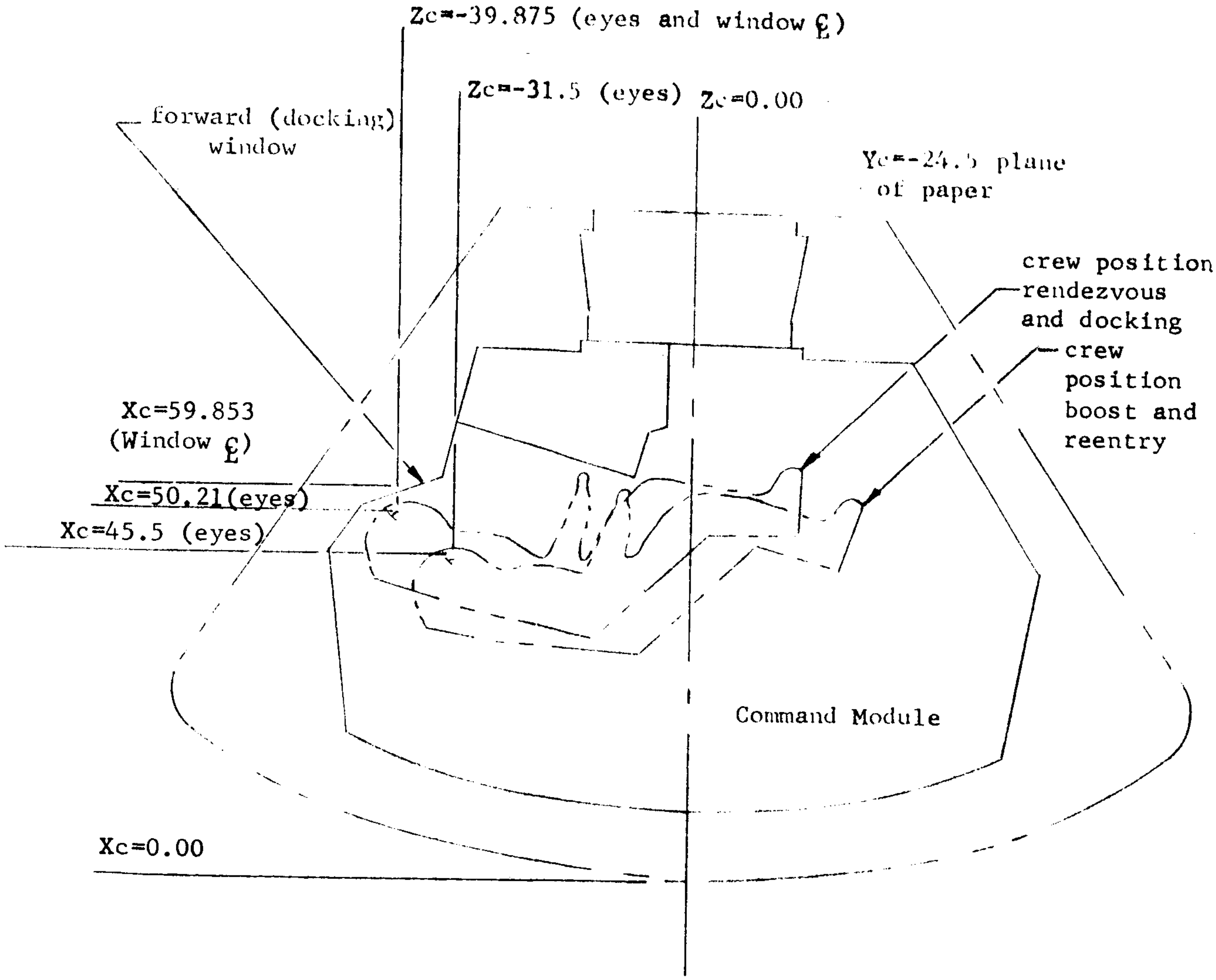


Figure 3 CM Docking Eye Positions

All window patterns were measured by NAA for ambinocular vision. Measurements were made utilizing a partial quarter CM mockup containing the left forward and left side windows. Two Dialco panel lamps were mounted on a bracket 2.5 inches apart to simulate the left and right eye position. The CM window mockups containing X, Y and Z coordinates were placed against grid plotting boards. For the forward window the grid board was located at Xc station 83.415. Each lamp was project separately on the grid board and the projection outline permanently marked. For plotting the field of view patterns from the left hand window, the grid board was located at Yc station -62.5. The lamps were located assuming the head to be in the headrest with the head rotated 45° left of the X-Z plane. Figure 4 shows the NAA test mockup.

3.2 Data Evaluation - Figure 5 illustrates the viewing plot thru the Block II left forward window with the crewman located in the boost and entry position. Eye locations represent a 50th percentile man. To eliminate a two coordinate system (one for each eye) the angular coordinates shown represent an average of the two. Viewing angles along the vehicle's Z axis measure from +12° to +46°. Along the vehicle's Y axis the left limit measures 21° and the right about 12°.

Viewing limits for the Block II left forward window with the eyes at the docking position are shown in Figure 6. These were plotted with the eyes located at the Crewman Optical Alignment Sight (COAS) reference station. Angular limits measure: Y ± 21°, Z + 16° to + 23°.

The plot for the left side window, shown in Figure 7, was made for a 50th % crewman seated in the boost and entry position. The head was assumed to be located in the headrest and rotated 45° to the viewer's left. No vertical deviation was assumed. The intersection of the X and Z axes marks the projection of a line running from the eye midpoint position to the grid board at station Z = -32.9 inches. Limits of this plot measure from +1½° to -27½° along the Z axis and from +47½° to +75½° measured from the 45° reference X axis. This plot was made using a Block I side window mockup.

To measure viewing limitations imposed by the carrier and SLA truss assembly a layout was developed using polar projection. Figure 8 depicts the reduction of the viewing envelope for the left forward window with the eyes located at the docking position. The baseline configuration was used for CM/carrier alignment which locates the SLA truss members containing the subsystem racks along the Y axis (relative to CM). For this orientation, a diagonal SLA attach truss member obstructs direct vision of the nadir, however by translating the head 2 to 3 inches to the left (along Y axis) an unimpeded view of the nadir with the left eye is anticipated. (Figure 8 does not illustrate this obstruction.)

Minimal (if any) obstruction would be imposed by the carrier and SLA attachment truss on the forward window with the eyes oriented in the docking and entry position. Because this viewing envelope is not critical to target observation at the nadir, a detailed analysis was not made.

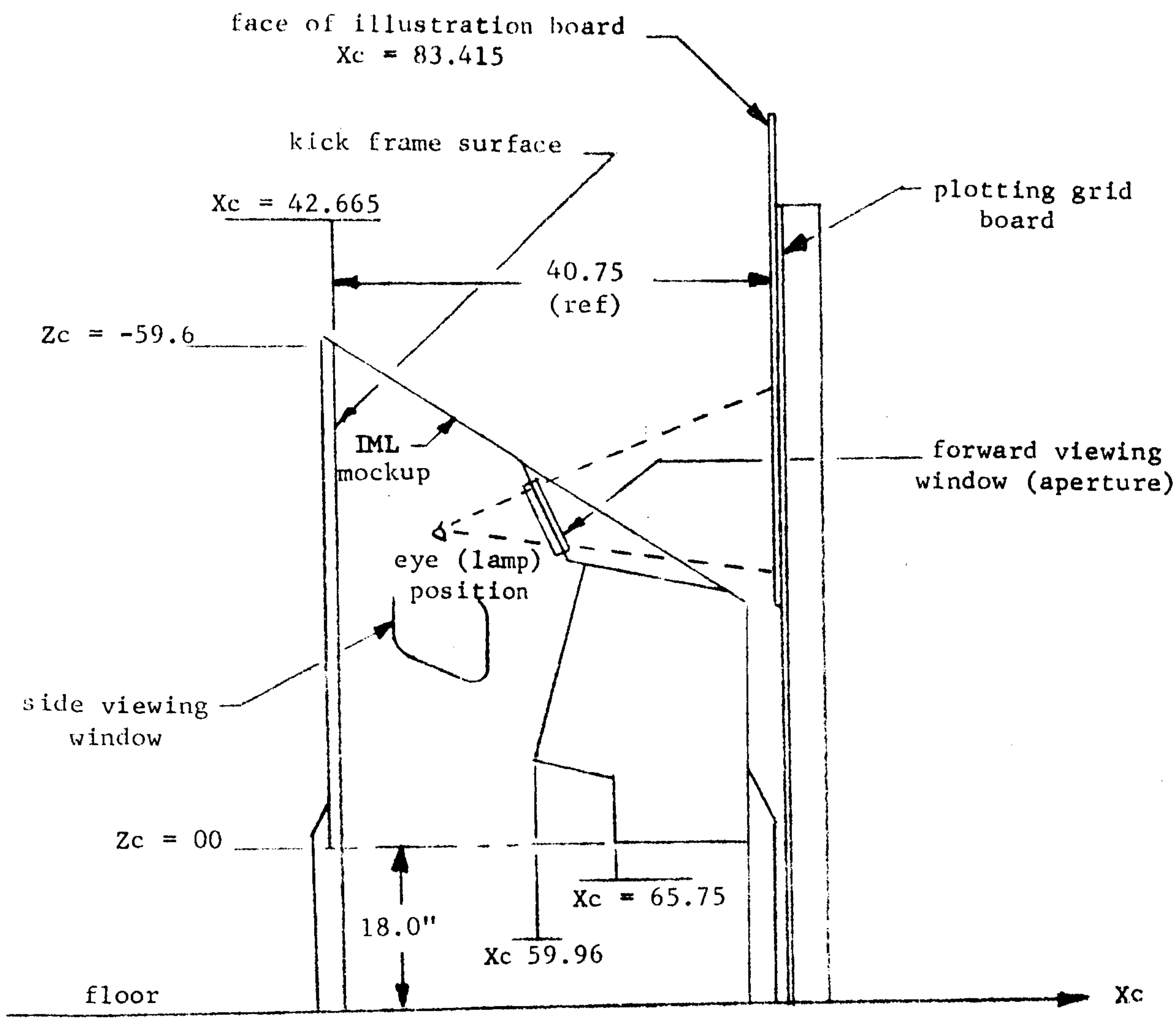


Figure 4 Left Side View of Partial Quarter Mockup (Looking Outboard)

Used in NAA Test, Showing Control Points
(Ref Fig. 2 NAA CSU-402076)

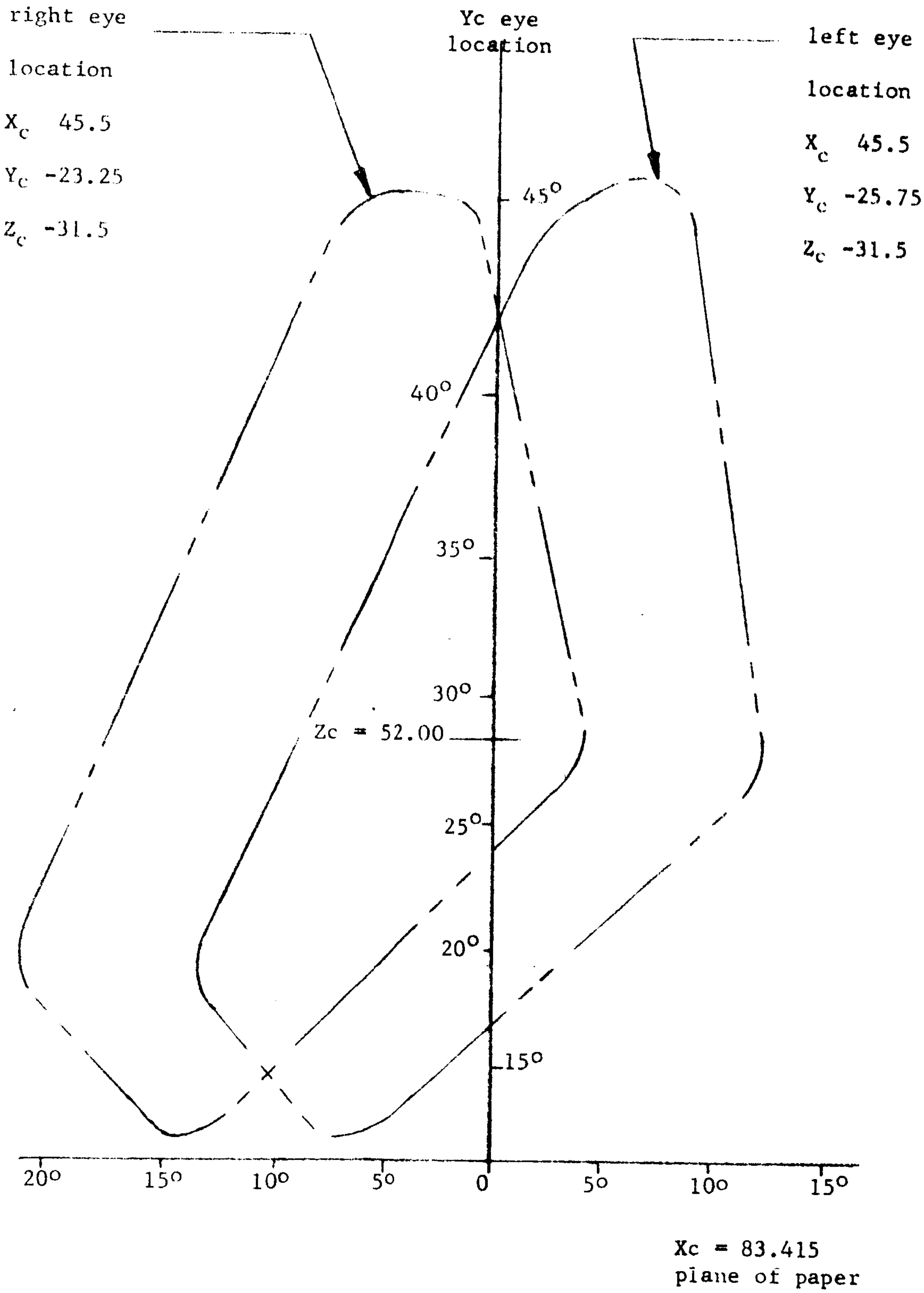


Figure 5 Field of View Plots, Boost and Entry Eye Position

Block II, 50th Percentile Man
Left Forward Viewing Window

(Ref. Table 7 NAA CSU 402076)

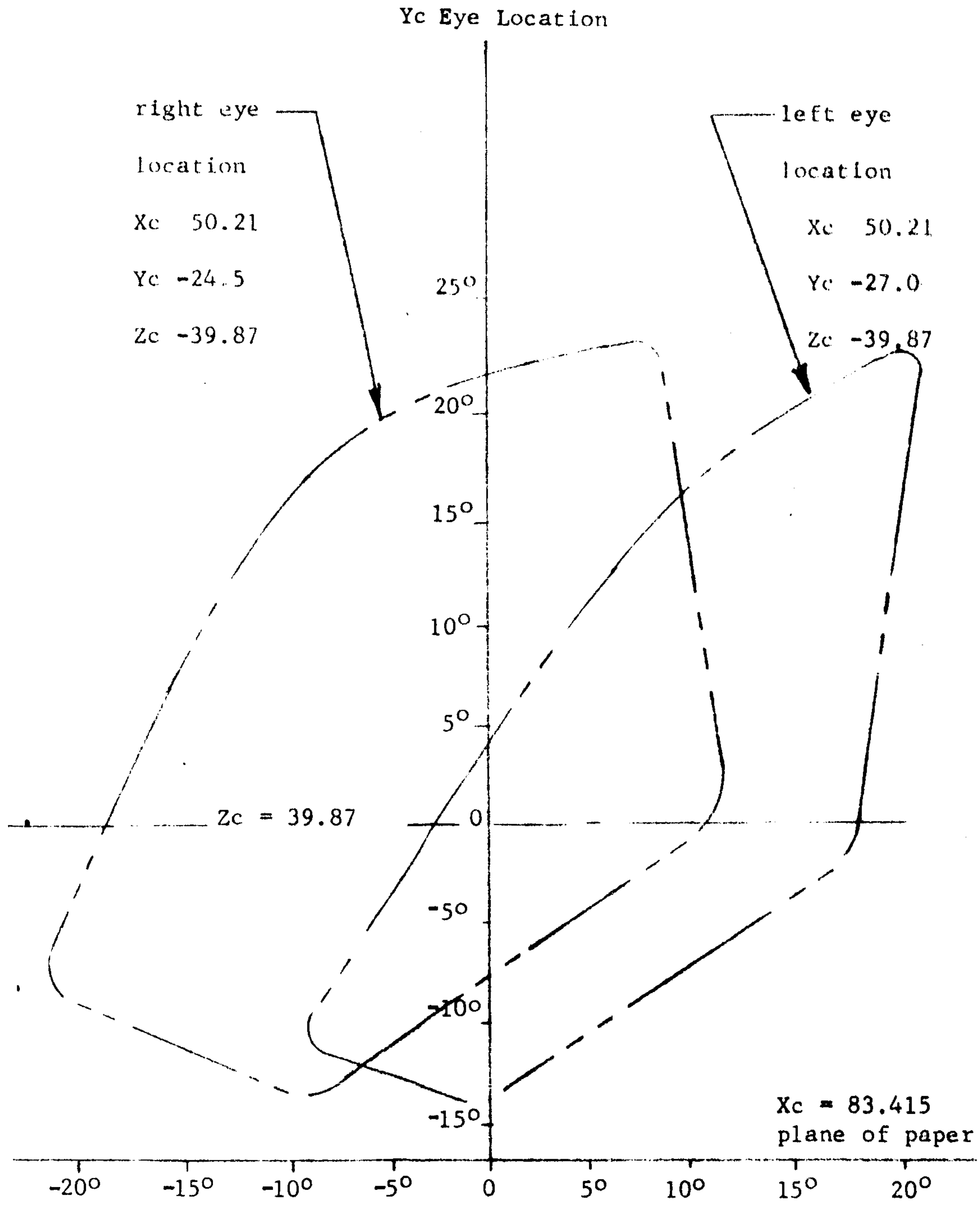


Figure 6 **Field of View Plots, Docking Eye Position**

Block II Left Forward Viewing Window with
Crewman Optical Alignment Sight
(Ref Table 10, NAA CSU 402076)

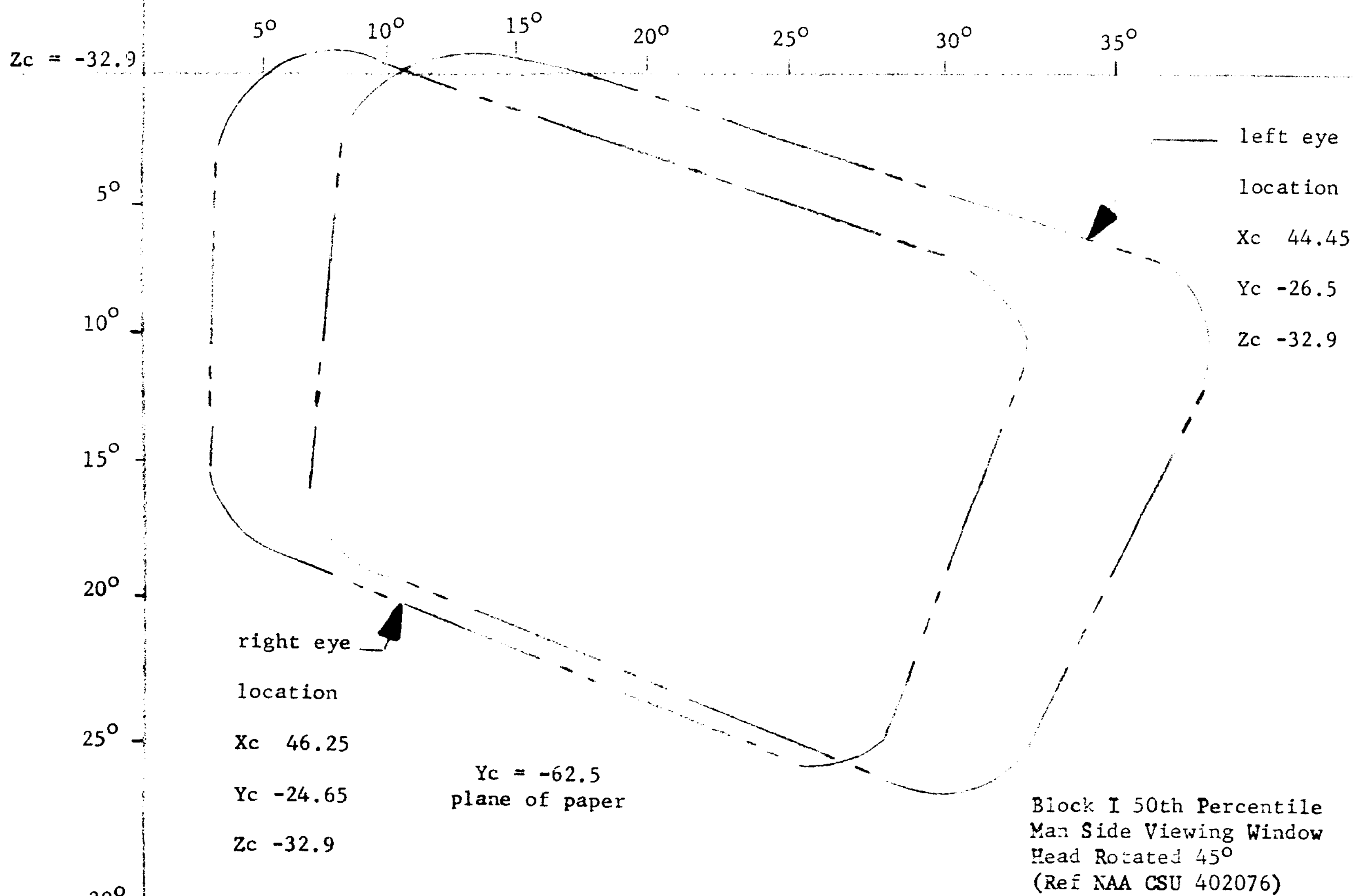


Figure 7 Field of View Plots, Boost and Entry Eye Position

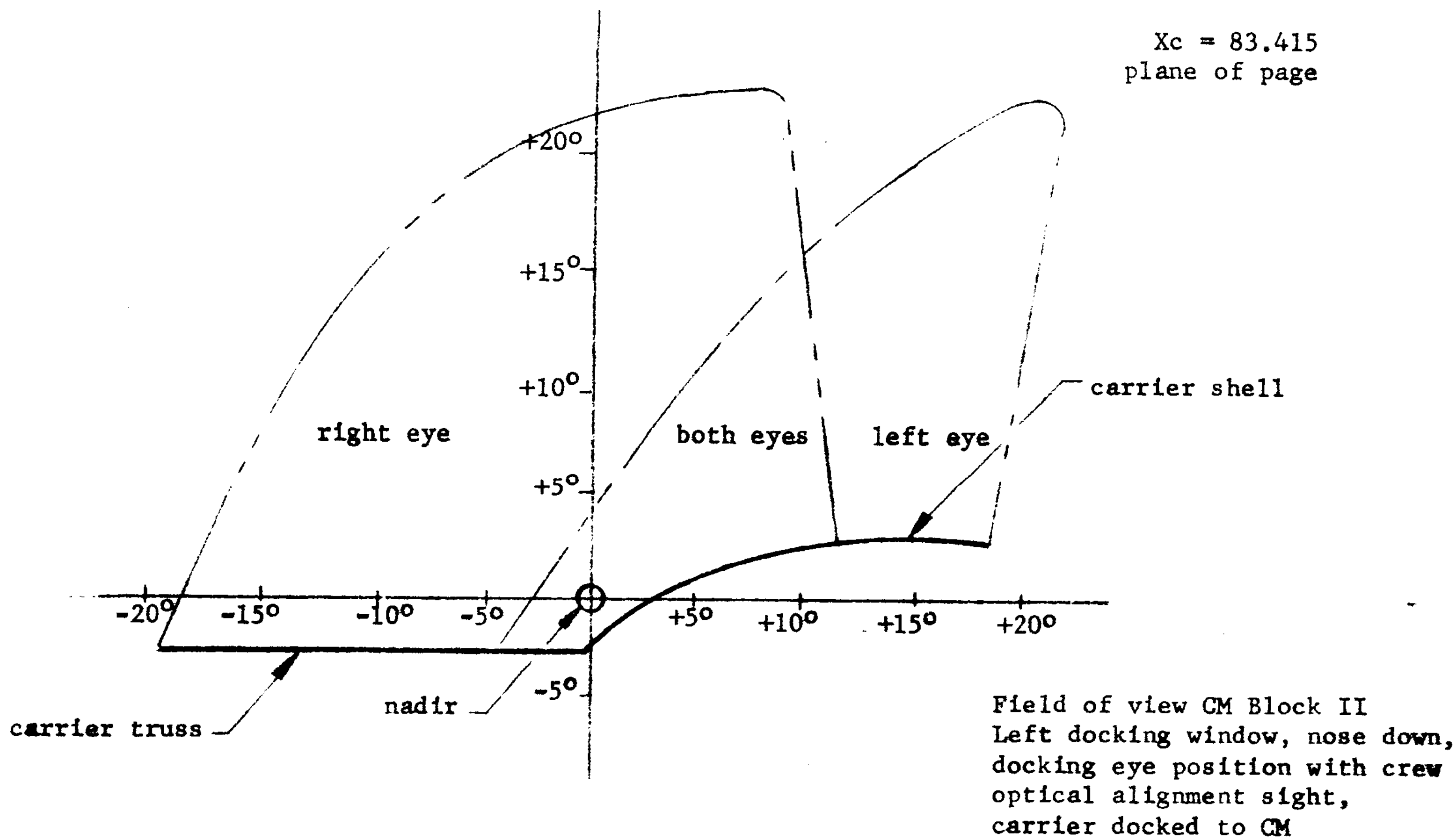


Figure 8 Left Forward Window Visibility - Docking Eye Position

For angles from 5° to 75° measured from an earth radial the arc projection on the surface was computed in nautical miles for each 5° increment. The apex height was 140 n mi. Translations are shown in Table 1.

5° = 12 n mi	45° = 144 n mi	
10° = 24	50° = 174	
15° = 36	55° = 210	
20° = 51	60° = 252	
25° = 69	65° = 360	
30° = 84	70° = 492	
35° = 99	$75^{\circ} \sim 960$	(horizon)
40° = 114		

Table 1 Angular Translation for Earth Projection

These arc measurements presented above were applied to the viewing plots for both the nose down and streamlined vehicle flight orientations mentioned earlier. The resulting viewing envelopes projected on the earth's surface are shown in Figures 9 and 10 of this report.
The earth radial becomes the vehicle local vertical. The nadir is the target point or center of the area at which cameras and sensors would be aimed for earth oriented experiments mounted in the carrier.

3.3 <u>Nose Down Orientation</u> - Figure 9 presents the earth projections of the viewing envelopes for the left forward and side windows as they would appear both with and without the obstruction imposed by the exterior structure of the baseline carrier configuration. Both boost and reentry, and docking eye positions are projected for the left forward window.

The elapsed time on track forward of the spacecraft local vertical is shown to the right of the ground track.

As noted earlier, visibility limits and location data were not available for the main access hatch window. However, assuming this window to be located on center with respect to the Y axis of the vehicle, it would provide direct observation to a crewman located in center couch only. Placement of the experiment/carrier D&C panel in the center cutout of the main panel makes occupation of the center couch undesirable during experiment operation. The fields of view illustrated in Figures 9 and 10 are available only to a crewman seated in the left couch. These projections would typify the right couch visibility if they were rotated 180° (mirror images) about the vehicle's X axis or ground track.

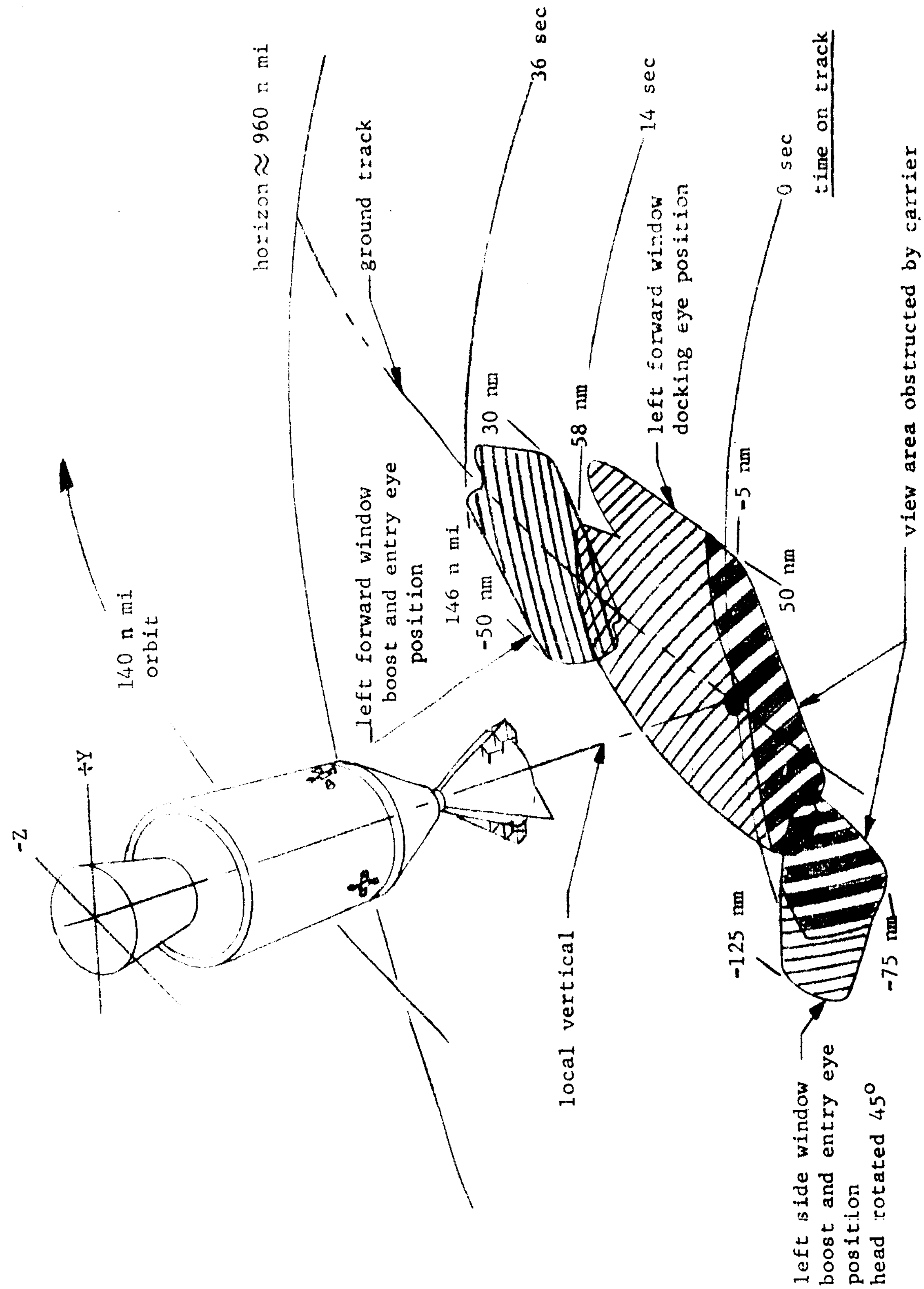


Figure 9 Window Visibility - Nose Down Flight Orientation

It should be noted that the viewing envelope projection thru the left side window as shown in Figure 9 represents an estimate of the unobstructed field of view. A more detailed test and analysis using full scale CM mockups will be necessary to verify the actual limitations.

In addition, the earth field of view thru the forward window with the eyes at the docking position does not consider the restriction imposed by the carrier docking and alignment target. Once the target configuration and carrier mounting location are established an analysis and test will be made to determine the impact of the target on nadir visibility. These analyses and tests will be incorporated in the pointing and tracking simulation program identified in Phase D Simulation Plan, PR 29-15.

3.4 Streamlined Flight Orientation - The earth field of view from the forward window with the crew flying heads down is constricted to an area extending from 130 n mi forward of the nadir to the horizon. (Ref. Figure 10) The boost and entry eye position affords the better view relative to nadir. Visibility for the docking position is limited to an area extending approximately 400 n mi from nadir to the horizon. The carrier affords no limitation to the earth field of view for either eye position.

No sector of the earth may be seen thru the side window.

It appears that the access hatch window would afford the better field of view from the center couch. Whether the earth projection would include the nadir could not be determined.

3.5 Mirrors - The mirrors presently located in the CM augment viewing thru the forward window by extending the field view in the +Z direction to improve visibility of the docking maneuver. The carrier and associated truss assemblies would negate this field of view extension past the nadir.

At the side windows, mirrors are used to enlarge the viewing envelope for observations of the booster, launch escape tower and the parachutes during boost and reentry. Data were not available to provide evaluation of their effect on the earth viewing projection.

Figure 11 depicts possible mirror location for enhancement of viewing earth areas forward of the target area. Mirror dimension, exact location, light obscuration should be evaluated in detail during the Phase D simulation program. In addition, the side window should be analyzed for increased viewing capability by the incorporation of mirrors.

4. VIEWFINDER STUDY

4.1 Existing Capability - The viewing capability for guidance and navigation reference of the CSM is provided by the scanning telescope and sextant (PGNS) located at the lower equipment bay.

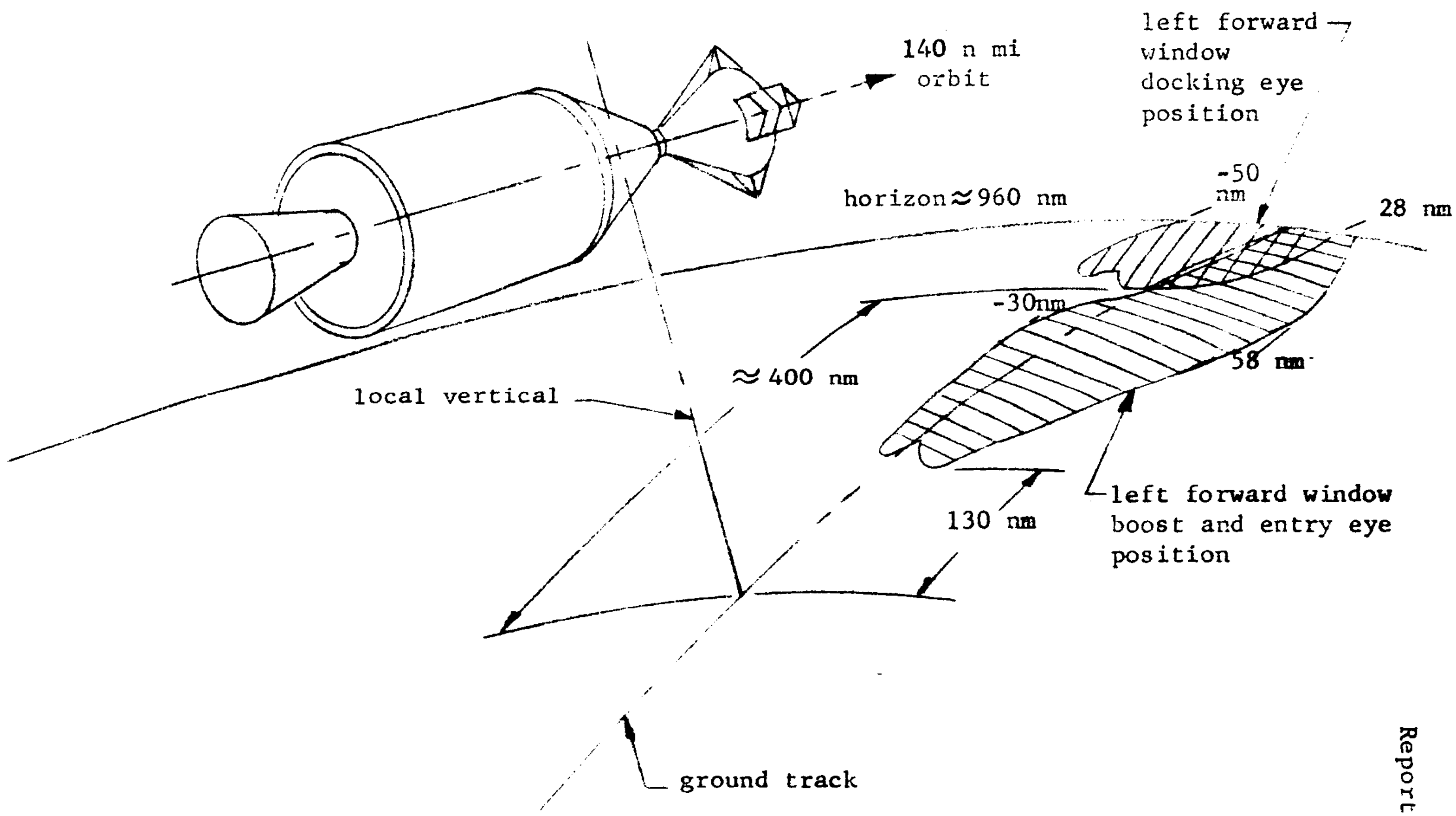


Figure 10 Window Visibility - Flight Orientation

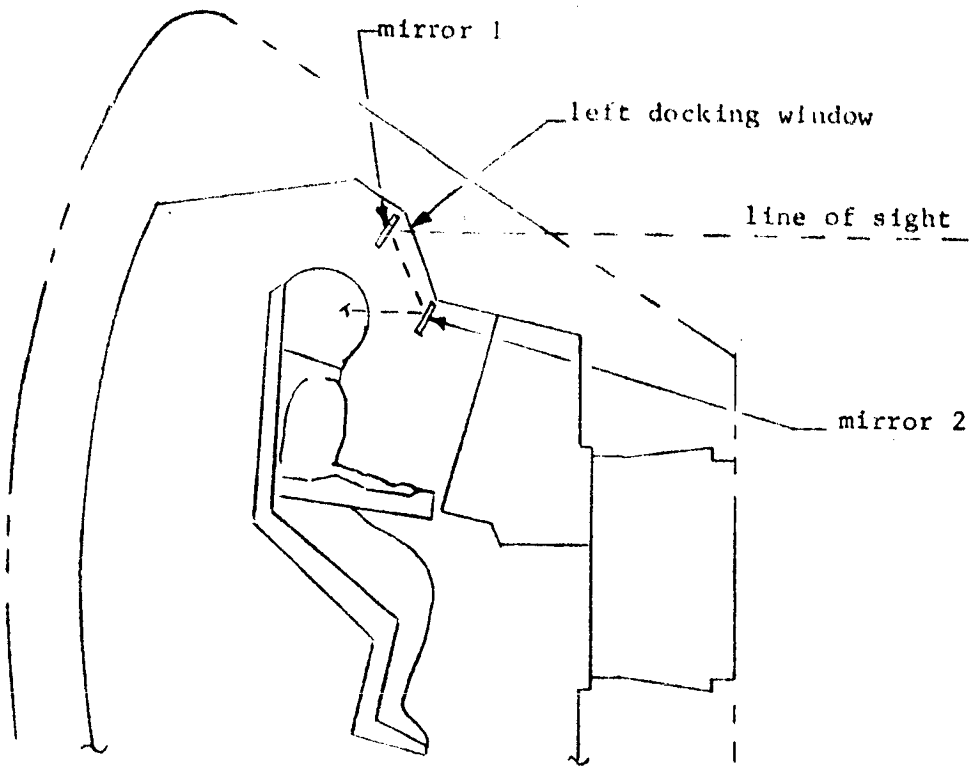


Figure 11 Mirror Usage for Forward Target Viewing

The PGNS telescope provides scanning in two axes. Limits of its field of view as well as location of the shaft axis (null point) are shown in Figure 12. The sextant provides single axis translation between the horizon and stellar viewfinders. Only one of these has scanning capability. At the time of this study data were not available regarding the sensors' scanning capability, the plane in which the sensors are located, or the scanning limit.

4.2 Augmented Viewfinder Capability - Several systems have been studied which would augment the existing CM capability. Their usage is categorized by target (earth) viewing, vehicle attitude determination, and CSM/carrier misalignment measurement. The latter two calibrations would require stellar acquisition to minimize error.

Means for enhancing earth observation include employment of the following: a two axis viewfinder (such as a Kollsman scope) at a forward (docking) CM window, a handheld telescope used at a forward CM window, mirror systems at either the side or forward CM windows, a window located in the dome and/or forward wall of the carrier, a viewfinder mounted in the carrier wall.

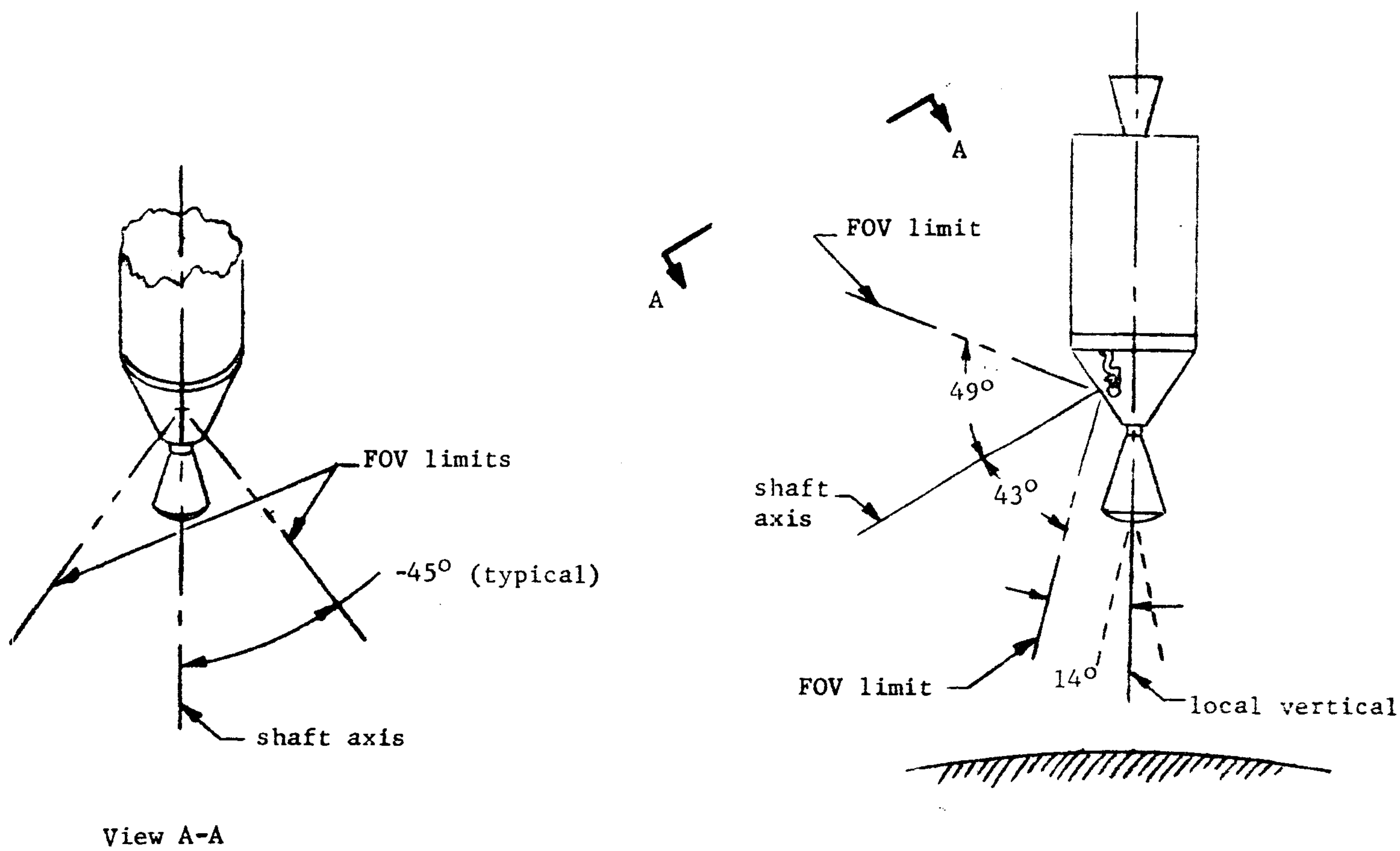


Figure 12 Viewing Limits for PGNS Scanning Telescope

Other systems studied for stellar acquisition to ascertain vehicle attitude and/or CSM/carrier misalignment include: usage of T002 or D009 sextant from the carrier on a gimballed platform, use of the COAS from both the CM and carrier, and employment of the S019 viewfinder from the carrier.

Additional study is necessary to determine the optimum system and technique for accomplishing the PGNS augmentation. Any candidate system must be evaluated for its compatibility with the CM and carrier configurations, carrier habitation constraints and experiment requirements.

5. CONCLUSIONS AND RECOMMENDATIONS

In consideration of the preferred work stations identified for experiment operation and vehicle attitude control in support of the AAP 1A mission, the primary earth observation position would be from the left couch. It is concluded from this study that only the nose down flight orientation provides nadir viewing from either the left or right couch while the crew is in normal seat position. Further, only in the docking position does the right or left couch permit direct visual contact of the nadir. Deviation from the normal body position is required by shifting the head laterally (along Y axis) several inches to eliminate nadir obscuration by the carrier's forward left truss member and docking target.

Selection of the seat position is contingent on the time availability to target overpass. Should the initial target observation indicate that conditions at the target area are within tolerance for experiment operation, the nadir observation during overpass may be precluded. Consequently a seat adjustment (from boost and reentry to docking) may not be warranted. In addition, the workload may prohibit seat adjustments between the time initial target observation is made and target overpass is accomplished.

It is recommended that the experiment groupings (earth resources) which require specific atmospheric conditions for data collection or which require observation of particular targets (targets of opportunity) be studied with respect to minimum acquisition time to ascertain the optimum eye/window position.

The usage of mirrors to facilitate viewing thru both the foward and side windows should be investigated. Adjustable mirrors might permit the view to track the target from initial acquisition to overpass without changing couch or body position.

The effect of light reflection on both the windows and pressure helmet visors should be studied for possible viewing obscurity. Window filters should be analyzed to ensure they do not interfere with head location adjacent to the window when the couch is in the docking position.

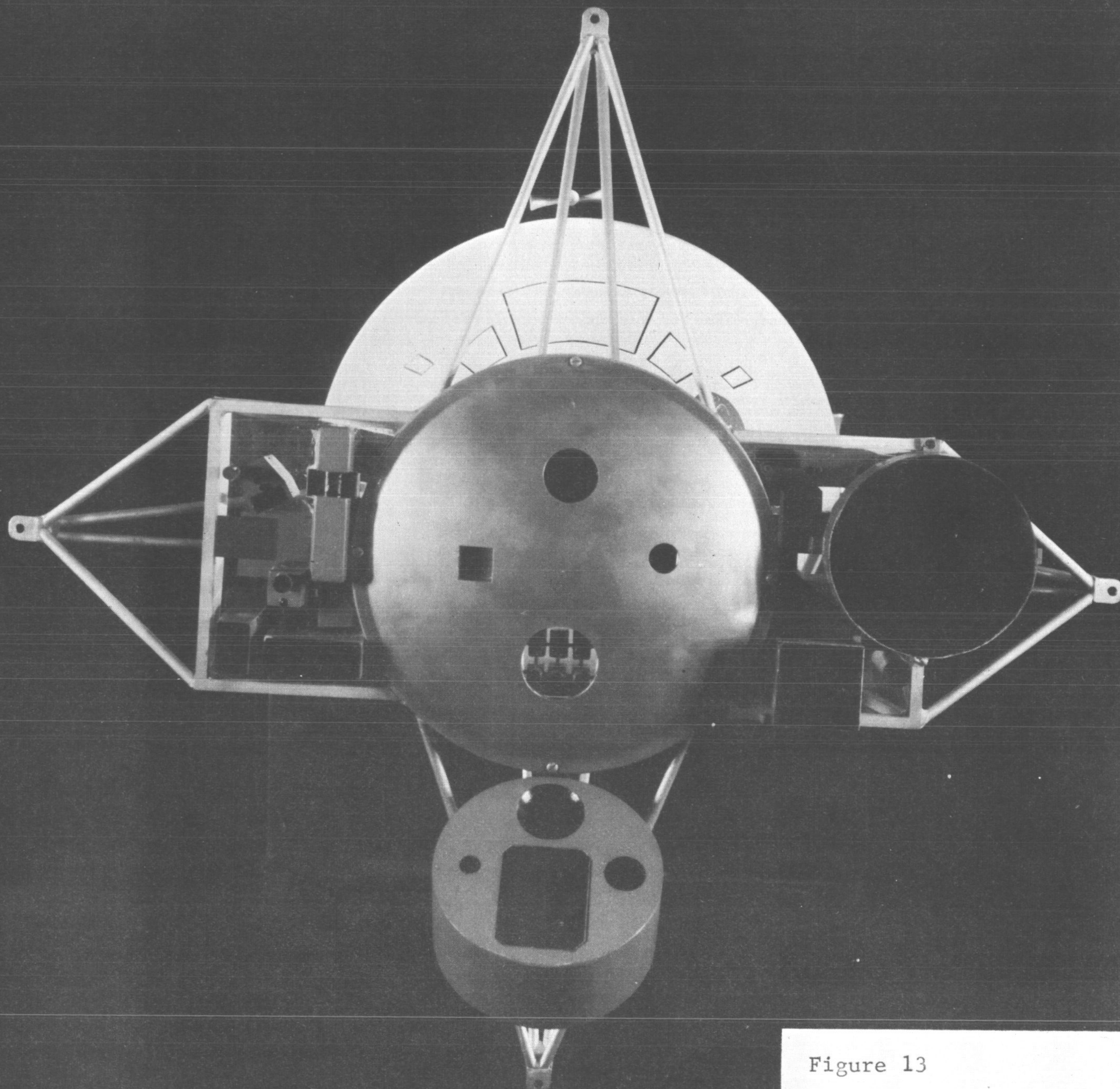


Figure 13

1/10 Scale Model
of CSM and Carrier
showing window view
over carrier structure.

The carrier dome, SLA trusses and subsystems mounting racks should be mocked up full size for incorporation into the pointing and tracking simulation facility. The structural interferences with the CM window visibility can be seen in the 1/10 scale model in Figure 13. Measurements may then be made for the optimum head location with respect to the forward window for all phases of the flight including rendezvous and docking, earth target acquisition, target tracking and general earth observation.

A comprehensive evaluation of systems which would augment the PGNS is necessary before any conclusions relative to design and system integration may be made. Candidate systems should be included in the Phase D simulation facility for detailed analysis of system compatibility.

PR-29-13

EVALUATION REPORT

MODULAR MISSION AND CONTINGENCY PLANNING STUDY

AAP/PIP EARLY APPLICATIONS

MISSION 1A

Contract NAS 8-21004

29 August 1967

Prepared by J. R. Steele

Approved by J. T. Keeley

MARTIN MARIETTA CORPORATION

DENVER DIVISION

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to document the current status of modular mission and contingency planning for AAP Flight 1A and to identify areas of continuing study.

1.2 Objectives - Successful accomplishment of the Flight 1A mission is in part dependent upon flexibility in gross mission definition and in detailed mission planning. The objectives of this study are to (1) identify an approach to mission definition and detailed planning which provides maximum contingency flexibility, and (2) identify possible contingency situations with recommended alternatives.

2. SUMMARY

The modular mission planning approach currently being implemented is discussed. Gross mission alternatives, payload alternatives, scheduling alternatives, and general ground rules are included. In all cases, the list presented is by no means all inclusive. Tabulation of identified contingencies with recommended alternatives will be a continuing process.

3. DISCUSSION

3.1 Building Block Concept - Adequate reaction to contingency situations is dependent upon flexibility in mission planning redesign. That flexibility can be attained through preparation and utilization of mission planning building blocks. Specifically, overall mission time lines should reflect phasing of grouped activities in such a way as to permit resequencing of major groups. Detailed time lines for each group, or for unique tasks, prepared as stand-alone sequences, can then be applied as appropriate without rewrite of a complete mission detailed sequence. Such time lines are being prepared to assist NASA in mission planning. Mission Modular Data Book building blocks, containing such things as detailed procedures, consumables required, constraints, and prerequisites for unique tasks will complete the data input as required for both initial modular mission planning, and real time on orbit planning and redesign.

3.1 Continued

Building blocks as applicable to standard Apollo tasks are available in North American Aviation's Mission Modular Data Book. That data will be augmented for Mission 1A peculiar tasks by MMC. Figure 1 depicts the basic building block sequence, top line, with additional planning blocks shown below. Figure 2 presents a sample detailed sequence as applicable to conduct of the applications experiments. Table 1 includes all sub-blocks currently identified as Mission 1A peculiar. Scope, content, and level of detail for the MMC prepared building blocks will be consistent with the NAA document. The "100" series numbering is arbitrary and applicable to this report only.

3.2 Gross Mission Alternatives - For the purpose of this report it is assumed that the baseline mission is as follows:

Single launch, SIB, Block II CSM (Min. Mod.)
140 n. mile circular orbit, 50° Incl. Desired (30° min)
14 day max. mission
5000 lb payload
1969 launch with date and time to optimize experiment yield

Contingencies to be discussed are those which degrade that overall mission capability.

3.2.1 Late changes in boost payload capability will necessitate either a decrease in planned orbital altitude or attainable inclination. The following approximate relationships exist:

78 lb payload per n. mile injection altitude
116 lb payload per degree inclination (no yaw turns)

To maintain a 14-day mission the final orbit must exceed approximately 125 n. mile circular (assumes no station keeping).

3.2.2 Minor launch date changes will necessitate only small changes in optimum launch time of day. Significant date changes could result in a decrease in applications experiments data yield due to poor lighting conditions. In event of the latter, inclination and mission time allocation studies should be conducted. Data applicable to launch date and time of day selections are included in PR29-2, Comparison of Launch Times for Best Mission Operations.

3.2.3 Report PR29-2 which concludes optimum launch time being 10:00 to 11:00 AM EST was based on requirement for optimum lighting conditions over the ZI throughout the 14 day mission and for daylight recovery in the primary (Atlantic) zone. Allocation of 4 to 5 days of the total 14 day mission to the applications experiments permits scheduling latitude. If these experiments are conducted early in the mission, launch as early as 08:00 to 09:00 could be accomplished without sacrificing desired lighting. Conversely late mission conduct would permit launches as late as 12:00 to 13:00 EST. In both cases primary recovery area lighting conditions are acceptable. Thus, through mission scheduling flexibility, launch window contingencies can be accommodated.

3.3 Payload Alternatives - In the event of failure to deliver or unacceptability of a given experiment, two alternatives exist; (1) substitute an "equivalent" experiment, or (2) fly a "dummy." Equivalent and dummy experiments are defined as follows:

Equivalent Experiment: similar in size, interface requirements (mechanical, power, data, thermal, space exposure), on-orbit schedule compatibility, and training requirements - The degree of similarity required will increase as final prelaunch test dates approach.

Dummy Experiment: identical in mass properties and mechanical interface - Dummy experiments should be available for all experiments in the event of late contingencies.

3.4 Experiment Scheduling Alternatives - On Orbit

3.4.1 Failures

a) Support subsystem failures which result in total failure to support an individual or block of experiments will result in elimination of those experiments from the mission plan and a rescheduling of all others to optimize remaining time. Shortened mission duration should be considered only after objectives of other experiments are satisfied.

b) Support subsystem failures which result in partial inability to support an individual or block of experiments will, in most cases, result in a decrease of time allocated to those experiments. For example, loss of data record/dump capability should result in limiting conduct of dependent experiments to selected real time readout runs (obtain sensor/concept qualification data).

c) Any faulure which could jeopardize crew safety will result in termination of experiment activities and early reentry.

NOTE: Contingency plans will be prepared for all identified failure modes and available to assist in real time mission redesign.

3.4.2 Weather - Real time mission planners will take into consideration zone of interest weather when selecting mission days to allocate to the applications experiments.

3.4.3 Shortened Mission - Anticipated decrease in mission duration should result in reallocation of experiment time to prevent total elimination of individual experiments.

3.5 General Groundrules - The following are additional recommended contingency ground rules:

a) Launch will not be attempted if malfunction within the carrier support systems would jeopardize experiment success.

3.5 (continued)

b) If any experiment component failure causes loss of any one complete experiment, launch will not be attempted and the experiment will be replaced or repaired.

c) Partial experiment failures which only degrade the quality of data or in some way limits the success of the experiment will be weighed by the Flight Director and principal investigator for that experiment. Considerations for the launch GO/NO-GO will entail percent of experiment success expected, the time factor in the countdown, weather, status of the launch vehicle, command and service modules, the control center and tracking network status and many other factors which must be considered before scrubbing the flight.

d) Instrumentation failures or transducer shifts must be weighed against the Mandatory, Highly Desirable lists. The Flight Director, the instrumentation engineer and the experiment representative will determine whether or not launch will be attempted.

e) Aborts during launch phase will not be attempted due to carrier systems or experiment failures of any kind.

f) Only catastrophic failures of the carrier resulting in SM structural failures should be considered for launch aborts.

g) Should a total failure of the carrier occur which cannot be repaired or reactivated by the crew within a reasonable length of time, the carrier mission will be abandoned; as much data as possible will be gathered by the ground and crew and the mission will revert to other objectives as defined by the Flight Director or terminated at his discretion.

h) Carrier visitation for data retrival is not planned should the mission have to be suddenly aborted. Should an early reentry be required due to a malfunction, the Flight Director will decide whether or not conditions are satisfactory for data retrieval prior to reentry.

3.5 (continued)

i) In general, most orbit maneuvering will be completed, lifetime and ephemeris verified before activation of experiments. Should subsequent orbit changes be necessary, certain equipments may have to be stowed and/or deactivated.

j) Should the lifetime go below the time to go to end of mission, a lifetime maneuver will be performed.

FIGURE

Mission Modular Building Block
Tree - AAP Mission 1A

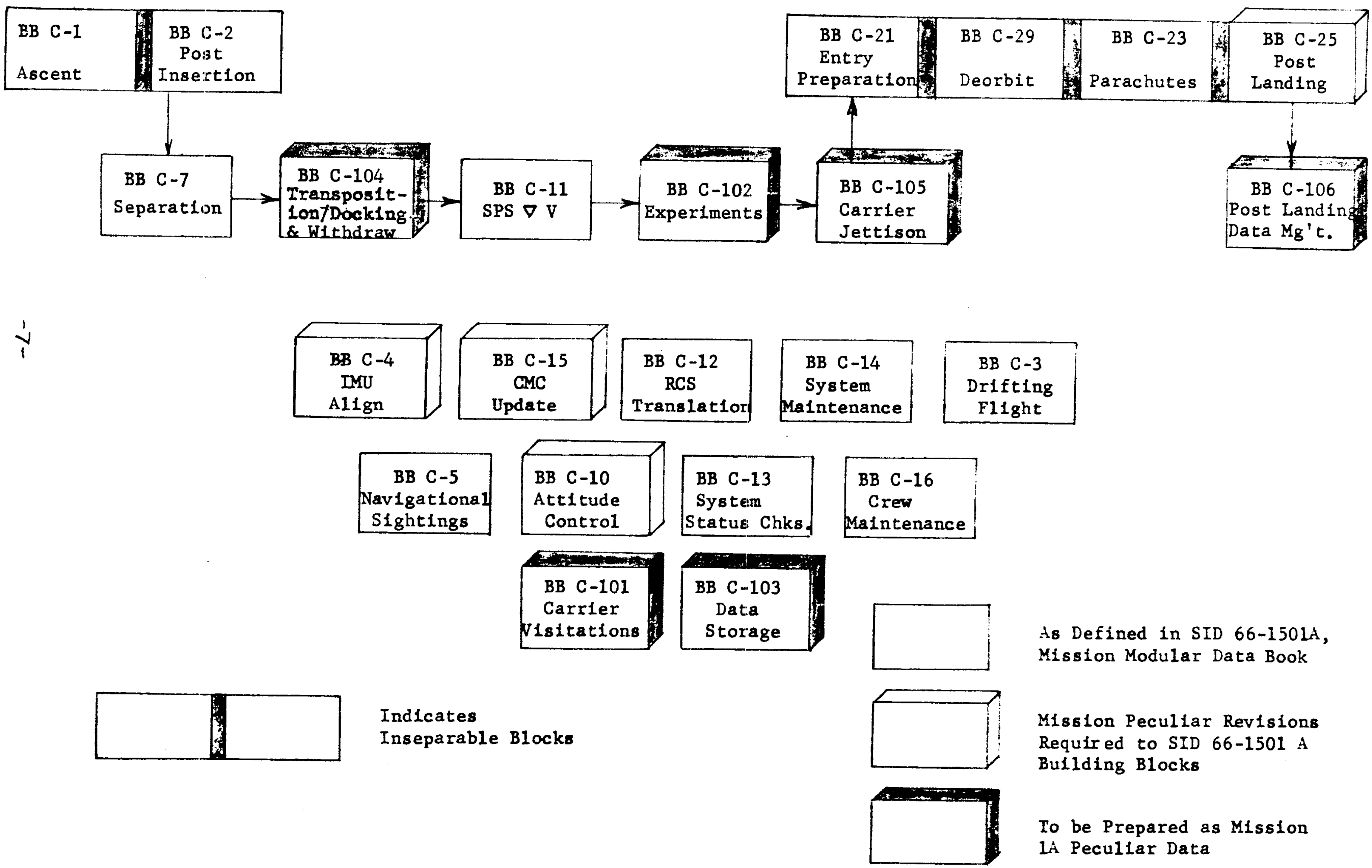


FIGURE 2

Typical Mission Sequence For
Standard Applications Experiments

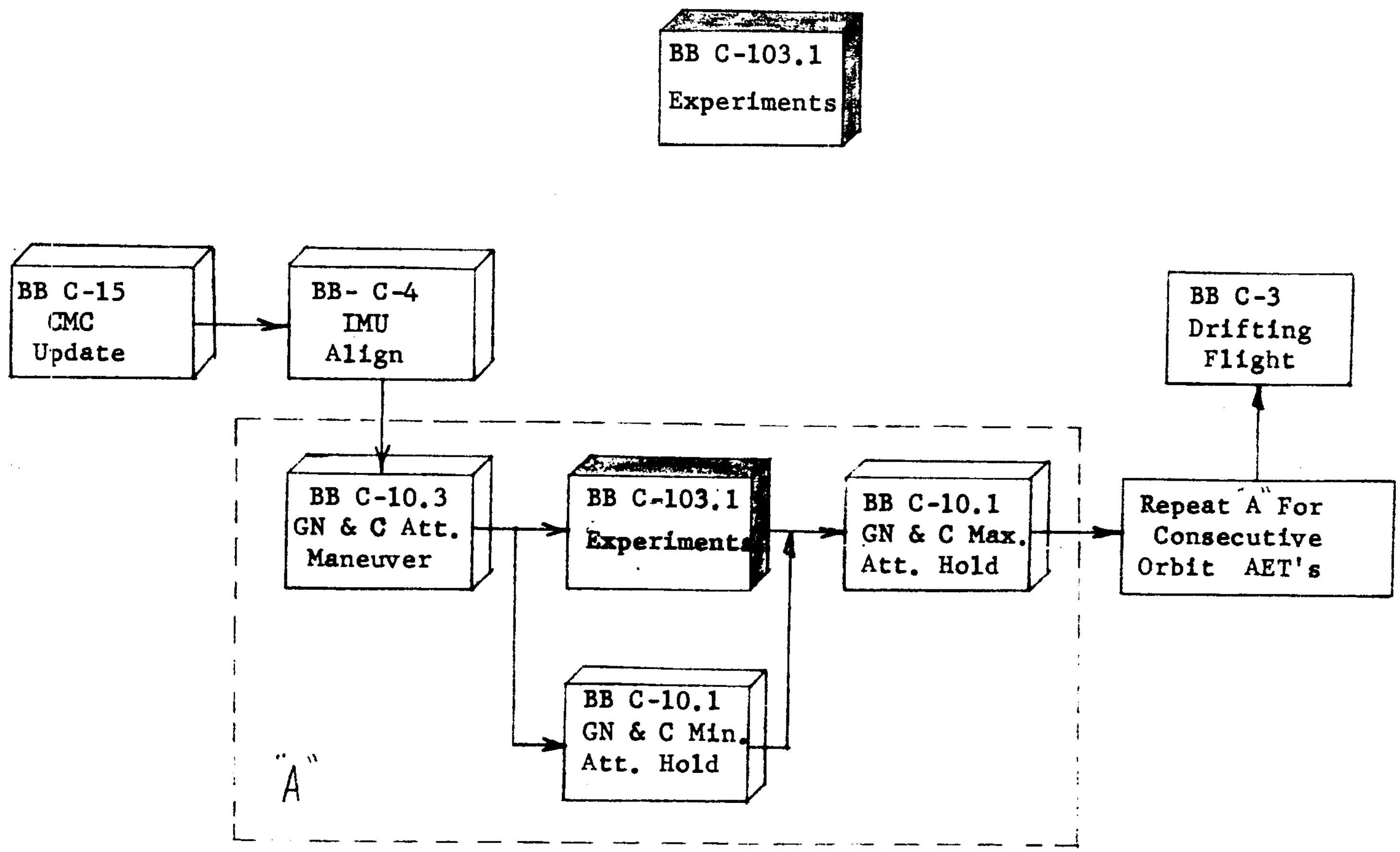


TABLE 1

MISSION 1A BUILDING BLOCKS

100. Mission 1A Peculiar
  101. Carrier Visitation
    101.1 Activation
      101.11 Pressurization/Entry
      101.12 Electrical Connect, D&C Preps
      101.13 Probe & Drogue Source
      101.14 S019, S020 Alignment
      101.15 Airlock Preps
      101.16 Secure for Intermediate Mission
      101.17 Pointing & Tracking Scope Mount and Checkout
    101.2 Experiment Operations (Internal to Carrier)
    101.3 Data Retrieval
  102. Data Storage
    102.1 Intermediate Storage in CSM
    102.2 CSM Storage Secure for Reentry
    102.3 Transfer to Carrier
  103. Experiments
    103.1 Standard Applications (E06-11, S042, E06-1, E06-7, E06-9, S044A, S048, S043, S065)
    103.2 S019
    103.3 S020
    103.4 T004
    103.5 S018
    103.6 S017
    103.7 T002
    103.8 D009
    103.9 S016
    103.10 D017
    103.11 Continuous (T003, D008, S015)
    103.12 Continuous (S044, S048)
    103.13 S043
    103.14 S039
    103.15 S040
  104. Transposition/Docking and Withdrawal
  105. Carrier Jettison
  106. Post Landing Data Management

PR 29-14

CREW EQUIPMENT AND CARRIER ILLUMINATION STUDY

AAP/PIP Mission 1A

Contract NAS 8-21004

14 September 1967

Prepared by W. Carmean
W. Carmean

Approved by J. T. Keeley
J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

This study was conducted to establish the preliminary requirements and identify potential solutions for the provisioning of crew equipment and carrier illumination. MMC proposes to maximize the utilization of existing hardware by commencing the effort with the evaluation and test of those systems considered candidate for the 1A mission requirements. The evaluation and design of crew equipment will be closely coordinated with the evaluation of existing experiment configuration, and the development of new experiment design to ensure maximum compatibility between crew and equipment.

2.0 SUMMARY

This report defines the equipment required to support the crew during activities within the carrier. Main-line Apollo components such as the space suit assembly, oxygen umbilical, flight coveralls and cobra cable are identified in addition to newly required equipment, including crew and equipment restraint assemblies and special tooling, the quantity, periods of usage, current status and configuration are presented, trade off considerations are discussed and the recommended approach or configuration is denoted where sufficient knowledge is available to warrant a selection.

A preliminary carrier illumination evaluation follows the crew equipment presentation, lighting intensity, source location, control requirements and safety considerations are discussed.

3. CREW EQUIPMENT

This study encompasses the equipment required to support the crew during experiment oriented operations. Both existing mainline Apollo components and newly defined hardware are evaluated. MMC has attempted to confine the study of existing mainline equipment to those items providing primary support during the experiment duty cycle. These are the space suit assembly, flight coveralls, oxygen umbilical and cobra cable.

The equipment identified for use by the crew during operation of the experiments in the carrier, data retrieval, crew transfer between vehicles, and equipment stowage, is listed in Table 1. Also shown, is the anticipated usage of subject equipment relative to flight phase, quantity required, and development.

3.1 Space Suit Assembly

For the AAP 1A flights, MMC anticipates usage of the Apollo Block II A7L suit. As presently defined, this suit incorporates a single shell non-visored helmet plus an integrated thermal meteoroid garment at the torso, arms, and legs. Usage of the over-garment (TMG) for the helmet, boots and gloves or connector over-patches is not recommended in that primary thermal/meteoroid protection will be provided by the carrier.

Operational pressure of the suit assembly is nominally 3.7 psi. All normal mode operations requiring the suit assembly specify a soft-suited condition with a suit pressure of 0 to 0.1 psig.

Problems imposed by employment of the suit include: (1) Inaccessibility of the eye for direct viewing through the sextants and viewing scopes associated with the baseline experiments; (2) Degraded mobility and dexterity resulting from the suit encumbrance of the body; and (3) Additional time required for suit donning, doffing, retrieval, stowage, checkout, and maintenance.

Table 1 Crew Equipment Requirements

Description	Qty	Usage	Development Status	
			GFE	CFE
Space Suit Assembly	3*	Worn during launch, reentry and specified periods of orbital flight.	X	
Flight Coveralls	3*	Worn during specified periods of orbital flight.	X	
Suit Oxygen Umbilical	3**	Provide oxygen for respiration and ventilation during suit usage.	X	
Cobra Cable	3**	Provides communications and biomedical link during all flight operations (both suited and shirtsleeved).	X	
Crew Worksite Restraints	1 set per worksite	Used during crew activities at specified locations in the carrier.		
Data Package Worksite Restraints	Not defined	Used to tether components at carrier worksite prior to installation or after retrieval.		
Crew and Equipment Translational Tether	1 assy	Provides restraint for crew and equipment during periods of transfer between the CM and carrier.		X
Data Package Stowage Restraints	Not defined	Provides restraint for stowage requirements in both the CM and carrier.		X
Special Tools	Not defined	Used to implement D&C panel retrieval and CM mounting, and data package installation, retrieval and stowage as required.	X	

* No modifications anticipated for garments worn by crewmember involved in carrier operations.

** Extension of right couch assembly required to nominal 12 foot for baseline carrier operations.

3.1 (continued)

Recent discussions between MSC and MMC indicate a desire to reduce suit usage after the carrier and CM/carrier interface pressure integrity have been ascertained.

No suit modifications are anticipated for the 1A mission. It is assumed that the crew restraint assembly worn during carrier activity will interface the suit with a belt or harness assembly.

3.2 Flight Coveralls

The flight coveralls will be worn by the crewmembers during duty periods not requiring usage of the A7L suit assembly. Additional information is needed by MMC to determine coverall donning and doffing time and the sequence employed. It is not presently known whether the coveralls will be worn during sleep periods.

It is recommended that the hard hat be worn for all carrier operations permitting a shirtsleeve mode.

Sizing adjustments of crew restraint harness assembly should allow its usage with either the pressure suit or flight coveralls. No modifications to the flight coveralls are anticipated.

3.3 Suit Oxygen Umbilical

The oxygen umbilical designated for use at the right CM couch, longest of the three provided, measures 119 inches. Access to the experiment truss assembly in the baseline carrier will require lengthening of this umbilical to approximately 144 inches. Alternate provisions such as incorporation of a suit oxygen supply station in the carrier are not considered compatible with the carrier design philosophy.

3.4 Cobra Cable

For both suited and shirtsleeve operations in the carrier, the cobra cable is the primary system available for voice communications and biomedical measurements. It links the CM bulkhead connector with the biomed harness and the communications soft hat. As in the case of the oxygen umbilical, the cobra cable must be lengthened to approximately 12 feet to permit experiment access at the carrier truss.

Alternate considerations for voice communications and biomedical monitoring would entail a carrier mounted station employing its own umbilical. This system would require CM interface thru the existing pin connectors at the tunnel ring flange. Weight, volume, schedule and cost constraints would favor extending the existing cable connector to addition of a carrier substation.

3.5 Crew Worksite Restraint

MMC recommends the rigid worksite restraint as superior to a single tether mode requiring one handed operation. Experiments S019 and S020 will require crew activity at a single location for periods approaching four hours. Viewing requirements thru the S019 and S020 scope as well as the S019 prism change necessitate complete body stability.

The activities anticipated at the experiment truss include installation and retrieval of S016 at the airlock, reload of the film cartridges on the six E06-4 cameras, retrieval of T002 and D009, plus stowage of experimental components and expendable equipment prior to carrier deactivation. These tasks also would indicate an advantage for rigid crew restraint to minimize crew fatigue and reduce time expenditure.

3.5 (continued)

Three assemblies are foreseen for the worksite restraint system. These are carrier tether, connector, crew attachment harness and foot stabilizer. Figure 1 presents a conceptual illustration of this system. A more thorough analysis is required to determine whether the tether member should be attached to the carrier or the crew assembly during storage. If normally attached to the carrier, the crewman could disconnect them from the carrier hard attach point and transfer them to each worksite as required. Or a separate set of tethers might be provided at each station which sould not be removable from the carrier structure. In the latter case, the tether members could be set at the prescribed length (assuming this adjustment is required) prior to launch. If all activities at each worksite could be accomplished without additional tether adjustment crew time and energy would be conserved.

If the tether members were not detachable from the torso harness assembly, additional volume would be required for stowage. However, should more than hand contact with the translational assembly (rail) be required during equipment transfer between the vehicles, the tether members could provide the additional restraint. The latter case would require a connector such as a slip ring or sliding socket for mating with the translational structure.

An additional consideration for the torso harness assembly is donning location. If CM volume limitation requires stowage in the carrier it is recommended the location does not require total entry for retrieval. It is believed the preferred donning location would be the CM for two reasons; first, the CM couches could provide temporary support to the crewman donning the harness assembly and second, the other crewmen located in the CM could assist in the procedure. The CM is recommended for stowage as well as donning and doffing .

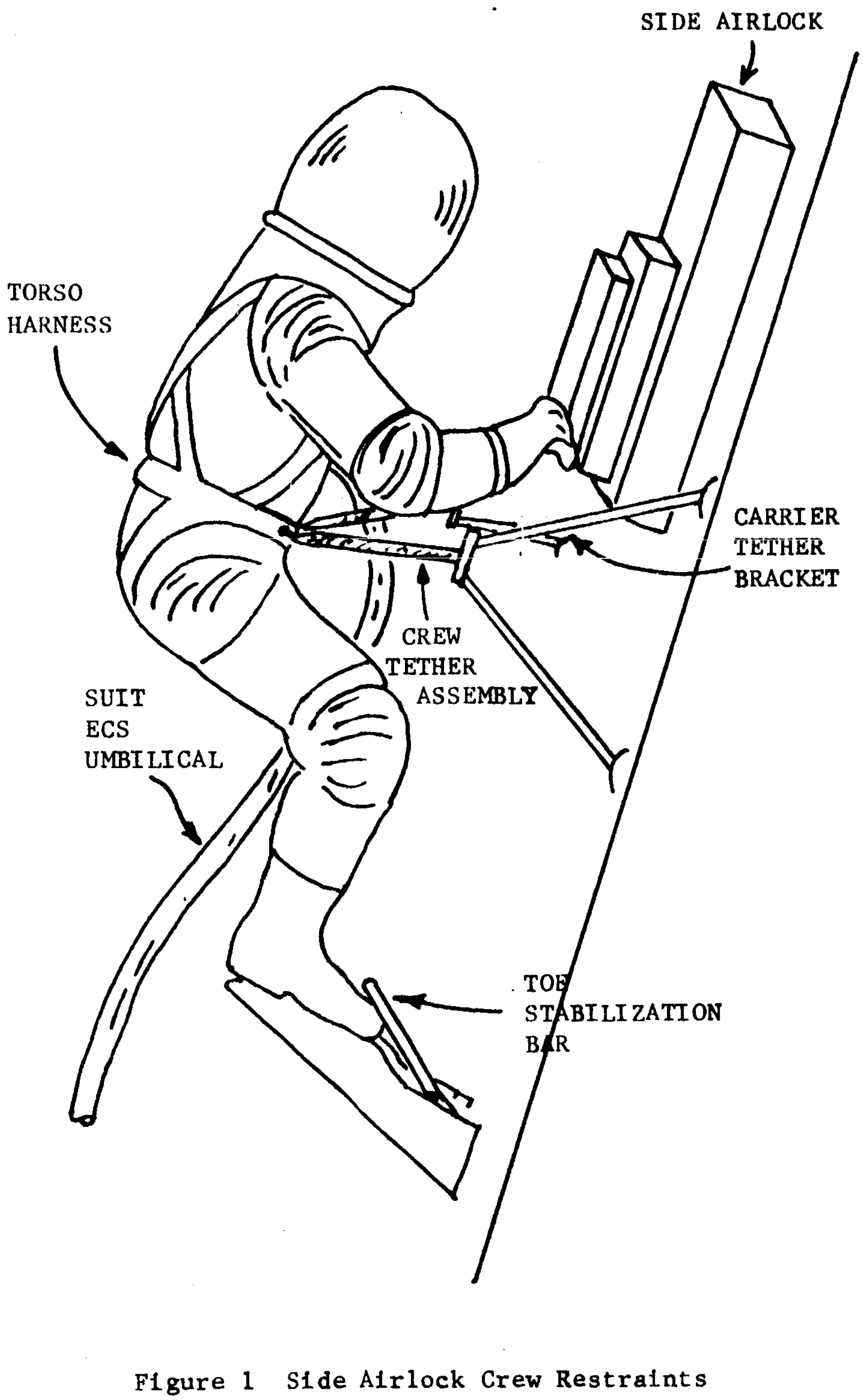


Figure 1 Side Airlock Crew Restraints

3.5 (continued)

Hardware to be considered for tether to wall attachment is, of course, dependent on the selection of either the permanently attached, or removable assembly. A ball and socket or hook and eye would be candidates for the permanently attached configuration. Removable tethers require a means for crew control which could be easily grasped, connected or detached. MMC has evaluated a pip-pin and socket assembly which provides an L-shaped handle on the pin for operator control. The socket may utilize a star slotting arrangement which could lock the pin at as many as eight different attitudes about the centerline of the shaft. On the other hand, a free rotation of the pin could be provided by deletion of the slot and key arrangement.

Tether attachment at the crew harness assembly must provide ease in connection or detachment if the tether members are to be permanently installed to the carrier structure. Some freedom of motion may be desirable at the harness interface, however, more detailed evaluation by simulation must be accomplished before these requirements can be established.

A foot stabilization assembly would provide the third point of restraint and is considered necessary for complete body stability. Several systems have been investigated which offer promise for this application. These include the "Dutch shoes" used on GT-12 and a compression bar which would press the foot against a base plate or platform.

MMC will evaluate all existing and proposed restraint systems which are considered candidate with respect to the requirements for stability, confort, ease of operation, and compatibility with the carrier configuration. Currently among the candidates are the Gemini 12 restraint (including Dutch shoes), GE variable restraint, tension reel tether, tubular restraint, and rigidized anchor points.

3.6 Data Package Worksite Restraints

To provide restraint at the worksite and during translation to and from the worksite a tethering system will be provided. Several methods have been studied for the transfer of components between the CM and carrier. One method incorporates a channel or rail mounted to the inner wall of the carrier. (Ref. Section 3.7). Where not more than two components are to be transferred they may be tethered directly to the crewman while in the carrier. The crewman could then translate to the workstation by grasping a series of handles. In either case, because of the limited size of the tunnel section adjoining the CM and carrier, the crewman must pass the components thru the tunnel section before he enters or receives them after his passage.

At the workstation, if film reload or component replacement is required, the package to be installed must be tethered during removal of the unit already emplaced. Conversely, temporary tethering is required for the component just removed, while the second unit is being installed. This temporary restraint may be provided by direct attachment of the crewman or by affixing the component to an attachment on the carrier structure adjacent to the worksite. Depending on the size of the packages and method of attachment, direct tethering to the crewman may encumber his mobility. Another consideration would be the distance of the workstation from either the CM tunnel entrance or the translational assembly if the latter were incorporated. If either were within arms distance from the workstation the crewman could transfer or receive the component directly after removal or before installation.

For equipment requiring more than one tether connection point in the carrier, the interfacing hardware on the data package side must mate with all carrier connectors whether used for fixed point or translational restraint.

3.7 Crew and Equipment Translational Tether

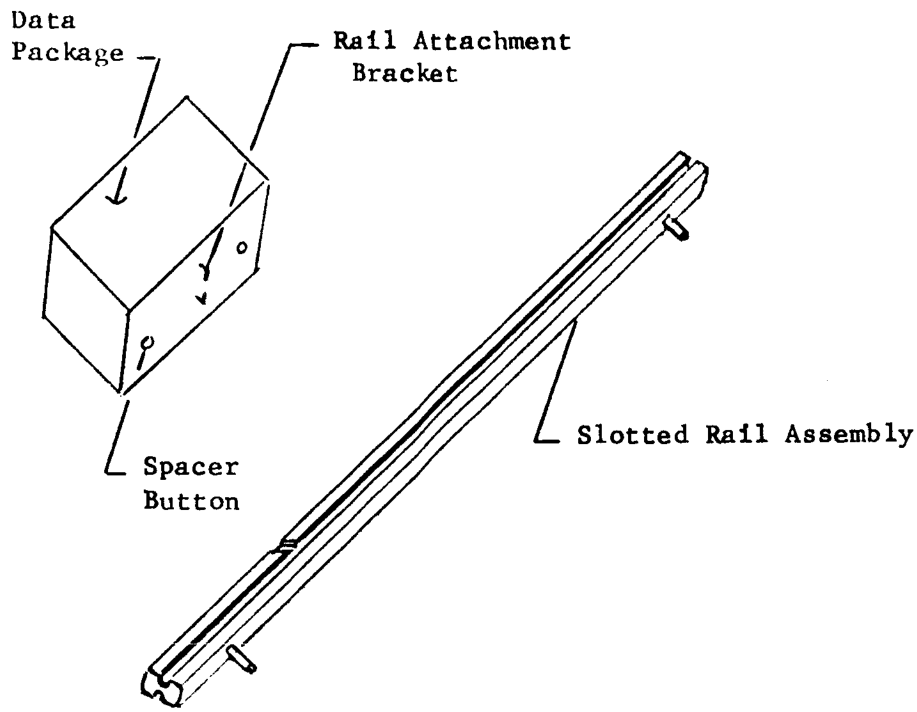
As noted earlier, several methods have been studied for the translation of both crew and equipment between the CM and carrier. The more simple system, obviously, would require direct tethering between data packages and crew, and would require a series of handles located on the carrier structure for crew movement. This approach, however, is not as satisfactory when more than one component must be transferred or when the size or shape of a component makes it difficult to handle.

This analysis was not confined to the experimental components and film cassettes, but included expendable equipment such as the probe and drogue assemblies and L:OH canisters which may be transferred to the carrier for final stowage. All components must be evaluated during the simulation program before the preferred method for translation can be determined.

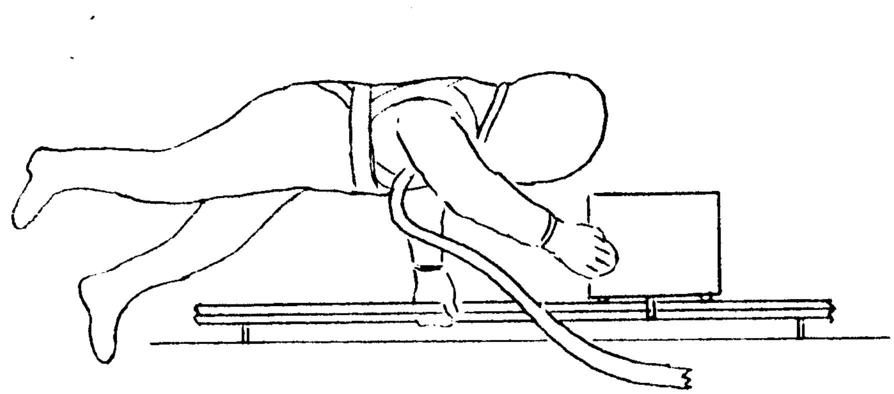
Figure 2 depicts a rail assembly developed by MMC originally for incorporation on the AEP structure at the SM. This device incorporated a universal adapter mounted to each transferrable component that mated to the rail. Subsequent study indicates a requirement for a removable mounting adapter to facilitate stowage of the components. If used on the carrier this assembly would probably require an extendable member similar to that proposed for the AEP which would provide component restraint thru the carrier/CM tunnel interface. This would facilitate access by the standby crewman in the CM. As designed for the AEP, the assembly is normally stowed flush with the mounting wall. Prior to use, the unit is deployed from the stowage position placing it approximately 3 inches from the mounting surface. The force for motion along the rail may be supplied directly by the crewman pushing the components before him or by a tension member operated from either end of the rail.

3.8 Data Package Stowage Restraints

The hardware provided for tethering the components during carrier operations may also serve as the primary restraint for the article for stowage, prior to and during reentry. MMC proposes a detailed stowage management study during which the stowage location for all transferrable equipment will be selected. The results of this study will be integrated with the equipment restraint evaluation to establish the optimum method for securing the subject hardware.



CREW AND EQUIPMENT TRANSLATIONAL ASSEMBLY (RAIL)



DATA PACKAGE TRANSFER ON RAIL

Figure 2

3.9 Special Tools

The current study has not been conducted in sufficient depth to determine the requirements for special tooling. In keeping with the overall design philosophy of the 1A carrier, all newly required hardware including film cassette fasteners and restraint hardware, will be designed for ease of operation. This hopefully, will preclude a requirement for any special tooling or crew aids. Should the operation necessitate special equipment, MMC will evaluate all existing mainline Apollo provisions for their application to the 1A carrier requirements.

4. CARRIER ILLUMINATION

A preliminary analysis of illumination requirements for the carrier indicates a lighting intensity of 20 to 30 foot candles for general activities is desirable. This lighting must be of a flood type provided by fixtures mounted to the carrier structure. A minimum of four sources are anticipated for overall illumination with augmentation provided by adjustable localized lighting positioned at the worksites. The localized light sources would negate the shadowing produced by the crewman and equipment which he is handling.

Transmission characteristics of the light source must be commensurate with the colors of the components when viewed thru the helmet visor. The lens and bulb assemblies must be constructed to non-breakable material and sealed from the ambient atmosphere.

To eliminate light reflection a flat pastel finish is recommended for the interior surfaces of the carrier pressure vessel, as well as the experiment components and fixtures installed within. When color coding is utilized shades should be sufficiently constrasted to provide quick identification.

Controls for carrier lighting must be located as near the tunnel entry as possible to facilitate accessibility without requiring total crew entry. If the D&C panel is stowed in the carrier during boost no advantage is anticipated by locating light control at the D&C panel. This assumes that CM tunnel lighting will be sufficient for probe and drogue removal, electrical plug connections at the CM/carrier docking interface and carrier hatch disengagement.

4. (continued)

MMC will evaluate candidate light sources, intensity requirements, shadowing, surface finishes, control panel location and safety considerations during the Phase D simulation program.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Crew Equipment

A rigidized 3 point tethering system is recommended at all carrier worksites where equipment installation and removal, and experiment monitoring and control are required. Existing crew restraint systems which meet the stabilization requirements should be evaluated for their application to the 1A mission. Candidate systems must be incorporated into the simulation mockups to confirm design and operational compatibility with system requirements. Where possible, component tethering attachment hardware should be standardized with crew tethering hardware to provide commonality of operation.

If required, the crew and equipment translational assembly should provide a minimum of interference to crew mobility and equipment access within the carrier. The rail mounting hardware, if applicable, should be of a single design, and removable from the attached components to facilitate stowage.

It is recommended that the crew tether harness assembly be stowed and donned in the CM. A standby crewman should assist the primary crewman (selected for carrier operations) in all activities pertaining to the transfer of data and equipment between the CM and carrier.

Special tooling and crew aids will not be required for data retrieval and installation or equipment stowage unless task performance is appreciably simplified or significant time can be conserved.

5.2 Carrier Illumination

A detailed evaluation utilizing the Phase D mockups is required to establish the location of light sources, light intensity, control requirements, and compatibile interior surface finishes.

PR 29-15

PHASE D SIMULATION PLAN

AAP-PIP MISSION 1A

Contract NAS 8-21004

September 14, 1967

Prepared by: J. T. Keeley

Martin Marietta Corporation
Denver Division

1.0 INTRODUCTION

This report identifies the primary crew interfaces with the 1A mission spacecraft, carrier and experiments which require verification prior to flight. Only those areas of simulation unique to this mission are covered. It is intended that mainline Apollo simulations would incorporate minor changes occasioned by this specific mission in preparation for the 1A flight.

2.0 SUMMARY

A preliminary phase D simulation program was identified for on orbit crew operation in the Command Module (CM), carrier, and prelaunch operations for the pressurized carrier experiments. CM simulations unique to the 1A Mission include display and controls evaluation, window visibility and target acquisition, experiment flight operations, attitude control and RCS propellant management, equipment and data stowage, and transposition docking and separation from the SLA. Carrier simulations are identified for crew activities in the pressure chamber and include work site configuration and restraint evaluation, experimental equipment configuration evaluation, crew equipment requirements, scientific airlock operation, carrier entry, pre-jettison, and contingency procedure, crew and equipment translation, tethering evaluation and preliminary timeline validation.

Ground operations for experiments requiring on-pad access will also be checked.

Available facilities at MSC, MMC, and NAA were considered whenever available.

3.0 DISCUSSION

3.1 Approach

Astronaut interfaces with the spacecraft, carrier and experiments for the first AAP mission - 1A must be verified as early in the development program as possible to assure maximum crew compatibility and mission success. MMC has emphasized the need for three dimensional visualization of the design and operational characteristic which affect flight crew capability and performance. The preliminary plan described in this report identifies the areas of simulation required for astronaut operation and control of the CSM, carrier and experiments, operations with the scientific airlocks, data cassettes and CSM-carrier stowage management. These areas of activity are then identified with simulation requirements and known facilities available, both government and contractor, to accomplish the task. A building block approach is utilized which proceeds from the simplest 1G approaches on IVA for example through neutral buoyancy to zero G aircraft in order to minimize simulation costs while maintaining program time conscious activities to verify analyses and candidate designs of the carrier and experiments, and concurrently to develop operating and contingency procedures for their use.

3.2 Simulation Activity

3.2.1 Simulation Categories

The 1A mission simulation activities are classified in the following categories:

Command Module IVA (1A Peculiar)

- Displays and Control Evaluation
- Window Visibility and Target Acquisition Pointing and Tracking Operations
- Experiment Flight Operations
- Attitude Control and RCS Propellant Management Operations
- Equipment and Data Stowage Management
- Transportation Docking and SLA Separation Operations

3.2.1 (Continued)

Carrier Pressure Vessel IVA
- Work Site Configuration and Restraint Evaluation
- Experimental Equipment Configuration Evaluation
- Crew Equipment Requirements
- Scientific Airlock Operation
- Data Cassette Retrieval Operations
- Entry Procedures
- Pre-jettison Procedures
- Contingency Procedures
- Crew and Equipment Translation & Tethering Evaluation
- Preliminary Timeline Validation

Ground Operations Simulation
- On-Pad Experiment Accessibility

3.2.2 Implementation Considerations

The operating modes, and facilities for fulfilling the simulation activities above include the following:

3.2.2.1 Modes of Crew Operation

- Shirt Sleeve Environment
- Pressure Suit Unpressurized (if visored helmet is used)
- Pressure Suit Pressurized to Ambient Pressure and Operated Closed Loop to CM ECS Suit Loop.
- Pressure Suit - Pressurized to 3.7 psig and Operated Closed Loop to CM ECS (This is only for contingency modes)

3.2.2.2 Facilities/Equipment

- 1G Full Scale Carrier and Equipment (ground based) MSC-MMC Simulation - Some with 6 degree of freedom simulation
- Neutral buoyancy simulators - MSC/MMC
- Block II CM Crew Station Mockups MSC/NAA
- Block II CM Crew Procedures Trainers MSC
- Apollo Mission Simulators (AMS) MSC
- Experiment Mockups/Engineering Prototype/MSC/MMC/ Training Articles - Full Size
- CM Flight Controls, SCS/RCS Computer Simulation Facility MSC/MMC/NAA

3.2.2.2 (Continued)

CM Docking Facility MSC/MMC
1/10 Scale Models of CSM, SCA, Carrier and Experiments MSC/MMC
Stowage Mockups 1/5 and full scale MSC/GE/MMC

3.2.2.3 Locations

- NASA-MSC
- NAA-Downey
- MMC-Denver
- Other-Experiment Hardware Contractors

3.3 Command Module IVA Simulation

3.3.1 Display and Controls Evaluation

MMC has prepared a preliminary full size D&C panel mockup during the two month study period for visualization and preliminary fit checks inside the CM mock-up at MSC. Initial checks indicate either contouring to available areas or perhaps relocation should be considered. Continuing effort will provide the most suitable panel shape, identifying mounting location, and configure the panel face for crew convenience. The D&C panel mockup will be updated and returned to MSC for further checks including combined visual target observation and preliminary procedures checkout.

3.3.2 Window Visibility, Target Acquisition, Pointing and Tracking

The primary crew station for experiment operation using the 1A D&C panels and for spacecraft attitude control and pointing are in the right and left CM couches. The only data available during the study was an NAA test report over a year old. An early verification of the study results must be made using an accurate full scale CM mockup with accurate CM window frames, carrier structural members and couch positions to determine the operating procedures for both command pilot and pilot during target overflight. A fixed or moving base simulator with a controlled earth scene enabling both forward on-track and nadir viewing is desired in continued simulation.

3.3.3 Experiment Flight Operations

The D&C Panel described above will be utilized both for table top run through of experiment procedures and mission timelines and for confirmation checks with the panel in the CM crew station mockups or procedures trainers. Viewing procedures described will also be incorporated in later simulations and combined with the experiment/subsystem and communications activities in complete sequences for pre, during and post target overflights.

3.3.4 Attitude Control and RCS Propellant Management

Simulation of crew operations with dynamic attitude control, spacecraft response and RCS propellant management evaluation (by individual quad thrusters) is necessary for verification of both manual and automatic control modes. Since all flight control will utilize the SM propulsion systems, the experiments require only RCS utilization, normally operated from the CM couches, the G&N station in the LEB or potentially from the airlock areas in the carrier using an extended cable hand controller. Typical control functions to be simulated include the local vertical attitude hold either generated by the CM computer or by a horizon scanning system providing crew displays for manual control. The S017, 19 and 20 experiments require spacecraft orientation based upon star or sun sensors with light matrix or analog displays for the crew, as well as attitude based on visual alignment of the S019 and 20 telescopes during target operations. MMC has recommended initial boresighting of the S020 and the G&N scope to a common target, which then permits use of the more convenient LEB work station, which already includes the RCS minimum impulse controller, for solar tracking. A sun sensor eyeball, providing a visual display on the panel, perhaps similar to the S017, if used, would also require this simulation.

The facilities required for these simulations may include simple crew stations, analog computers, and cathode ray visual images for the S017, 19, and 20 and horizon sensing verifications to specialized SCS/RCS systems such as the Honeywell system at MSC in the G&C facilities. More involved operations may require the combined crew stations, digital computer, and individual viewing presentations of the Apollo Mission Simulators for final confirmation.

3.3.5 Equipment and Data Stowage Management

Initial simulation may utilize Block II CM mockups at MSC or NAA for fit checks and procedures checkout. However, since mainline Apollo has a well defined stowage management program, it is expected that the 1A flight peculiar equipment, cassettes and transferables, would be identified and included in this mainline activity at an early date. Usage of the GE 1/5 stowage model at MSC or a similar item would provide an early understanding of equipment movement, placement, and location during all mission phases.

3.3.6 Transposition Docking and SLA Separation Operations

The 1A carrier/CM docking interfaces are identical or similar to the LM in all areas identified. However, the docking ring interface will be about a foot lower into the SLA than LEM, docking targets will be located about the same, and roll orientation (docking) during docking will require more precision than LM does. MSC will determine those changes and modifications required to the existing CM-LM docking simulator and also any procedural changes necessary to accomplish the docking operation. Crew operations in the tunnel will be covered under the carrier discussion, paragraph 3.4.6., CM un-docking and separation from the SLA would also be accomplished in this docking simulation.

These CM simulations combine the unique 1A mission requirements and should be interleaved with the on-going mainline Apollo simulations wherever possible to minimize costs and duplicate activities. Where existing schedule commitments require usage of auxiliary facilities, this must be identified early so immediate action can be taken to prepare other facilities and equipment for the required simulations. The consideration of NAA scientific airlock in the main hatch would require updating the Block I ground and zero G aircraft testing as required by the hardware and procedural revisions.

3.4 Carrier Pressure Vessel IVA Simulations

3.4.1 Work Site Configuration and Restraint

MMC constructed a full scale pressure chamber 1 G mockup, Figure 1 and 2, during the study to provide an early verification of the worksite areas for the airlocks, experiment frame and equipment. This mockup will be updated in configuration and incorporate the worksite restraints, harnesses, tether, locomotion and translational aids, illumination, docking connectors and any other required items to verify the analysis and preliminary design identified in PR 29-14, Crew Equipment and Illumination requirements. Preferred configurations will be incorporated in the neutral bouyancy simulators and tested for both shirtsleeve and pressure suited modes.

3.4.2 Experimental Equipment Configuration Evaluation

Since the experimental equipment for the 1A mission includes a wide variety of hardware, some already built, others still in the prototype stage, it is necessary to determine crew and carrier compatibility at the earliest possible time. Preliminary compatibility evaluations have begun at MSC and MMC in table-top reviews of existing hardware such as S019 and 20 and the Hasselblad cameras. Continuing evaluation of individual experiments will be made both on the table and installed in the pressure chamber mockup and neutral bouyancy simulators described above.

3.4.3 Crew Equipment Requirements

Soft suited and shirt sleeve operations are planned for the mission, so that modifications required for the Block II crew equipment must be identified and confirmed to permit hardware changes compatible with flight schedules. Those crew equipment items identified in PR 29-14 will be included in both the full scale mockup and neutral buoyancy simulators.

3.4.4 Scientific Airlock Operations

The NAA Block I scientific airlock was checked during ground and zero G aircraft simulation for installation in the CM main access hatch using the Block I suit. Use of the modified airlock in the 1A pressure chamber

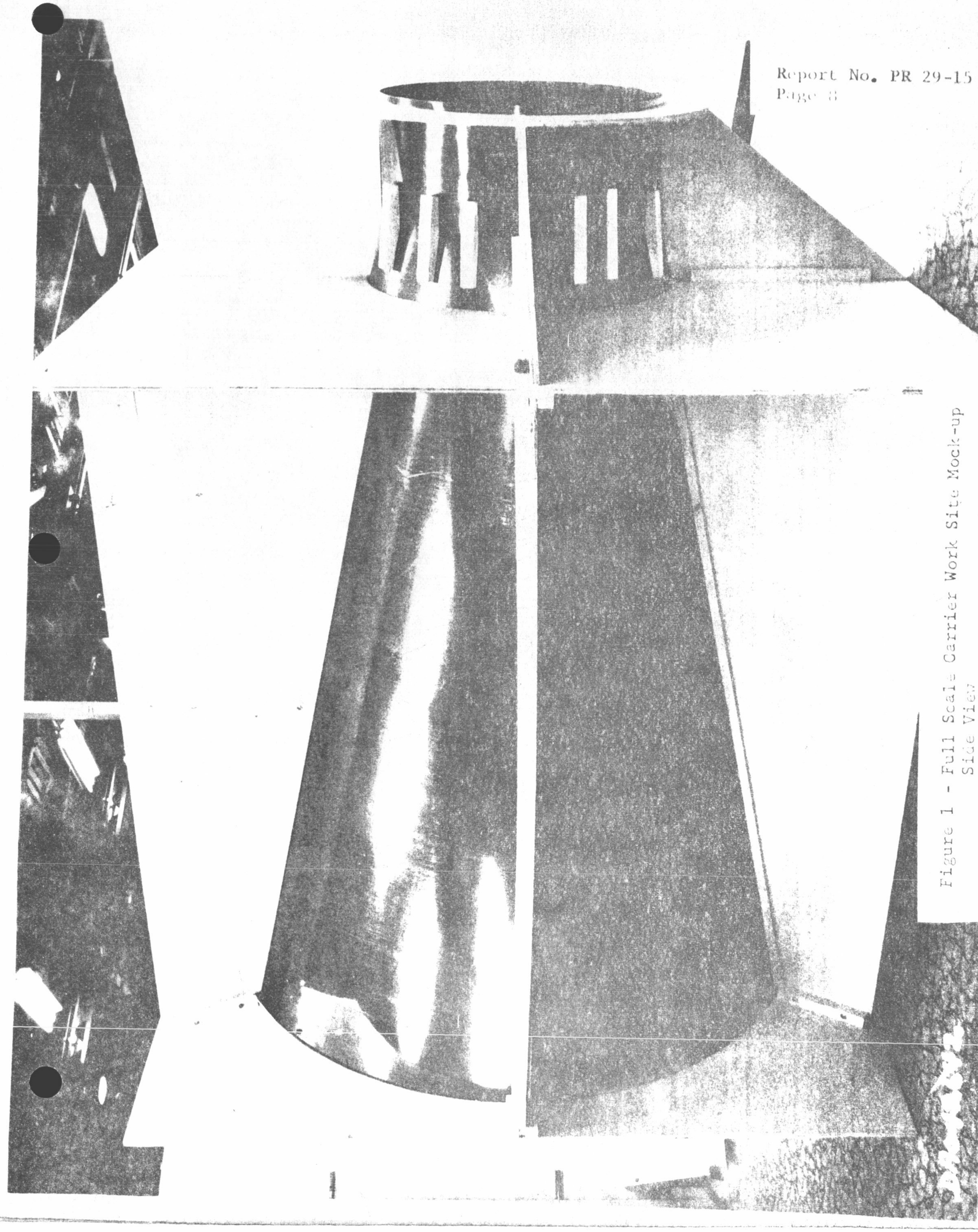


Figure 1 - Full Scale Carrier Work Site Mock-up
Side View

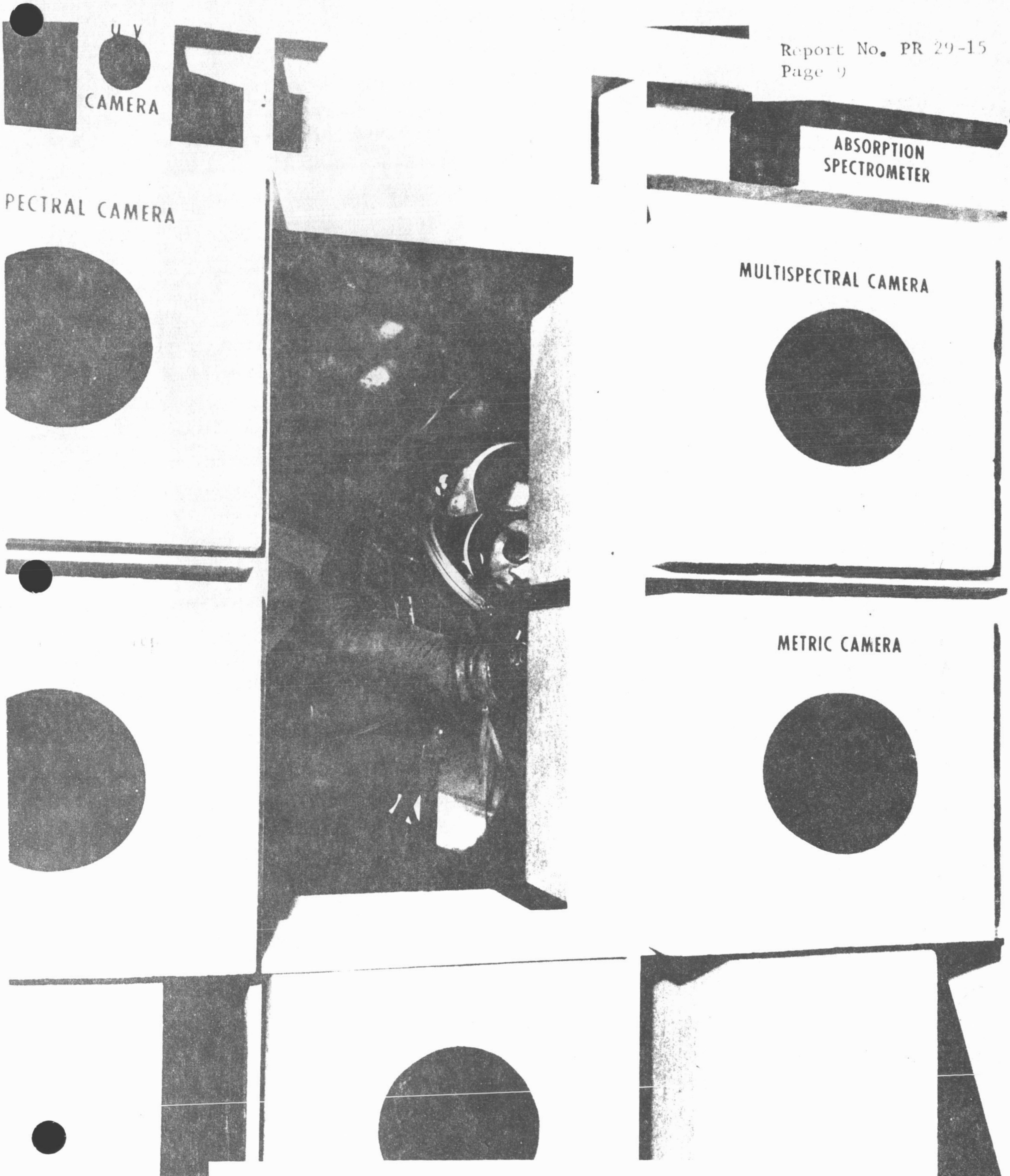


Figure 2 - Full Scale Camera Work Site Mock-up
End View of Experiments Frame with
Suited Crewman at Camera Area

3.4.4 (Continued)

involves use of a new suit, the ILC-A7L with different helmet configuration; a major change in work site configurations and potential modification to the experiments requiring airlock deployment. The actual prototype airlock should be installed temporarily in the full scale carrier mockup and neutral bouyancy simulators for thorough checks of interfaces, and operating procedures both normal and contingency modes.

3.4.5 Data Cassette Retrieval Operations

Each camera has a unique film data cassette configuration, whose fasteners and attachments must be evaluated for glove compatibility with a pressurized suit. Any protective covers or packaging, valve operations or other specialized tasks must also be checked initially for the equipment item itself and later on mockup prototype installed in the full scale mockup, as in Figure 3, and the neutral bouyancy simulator. Use of a 1/10 scale model and model astronaut for convenience and early visualization is shown in Figure 4.

3.4.6 Carrier Entry Procedures Simulation

The initial carrier entry during the transposition docking maneuver will require a CM/carrier interface mockup with the probe and drogue, docking latches, and the several electrical docking connectors in the tunnel. Carrier pressurization from the CM will be a longer process than for the LM and both procedural and hardware changes must be validated. Further study will recommend a facility location to accomplish this task, either at MSC or NAA. Repeat entries will be less complicated without interference from the probe and drogue.

3.4.7 Pre-Jettison Procedures

Carrier jettison from the CSM prior to reentry and earth landing of the crew, will require specific procedures for carrier subsystem and experiment shutdown, and preparation for CSM separation. Normal and contingency procedures will be validated using both the CM crew stations mockup, identified in

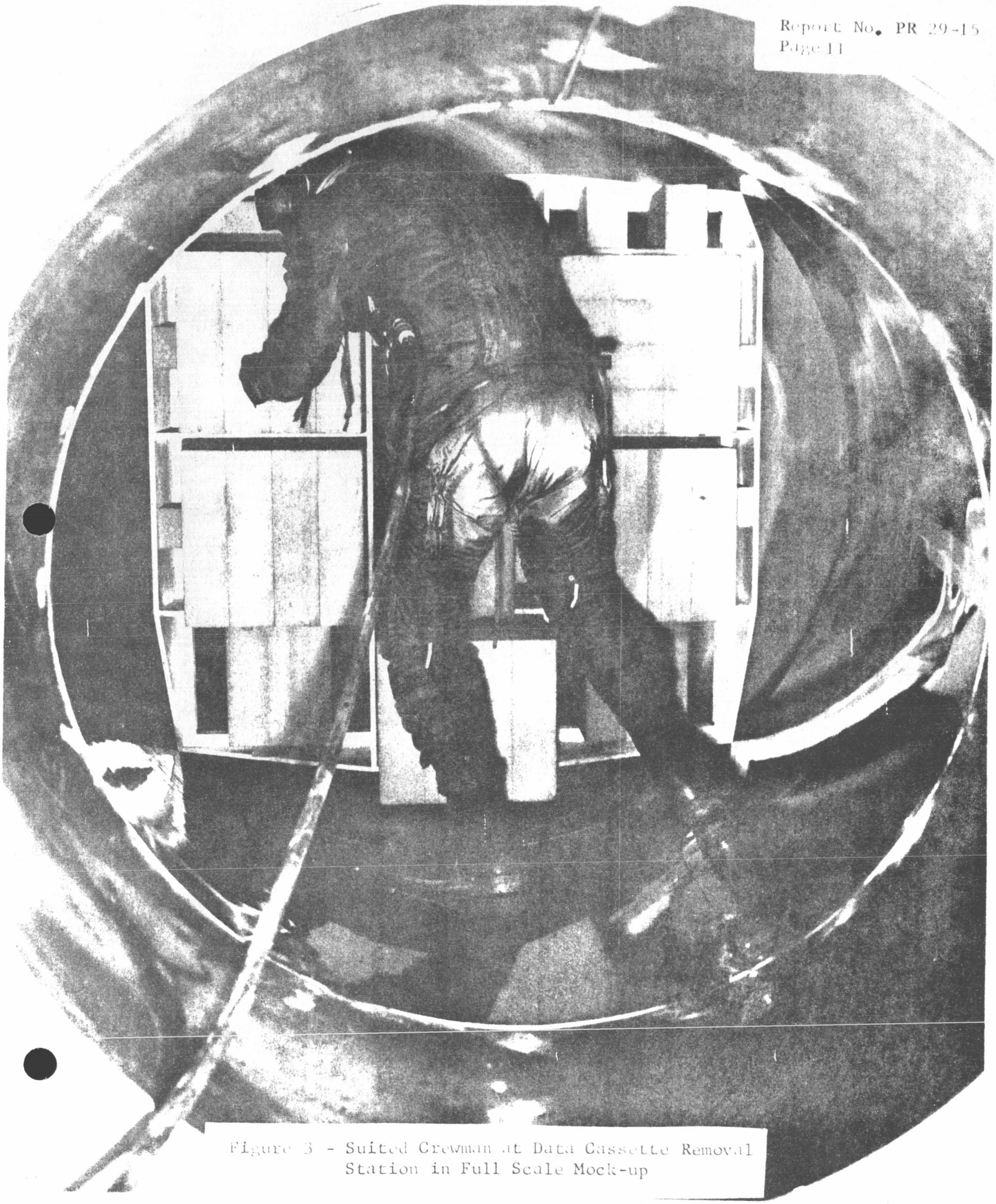


Figure 3 - Suited Crewman at Data Cassette Removal Station in Full Scale Mock-up

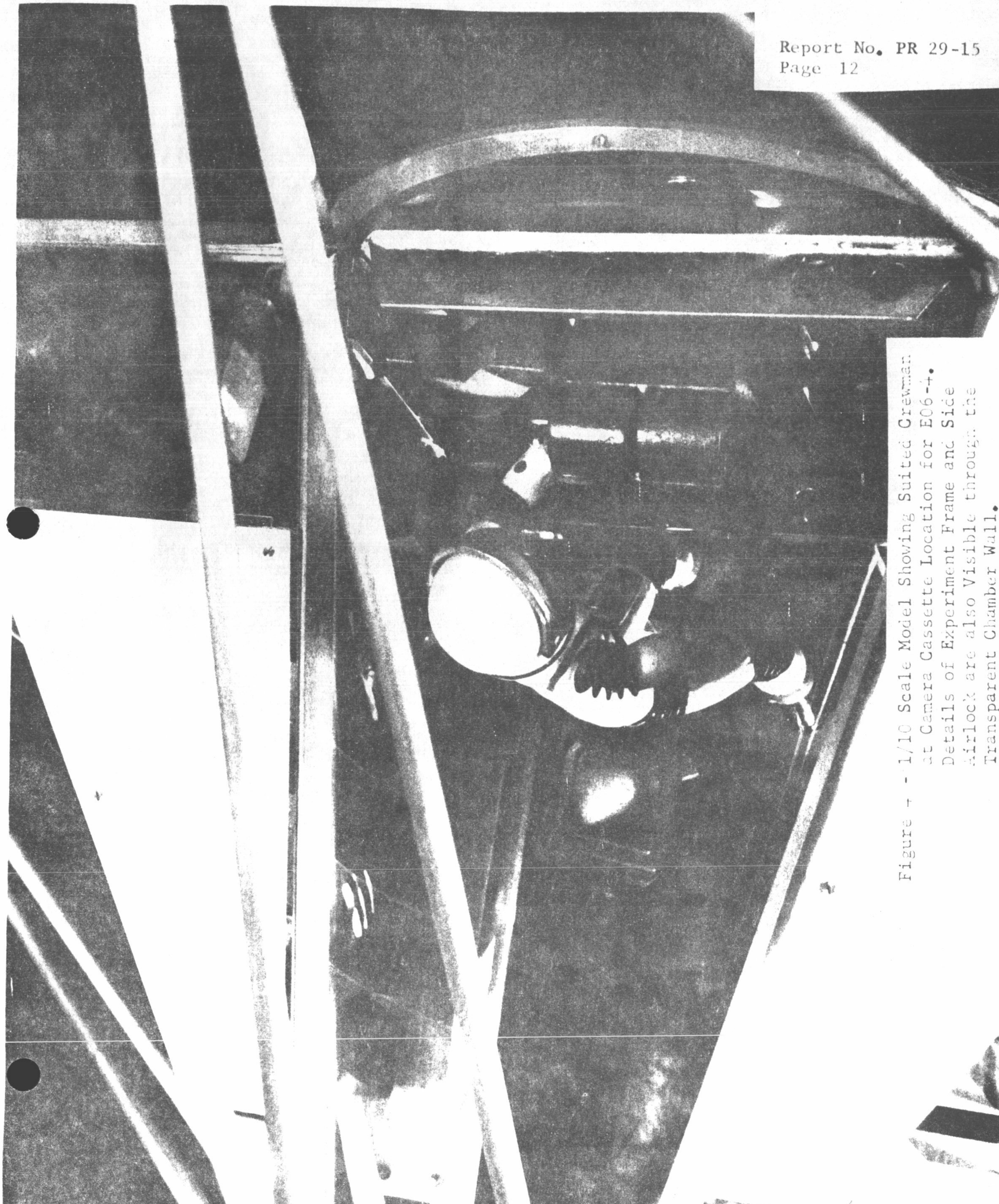


Figure 4 - 1/10 Scale Model Showing Suited Crewman at Camera Cassette Location for E06-4. Details of Experiment Frame and Side Airlock are also Visible through the Transparent Chamber Wall.

3.4.7 (Continued)

Paragraph 3.3.3 for the display and control portion of the procedures and the CM/carrier interface mockup identified in Paragraph 3.4.6 to complete the sequence.

3.4.8 Crew and Equipment Translation and Tether Evaluation

The full scale mockup and neutral bouyancy simulator will include candidate tethers, restraints and mobility aids, defined in PR 29-14, so that an early selection can be made by MSC and MMC personnel and provisions for mountings, support and stowage can be incorporated in the design. Six degree of freedom simulators may be utilized in specific areas where the configuration warrants.

3.4.9 Preliminary Time Line Validation for Standard Operating and Contingency Procedures

In addition to the basic purpose of hardware design validation and crew compatibility, the entire simulation program must provide the validation of assumptions predictions and related experience used to prepare mission timelines. Normal and contingency operations will be evaluated for selected tasks and performance time variations for different subjects throughout the simulation program so that crew procedures and mission timelines may be updated and refined.

3.5 Ground Operations Simulation

3.5.1 On-Pad Experiment Accessibility

Carrier experiments requiring access to the experiment frame after mating with the SLA, either in the MSOB or on the launch pad, will also be evaluated with the full scale mockup in the launch position. Film cassette loading, placement of biological and emulsion samples, and pre-boost stowage of display and control will be typical items checked in this position.

4.0 CONCLUSION

This summary of activities include those areas identified to date for Mission 1A which should be included in an orderly, comprehensive, simulation program, interleaved with related activities on mainline Apollo and definitized and scheduled at an early date. Consideration has been given to available simulators and facilities wherever possible.

PR 29-16

TRADE STUDY REPORT
CM STOWAGE MANAGEMENT
AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

6 September 1967

Prepared by: K. M. Poser

Approved by: J. T. Kuley

1. INTRODUCTION

Many of the experiments selected for the AAP Mission 1-A require CM mounting for the entire mission or CM stowage of the experiment module/data cassettes during re-entry. Mission peculiar or Apollo Mainline equipment may also require stowage in the CM during certain phases of the mission. To determine the capability of the CM to provide the necessary stowage during the various phases of the mission, an analysis of Mission 1-A stowage requirements versus anticipated CM stowage capabilities was prepared. This report summarizes that analysis.

2. SUMMARY

Based on the data available at the time of this study, i.e., the experiments, carrier, and Block II CM configuration, the Mission 1-A stowage requirements fall well within the CM stowage capabilities, both from a weight and volume standpoint. The North American (NAA) "Command Module Return Payload Capability" final report #SID-66-773 provided the basic data for determining the CM stowage capability and loading limitations. Current NAA CM Drawings F01-600002 and 2743-116 for Spacecraft #101, were used to update the study and the minor differences are indicated in the analysis and tables. The total available volume of 38.25 cubic feet in the original study was revised to 33.34 cubic feet from the more recent NAA drawings, whereas only 6.6 cubic feet are required for Mission 1-A CM return payload. CM return payload weight limitations may be met by relocating expendable CM equipment to the carrier prior to CM/carrier separation and CM re-entry. Selected experiment data was obtained from NASA Houston. The current carrier configuration was utilized. Mission planning information developed by other members of the study team was also used. The tabulated results of the NAA stowage study are included in Table 1. Tabulated results of the Martin Marietta Mission 1-A stowage analysis are included as Table 2. An illustration of proposed mounting/stowage locations within the CM is included as Figure 1. Figure 2 illustrates re-entry experiment modules shapes and dimensions.

3. DISCUSSION

The North American Aviation final report, "Command Module Return Payload Capability," #SID-66-773 under Contract NAS-9-5017 was obtained and studied in detail. This NAA study was considered the baseline and new information for Block II CM #101 provided by NAA was used to update the original study. Two sets of drawings, 2743-116, "CM Space Allocation and Equipment Storage-Volume Availability" and F01-600002, "Field Site Installation, Crew Equipment, Block II" were used. The report provides a starting point that analyzes the Block II CM return payload capability from a weight and volume standpoint. Two CM configurations were considered in the NAA report; with and without removal of Block II equipment. Each of the available stowage areas (with and without equipment removal) was identified with the available volume and allowable weight for each area. This information has been summarized, tabulated and included in this study as Table 1.

The selected experiment data utilized was developed by Martin Marietta from information provided by North American, the indifidual experiment contractors and NASA. This data provided experiment dimensions, total volume, weight and on many of the experiment modules, information relative to specific locations for mounting the modules within the CM. These original mounting locations were retained, wherever possible. For those items where the original installation area was retained, additional volume for G-load/vibration packaging protection was not considered; it was assumed to be considered during the original NAA study. However, where new stowage areas had to be selected, an additional one-half (1/2) of the required volume was added to allow for protective packaging.

3.1 Total Volume Comparison - From the NAA study, without any Block II equipment or transferables removed, a total stowage volume of 8.64 cubic feet was indicated. With only transferables (food, waste containers, LiOH containers, etc.) removed from the CM 18.35 cubic feet is available. With both equipment and transferables removed, the NAA study indicates a total available volume of 38.25 cubic feet.

The revised NAA drawings indicate an available volume of 13 cubic feet without removal of Block II or transferable equipment. With only transferables removed to the carrier, 26 cubic feet is indicated. With both equipment and transferables removed, the revised drawings show a total available volume of 33 cubic feet.

3.1 (continued)

Total 1-A experiment module/data packages volume for re-entry stowage in the CM, including an additional 50% for protective packaging is 6.6 cubic feet (Figure 1).

3.2 Total Weight Comparison - Again from the NAA study, without any Block II equipment or transferables removed, structural limitations in early 1966 allowed a total stowage weight of 188 pounds and re-entry parachute limitations allowed a total stowage weight of 131 pounds. Removal of transferables increases the allowable stowage weight to 392.5 pounds. Removal of Block II equipment and transferables increases the allowable stowage weight to 1066 pounds.

The revised NAA drawings do not directly show new allowable weights since the spacecraft modifications have not been accomplished. However, based on precentage of stowage volume increase/decrease, revised allowable stowage weights. have been extrapolated. Without any Block II or transferables removed, 200 pounds of stowage weight is estimated. With the removal of transferables, 560 pounds is estimated. With both Block II equipment and transferables removed, 930 pounds is indicated.

Total 1A experiment module/data packages weight for re-entry stowage in the CM, including an additional 25% for protective packaging is 219.9 pounds (Figure 1).

3.3 Specific Stowage Area Assignments - Table 2 provides detailed information for each module to be stowed in the CM during various phases of the mission. Comparisons are drawn between individual module stowage requirements and proposed stowage locations for weight, volume and general shape. Figure 2 illustrates the re-entry experiments modules shapes and dimensions. Where the proposed location is the same as the originally proposed NAA/NASA installation, this is noted. Changes and reasons for changes from the original installations are also noted. Assumptions made during the assignment of specific locations are as follows:

a. The two (2) rock-box locations will be available for experiment stowage;

b. Expended Lithium Hydroxide canisters can be transferred to the carrier prior to re-entry, and these volumes used for data cassette stowage;

3.3 (continued)

c. The Thermal Meteroid Garment will not be needed since no EVA is required;

d. The Portable Life Support System also will not be needed since CM umbilicals will be used for suited operations. However, a recent modification places the rapid repressurization system in the area vacated by the PLSS;

e. Modules can be packaged to withstand local compartment vibration and G-loads;

f. The CM pressure/thermal hatch will be stowed in the original left-hand equipment bay location during non-use.

3.4 Additional Potential Stowage Candidates

a. There may be periods during the orbital phase of the mission when the Experiments Display and Control Panel will not be in use and it may be desirable to stow the panel out of the way. One of the rock boxes seem to be a good location, and will be available since the boxes will be used for experiment stowage only during re-entry. It is assumed that the D and C Panel is expendable and will be transferred to the carrier prior to re-entry. Also, that the D & C Panel can be sized to the weight and volume limitations of the rock box;

b. The docking probe and drogue assemblies are currently planned for stowage in the experiment carrier after removal from the tunnel, during orbital operations and are considered expendable items to be left in the carrier during re-entry. Stowage in the carrier is preferred, since in that location, the additional crew task of transference to the carrier prior to re-entry would not be necessary. However, space may be available in the CM on the aft compartment floor, between the Pressure Garment Assembly storage bags and the Lithium Hydroxide containers. This should only be considered as a secondary location, since use of the fecal canister would be difficult as would the use of the Guidance and Navigation Panel (lack of foot space on the floor);

3.4 (continued)

c. The Multispectral Cameras (E06-4) will each require two film re-loads in orbit. These re-load cassettes are also currently planned for stowage in the carrier during boost until they are needed to re-load the cameras. Since the rock boxes will not be used for stowage until re-entry, they may be considered an alternate storage area for the film re-load cassettes. This could become the primary stowage area, should radiation prove to be a problem for film stowage. However, at the present time, stowage in the carrier is the preferred location, since the task of reloading the cameras would be easier.

3.5 <u>Conclusion and Recommendations</u>

a. Sufficient total volume is available for CM stowage of all modules currently planned for the CM without removal of Block II equipment. Although, for specific experiment stowage, removal of specific items of CM transferables and use of the vacant areas is desirable;

b. From a total weight consideration, removal of some CM transferables is necessary to remain within earth landing load limitations and for mounting/stowage of specific experiment modules;

c. Current CM stowage planning for the 1-A Mission is well within the total CM stowage capability specified in both the NAA stowage report and the revised NAA drawings. In fact, there is considerable room for additional stowage of Mission 1-A equipment, should it become necessary in the future.

TABLE I

PROJECTED BLOCK II CM RETURN PAYLOAD POTENTIAL WITH & WITHOUT EQUIPMENT DELETIONS

1	2	3	4	5	6	7	8	9
SPACE LTR	CM VOL AVAIL. WITHOUT REMOVING BLOCK II EQUIP. (Ft^3)	ALLOWABLE WT. IN "2" (LB)	CANDIDATE BLK II EQUIPMENT FOR REMOVAL	WTS OF "4" (LB)	ADDITIONAL VOL BY REMOVAL OF "4" (Ft^3)	ALLOWABLE WT IN "6" (LB)	TOTAL VOL (Ft^3)	TOTAL WT (LB)
A	0	-	Food Containers Compartment Door	26 .5	1.71 0	35 total	1.71	35
B	.1	3	None	-	-	-	.1	3
C	.09	5	LDEC Extra Food	24 20	.58 .94	24 20	1.61	49
D	0	-	Food Container Compartment Door Door Retainer	21 2 .2	1.28 0 .06	27 total	1.34	27
E	0	-	Sequence Camera Still Camera Med Refrig	10 16 5	.16 .42 .11	10 15 5	.69	30
F	95 (Empty Rock Box)	50	Rock Box & Supt Film/Tape & "	3 8	0 .24	3 8	1.19	61
G	95 "	50	Rock Box & Supt	3	0	2	.95	52
H	15	5	Med Supplies	10	.09	10	.24	15
I	0	-	None	-	-	-	-	-
J	0	-	Vacuum Cleaner Waste Bag Box	3 .5	.2 .04	3 .5	.24	3.5
K	0	-	Waste	9	.94	9	.94	9
L	0	-	NASA Bio Inst	5	.12	5	.12	5
M	0	-	None	-	-	-	-	-
N	0	-	PGA Cables	4	.15	4	.15	4
O	0	-	Sanitary Supp.	18.5	.65	18.5	.65	18.5
P	.4	20	None	-	-	-	.4	20
Q	.1	5	None	-	-	-	.1	5
R	.1	5	None	-	-	-	.1	5

TABLE I (Continued)

1	2	3	4	5	6	7	8	9
SPACE LTR	CM VOL AVAIL. WITHOUT REMOVING BLOCK II EQUIP. (Ft^3)	ALLOWABLE WT. IN "2" (LB)	CANDIDATE BLK II EQUIPMENT FOR REMOVAL	WTS OF "4" (LB)	ADDITIONAL VOL BY REMOVAL OF "4" (Ft^3)	ALLOWABLE WT IN "6" (LB)	TOTAL VOL (Ft^3)	TOTAL WT (LB)
S	1.0	10	EVCT Device CWG, LCG, Tools PLSS Sandals & LV TV Camera	6.3 12.4 60 10 13.4	.35 1.83 2.56 .56 .38	6 12 60 10 13	6.68	111
T	2.8	25	PGA (2) & TMG CO_2 Absorbers Data Storage	69 154 4	12.26 3.9 .08	420 154 4	19.04	603
V	2.0	10 (CG Limit)	None	-	-	-	2	10
TOTALS	8.64	188		517.80	29.61	878	38.25	1066

TABLE - 2

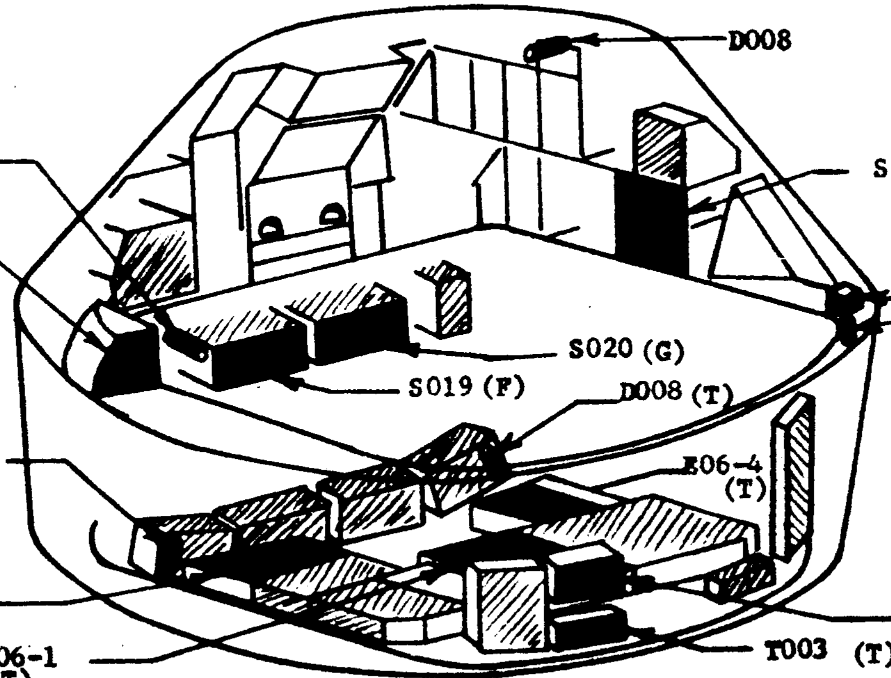
CM MOUNTED EXPERIMENT/DATA/EQUIPMENT MODULES - STOWAGE STUDY

EXP. NUMBER	EQPT. STOWED	MISSION PHASE	ITEM WT.	ITEM VOL.	ITEM DIMENSIONS	PROPOSED LOCATION	LOC. LTR.	ALLOW. WT.	AVAIL. VOL.	ADDITIONAL INFORMATION
S019	Comp.Exp.	(2)	43	1750	8x11½x19	Replace Rock Box	F	61	2060	Original NAA/NASA Installation Proposal
S020	Comp.Exp.	(2)	35.2	1750	8x11½x19	Replace Rock Box	G	52	1645	Original NAA/NASA Installation Proposal
S015	Comp.Exp.	(4)	22	800	15½x6½x8	Replace TV Camera and Camera Mount	S	25	864	Original NAA/NASA Installation Proposal (S015 Only) Could not be used since the RRS now occupies that space
T003	Comp.Exp.	(4)	5.5	140	3.75x7.5x5.5	Avail. Locker Space, Aft Bulkhead	T	30	1000	
E06-1	Film Packs	(2)	20	1440	12x12x10	Avail. Space, Aft Bulkhead (E06-1, E06-4, E06-7)	T	150	430	Revised NAA drawings show additional storage space on the aft bulkhead
E06-4	Film Packs (18 cassettes)	(2)	21.5	1152	4x4x4 (ea)					
E06-7	Film Packs	(2)	10	243	9x9x3					
D008	Elect./Act. DSM.	(4)	2.5	90	7x4x3.18	Girth Ring, Forward surface, Avail. Space. (both D008 above and below)	Q	5	173	Original NAA/NASA Installation Proposal
D008	Pass. DSM.	(4)	.5	10.6	6x1.5(Dia.)					
D008	Pass. DSM.	(4)	.5	10.6	6x1.5(Dia.)	Upper inside surface, film & tape pkg.	W	-	-	
D008	Pass. DSM.	(4)	.5	10.6	6x1.5(Dia.)	Outside rt. L_iOH can, outside surface	T	25	4840	L_iOH cans on Aft. Compt. Fl. against lower eqpt. bay. — Original NAA/NASA installation proposal
D008	Pass.DSM.	(4)	.5	10.6	6x1.5 (Dia.)	Outside lt. L_iOH can, outside surface				
D008	Pass. DSM	(4)	.5	10.6	6x1.5 (Dia.)	Avail. space @ X_c 79, Y_c 31.7, Z_c 16.2	-	-	-	Mounted to existing bracketry.

TABLE-2 (continued)

EXP. NUMBER	EQPT. TO BE STOWED	MISSION PHASE	ITEM WT.	ITEM VOL.	ITEM DIMENSIONS	PROPOSED LOCATION	LOC. LTR.	ALLOW. WT.	AVAIL. VOL.	ADDITIONAL INFORMATION
D009	Accessories	(2)	.1	4.2	7x6x.1	Avail.Stor. Space	B	3	173	
S016	Nuc. Emul.	(2)	8	63	3.5x5(Dia.)	Avail.Stor. Space (S016 and S018)	P	20	692	Original NAA/NASA installation was in the aft lower eqpt. bay. Specific intended area could not be located. Alternate location was chosen (S016).
S018	Collector Box	(2)	5.5	98.5	5.1x5.1x3.8					Original NAA/NASA Installation was in ther personal hygiene container. Since a storage area was available, the PHC was left undisturbed (S018).
T002	Accessories	(2)	.1	4.2	7x6x.1	Avail.Stor. Space	B	3	173	
A11	D&C Panel	(3)	-	-		Rock Box	F	61	2060	Stowage area for periods of non-use of D&C panels, during orbit phase only. (A11 and S017)
S017	D&C Panel	(3)	25	1100	6.75x10.75x6.25	Rock Box	G	52	1645	
-	Pressure Hatch	(3)	-	-		Strapped to aft portion of left hand eqpt. bay.	S	-	-	Original NAA/NASA stowage location.
-	Probe & Drogue	(1)	-	-		Aft compartment Floor	T	-	-	Primary stowage in carrier. CM stowage would only be an alternate location. (Probe & Drogue and E06-4)
	E06-4 Relcad Film Packs (12-cassettes)	(1)	15	768		Rock Box	G	-	-	

(1)- Alternate Location, (2)- Re-entry Only, (3)- Orbit Only, (4)- Boost, Orbit and Re-Entry



	ORIGINAL NAA STOWAGE STUDY (5-5-66)		NAA STOWAGE CONFIGURATION DWG. #2743-116 (6-1-67)	
	WEIGHT (POUNDS)	VOLUME (Cubic Ft)	WEIGHT (POUNDS)	VOLUME (Cubic Ft)
AVAILABLE STOWAGE WITHOUT BLOCK-II EQUIPMENT DELETION OR TRANSFER TO CARRIER	131	8.64	200	13
STOWAGE AVAILABLE AFTER EQUIPMENT TRANSFER TO CARRIER	392.5	18.35	560	26
STOWAGE AVAILABLE AFTER EQUIPMENT DELETION AND TRANSFER TO CARRIER	1066	38.25	930	33
MISSION 1-A STOWAGE REQUIREMENTS (REENTRY)	219.9	6.6	219.9	6.6

FIGURE I

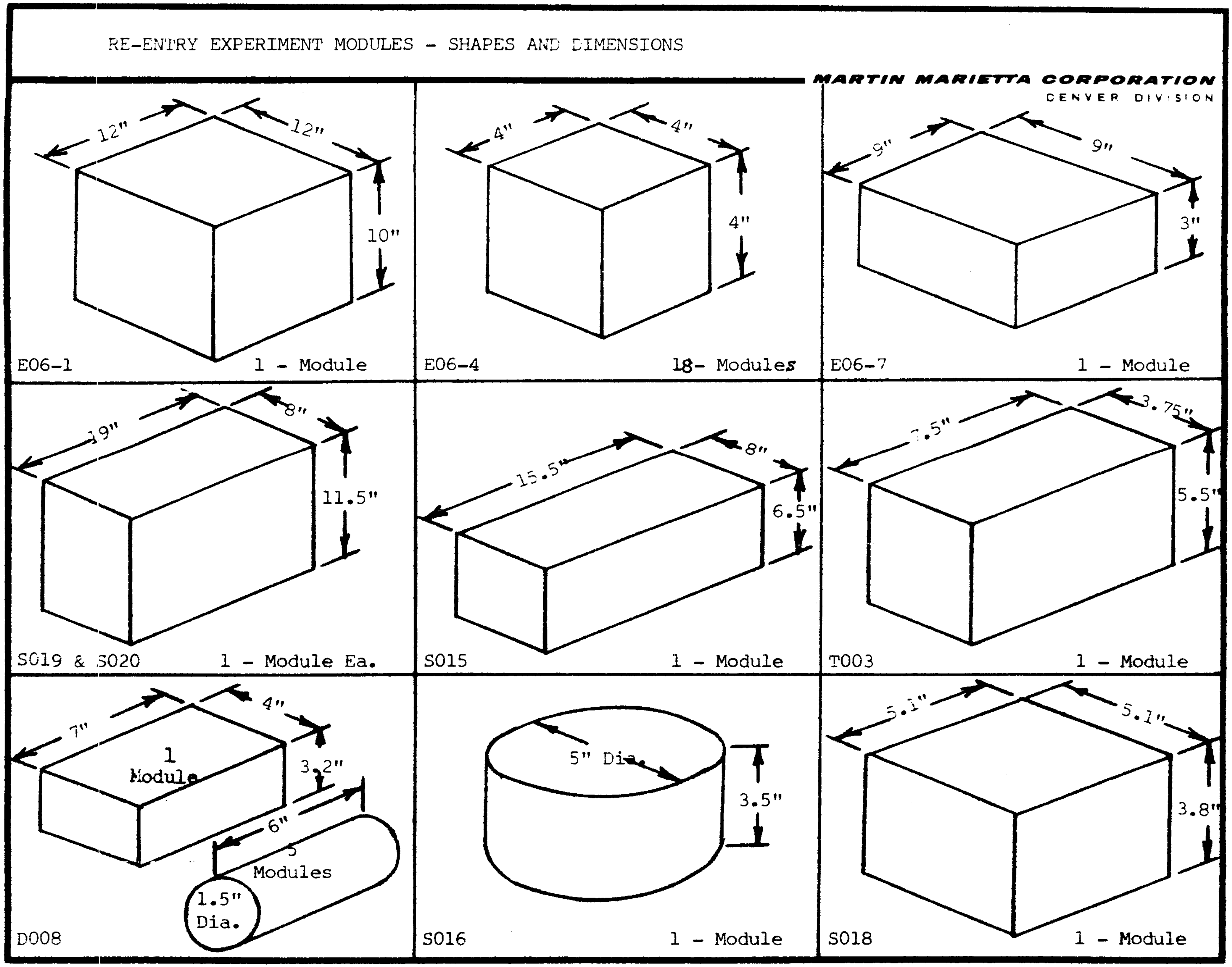

RE-ENTRY EXPERIMENT MODULES - SHAPES AND DIMENSIONS
MARTIN MARIETTA CORPORATION
DENVER DIVISION
12"
12"
10"
E06-1
1 - Module
4"
4"
4"
E06-4
18- Modules
9"
9"
3"
E06-7
1 - Module
19"
8"
11.5"
S019 & S020
1 - Module Ea.
15.5"
8"
6.5"
S015
1 - Module
3.75"
5.5"
T003
1 - Module
7"
4"
3.2"
1
Module
6"
5
Modules
1.5"
Dia.
D008
5" Dia.
3.5"
S016
1 - Module
5.1"
5.1"
3.8"
S018
1 - Module

FIGURE 2

PR 29-17

PHASE D

TRAINING/TRAINER REQUIREMENTS

AAP/PIP MISSION 1A

Contract NAS8-21004

August 1967

J. T. Keeley

J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

This report summarizes a preliminary crew training and training equipment survey conducted for the Mission 1A during the initial study period. This study identifies the training analysis technique, experiments already evaluated for AAP cluster flights, and significant items of training equipment for support of the flight program.

2.0 SUMMARY

Recent MMC efforts in support of the MSFC AAP integration contract have included an analysis of nine of the twenty-three experiments identified for Mission 1A, four others using hand-held cameras which are closely related to the 1A multispectral cameras and three earth resources experiments. The nine experiments included S016, S017, S018, S019, and S020; D017; T002, T003 and T004. Four other experiments, S005, S006, S062 and S065, all use hand held cameras. The three earth resources experiments E00A, E00B and E00D including metric cameras and IR systems, also are similiar to those on the 1A Mission.

These MMC data will be integrated with training documentation prepared by MSC, experiment contractors, NAA and GE, and updated for the specific 1A hardware configuration and flight schedule. Similar evaluations will be conducted for the earth resources, meteorology, solar and stellar experiments.

Primary training equipment identified for IVA includes a display and controls package incorporating both the MMC and T004/S017 packages installed in the AMS at MSC/KSC for combined crew training in spacecraft pointing, tracking and experiment operation. An IVA carrier trainer is identified for crew familiarization in experiment, airlock and stowage operations within the carrier during neutral bouyancy, and KC-135 zero gravity simulations. Unique training requirements for airlocks, certain experiments, retrieved data cassettes, and stowage management, both for the CM and carrier, were also identified.

3.0 DISCUSSION

3.1 STUDY OBJECTIVES

A training and training equipment survey was conducted for the 1A mission during this study period. The primary objectives were:

1. Define a training program approach which can be easily interfaced with mainline Apollo as well as being consistent with current AAP planning at MMC.

2. Identify related training documentation from MSC--MSFC-MMC applicable to this program, primarily in experiment analysis.

3. Identify program impact of training equipment required for Mission 1A.

The recommended program to accomplish these objectives is summarized in the remainder of this report.

3.2 PROGRAM APPROACH

The primary consideration for training program development on the 1A mission is ready interfacing with the ongoing mainline Apollo training and schedule compatibility with the flight crew and available mission simulation training equipment. MMC has prepared flight crew training reports for NASA under the MSC AEP (pallet) and MSFC AAP integration study contracts which were required to meet this ground rule. The 1A Training Program Development diagram shown in Fig. 3.2-1 identifies the primary tasks, interim and final products including analyses, schedules, deliverable documentation and courses, training plans, training equipment requirements, and specification inputs. Activities during the study were limited to identification of gross requirements, assistance in preparation of crew and mission timeline and preliminary identification of training equipment.

The recommended technique for analyses utilized for the AAP experiments, and applicable to all experiments

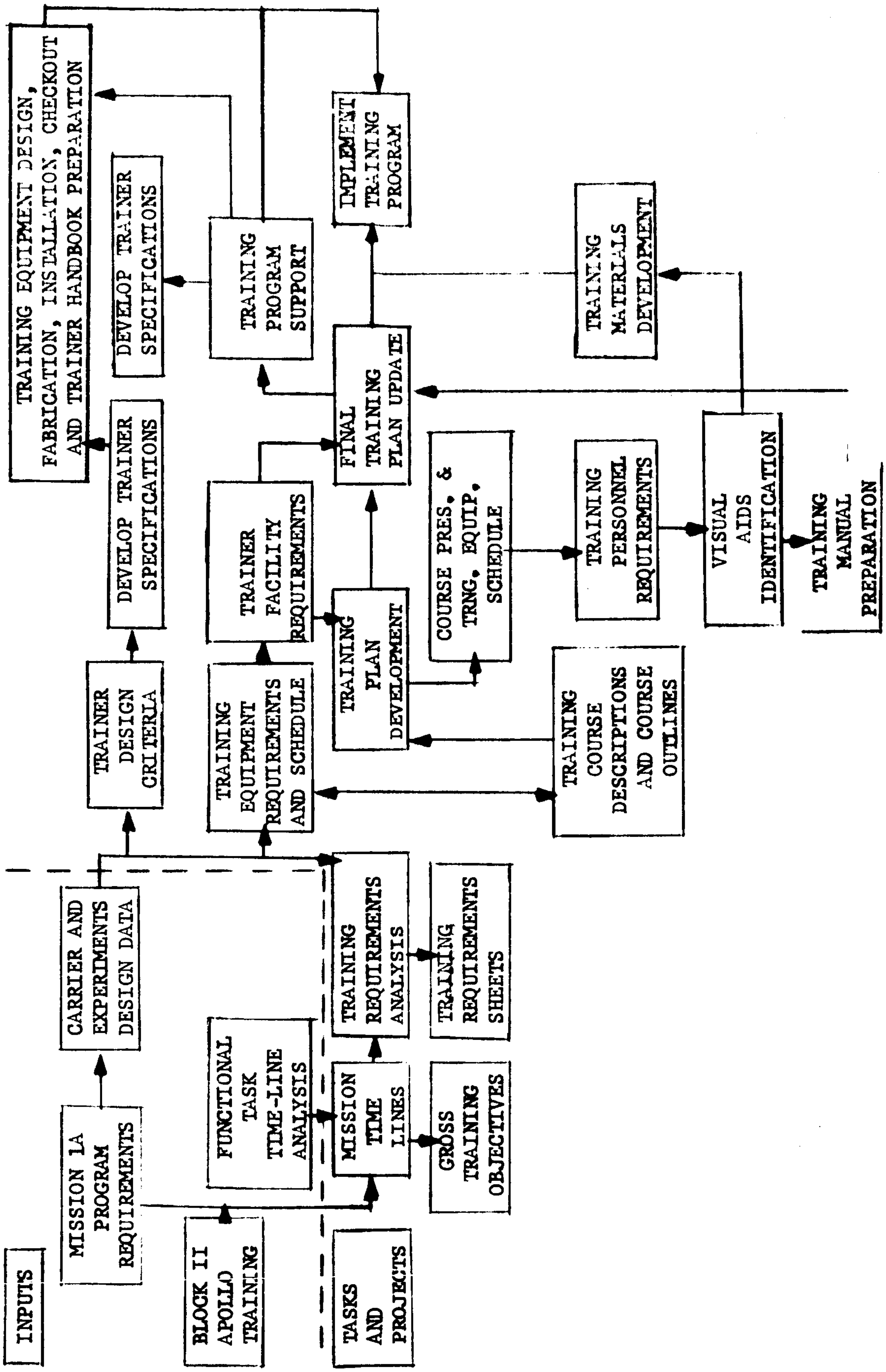


Figure 3.2-1 Mission 1A Training Program Development

and carrier subsystems is described below.

3.3 TRAINING REQUIREMENTS APPROACH

3.3.1 Training Requirements

For each experiment or subsystem, the following items must be determined.

a. Impact of experiment or subsystem operation on attainment of overall mission objectives.

b. Impact of experiment or subsystem operation on crew safety.

c. Complexity of tasks to be accomplished and commonality of tasks.

d. The role of the astronaut as an observer, monitor, and experimenter as well as spacecraft pilot and housekeeper.

e. Individual task proficiency requirements for the flight.

f. Apollo mainline training characteristics directly applicable to the 1A Mission.

Preliminary training requirements for flight crews are summarized in table form to delineate the Inflight Task Requirements for the preparation and operation of each experiment evaluated and also to identify the applicable areas of knowledge required to support the accomplishment of each experiment task. These data will form the basis for briefing development and training equipment definitions.

3.3.2 Inflight Task Requirements - Each inflight experiment and subsystem operation will be evaluated and a degree of required training assigned each task. Particular attention to man-machine relationships, personnel and equipment safety, and training equipment requirements will be made during this evaluation. The level of training assigned each task will define the degree of training and practice required for proficiency in accomplishing the experiment objectives.

3.3.3 Knowledge Requirements - Areas of knowledge required by astronauts to perform each experiment and operate each subsystem proficiently will be identified. The required level of training assigned to each knowledge area forms the baseline for preparation of detailed course descriptions and outlines.

3.3.4 Experiments and Subsystems - The individual experiments and subsystems will be analyzed for task and knowledge training requirements.

3.4 FLIGHT CREW TRAINING

A training program will be developed to assure maximum utilization of Block 2 Apollo elements (personnel, equipment, facilities, etc.) to accomplish the required training.

The following assumptions form the basis for development of the 1A Flight Crew Training Program:

a. A group of astronauts will be identified 9 - 12 months (minimum) prior to this mission.

b. Apollo Mission Simulators (AMS), and the CSM docking simulators, modified to conform to 1A mission requirements will be made available to the program a minimum of six months prior to each flight.

c. Concurrent with modification of simulators flight crews will start part task training on available training equipment items. Trips to experiment hardware developer's facilities should be scheduled to familiarize flight crews with hardware development and to incorporate crew suggestions into the systems.

d. Technical briefings required to establish a common experiment and carrier subsystem knowledge level will be provided to the flight crews.

e. Zero gravity flights and neutral buoyancy training to perfect IVA will be accomplished primarily on a "buddy" system basis with the astronaut assigned prime responsibility for an experiment function receiving primary attention. In situations where the work load must be shared, training will be accomplished on a crew basis.

f. Flight crew personnel will participate during the various phases of design verification and test at Denver, MSC, and KSC. This will provide first-hand knowledge of the location and operation of experiment and experiment carrier equipment.

3.4.1 <u>Flight Crew Training Plan</u> - 1A Mission training will be integrated into the current mainline Apollo specific mission training program. The integration will be accomplished by scheduling 1A training tasks identified in the training requirements analysis into the mainline Apollo training schedule on a timely basis. Training elements will be incorporated in the integrated program as described in the following paragraphs.

3.4.2 <u>Specific Mission Experiment Sciences Background Training</u>- Flight crews will receive, during the first three months of their specific mission training, a basic understanding of experiment science and technology directly applicable to this mission. This requirement is imposed to impart as basic understanding of the type of scientific data they will be required to observe and interpret.

3.4.3 <u>Experiment and Carrier Subsystem Briefings</u> - Flight crews will receive experiment and carrier subsystem briefings to prepare them for operations training.

3.4.4 <u>Experiment and Carrier Operations Training</u> - Flight crews will receive operations training on the following tasks:

a. Experiment and carrier operations utilizing actual hardware engineering prototypes or training equipment.

b. Intravehicular activities training utilizing the neutral buoyancy, 6° of freedom simulators and KC 135 aircraft to perfect astronaut inflight carrier operating procedures.

c. Experiment and carrier design verification and systems test participation.

3.5 MAJOR 1A TRAINING TASKS

The following 1A mission activities require flight crew training emphasis:

a. Intravehicular Activities - Movement of personnel within the CM and carrier will be required to accomplish such tasks as: manual docking activities, scientific airlock operations, translation of experiment packages, hookup of electrical lines, operation and data management of the experiments, film cassette reloading and retrival.

b. Multiple Experiment Operations - Flight crews must have: knowledge of and the ability to employ personal and experiment peculiar safety precautions; a thorough knowledge of the theory of operation of each experiment and its relationship to other experiments in flight operational requirements, methods and procedures; and proficiency in initiating the actions required by instructions transmitted from the ground after realtime ground evaluation of telemetered data.

3.6 FLIGHT CREW TRAINING SCHEDULE

Figure 3.6-1 presents the time required for each training element to prepare flight crews for the mission. The times depicted for each of the elements include mainline Apollo training requirements as well as those peculiar to the 1A Mission.

FIGURE 3.6-1

FLIGHT CREW TRAINING SCHEDULE

	MONTHS TO FLIGHT		
	12 11 10	9 8 7 6	5 4 3 2 1
Flight Crew Training for 1A Mission	Background	Systems	Operations

Background training is shown during the three months immediately preceeding systems training. It may be accomplished at any time prior to or interspersed into the systems training, provided that the indicated total time is allocated so as to complete systems training on schedule.

3.7 Training Equipment

3.7.1 <u>Considerations</u>

Mission 1A require crew operations in the Command Module, and in the Carrier pressure vessel for target acquisition, spacecraft pointing and tracking, and experiment controlling. Certain experiments require crew proficiency in scientific airlock operations, initiating experiment sequences and monitoring and manipulation during periods of data taking. Camera systems require crew operations for film reloading and cassette removal, manned opening of protective lens covers, stowage both for reentry in the CM, and relocation of CM expendable equipment into the carrier prior to reentry. Astronaut operations encompass shirt-sleeve and soft suited modes for normal operations and pressurized suits in depressurized compartments for contingency operations. No EVA is required for this mission. A preliminary evaluation indicates the following training equipment is required as a study baseline. Additional experiment peculiar equipment may be required after firm definitization of flight hardware.

3.7.1.1 Control and Display Trainer

The primary crew/subsystem/experiment interfaces for inflight carrier operations are on two panels. The main 1A mission panel as shown in Fig. 3.7-1 and the T004/S017 panel already provided for the Block I frog otolith/X-ray Galactic experiments will make up this trainer. These panels and associated wiring would be mounted in appropriate locations in MSC CM procedures trainer (DCPS) or in the Apollo Mission Simulator (AMS) and the wiring interfaced as necessary with the terminal boards, instructor consoles and digital computer system. A Block II CM crew station mockup will also be required to familiarize the crew with flight procedures involving out the window viewing, attitude orientation, experiment sequencing and carrier subsystem operation including interactions with the Block II CM housekeeping and orbital activities. Two D&C trainers would be provided six months prior to flight for AMS installation at both MSC and KSC, if NASA requires both simulators be utilized for the 1A mission. Detailed hardware selection and interfaces with MSC will be identified after further NASA coordination and defined in the appropriate training equipment specifications.

3.7.1.2 Intravehicular Activities Trainer

The carrier pressure vessel, all interior work stations, scientific airlocks, data cassettes, mobility aids and tethers, the docking tunnel and CM interfaces will be incorporated into a trainer for neutral bouyancy utilization during astronaut preflight training. Later study will determine the suitability of this unit for Zero G aircraft simulation or the need for specialized part task, partial vehicle simulators to fulfill this requirement.

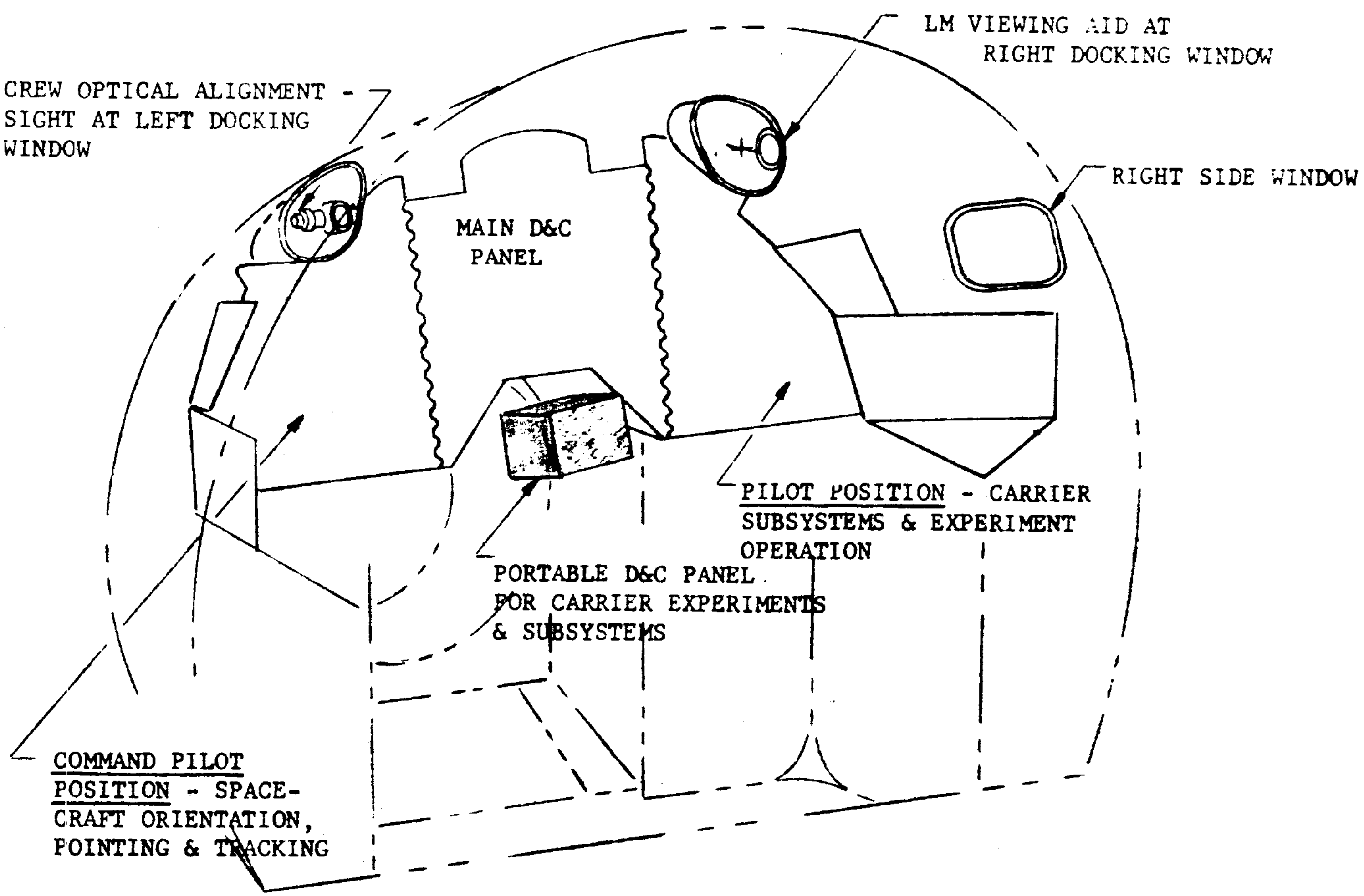


Figure 3.7-1 CM Work Station

This IVA trainer would provide part task and mission segment training in all manual operations within the carrier with the exception of viewing or vehicle orientation where out the window observations of earth or space are necessary. The trainer is initially envisioned as a full-scale skeleton structure with open mesh to configure the spatial envelope. Interior fittings, trusses, airlocks and experimental gear to be handled by the astronauts will be identical to flight hardware permitting high fidelity simulation for all operations in shirt sleeve or suited mode. The trainer interior configuration would be similar to the full-scale mockup shown in Fig. 3.7-2. The IVA trainer would be available six months prior to flight.

3.7.1.3 Specialized Trainers

The 1A experiments evaluated identified specialized part task training in several areas identified below. This partial list will be supplemented as training requirements are evaluated during Phase D.

The (NAA) scientific airlocks require astronaut training in basic operation, experiment emplacement and removal for normal and contingency operations. The manual sextant for T002 similarly requires special training as will the S016 and 18 experiments which both use emulsions exposed to free space which must be deployed and later retrieved and stowed for reentry. S019 and 20 both require boresighting at the airlock where the experiment is installed and manual operations during actual data taking. Precise spacecraft orientation by manual attitude control is necessary during experiment operation and data acquisition required for S019 and 20. The experiments requiring individual film cassette loading, handling, retrieval and stowage will require

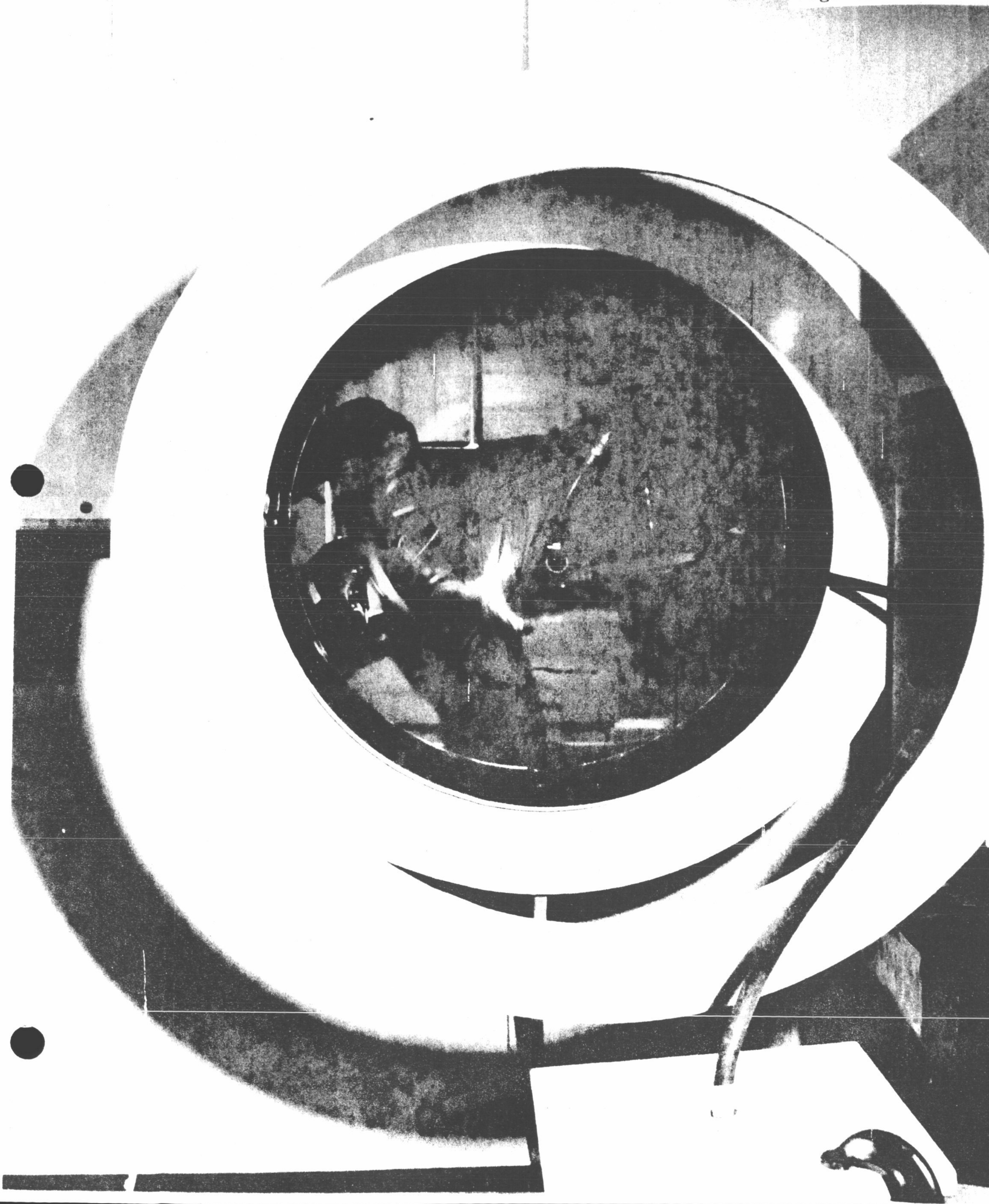


Figure 3.7-2 Full Scale Carrier Mockup

training with each camera/cassette system.

These specialized trainers may be already delivered as trainers, engineering prototype hardware, or where required new training equipment. The recommended approach for each item will be made during the training study to be conducted in the next program phase.

3.8 TRAINING REQUIREMENTS SUMMARY

The mission will be analyzed to assure that all training requirements are considered. Inflight Task and Knowledge Requirements identified during the preliminary training requirements and identified in Fig. 3.8-1 analysis will be updated for the 1A flight and summarized on Training Requirements summary forms. A sample analysis for the SO-20 X-ray solar photographic experiment originally prepared for the cluster flight is included as Appendix A.

FLIGHT 1A
(Summarized from AAP Analysis)

		TASK DESCRIPTION	T003 In-Flight Nephelometer	S017 X-Ray Astronomy	E00A Metric Cameras	E00B I. R. Imager	E00D Microwave Radiometer	S065 Multi-band Terrain Photo	S006 Synoptic Weather Photo	S005 Synoptic Terrain Photo	D017 CO_2 Reduction	S018 Micro Meteoroid Collect.	T002 Manual Navigation Sys.	S015 Influence of Zero "G" on a Human Cell
T	R	Checkout	C					B	B	B				
A	E	Test	C								A			C
S	Q	Fault Isolation												
K	U	Adjust	C			C					A		B	
	I	Calibrate	B					B	B	B			C	
	R	Operate	C		C	B	C	B	B	B	B	C	C	C
	E	Data Transmission												
	M	Pointing and Tracking			C	B	B	B	B	B			B	
	E	IVA Activity			C							C	B	
	N	Store	C	B	B	B		B	B	B	B	C	B	C
	T	Recovery/Data	C		C							C		C
	S	Safety Practices	C	C	C	C	C	C	C	C	C	C	C	C

REMARKS

A. Requires a general familiarization through discussion and/or demonstration.

B. Requires a briefing on the knowledge or tasks. Needs to perform on actual equipment or trainers.

C. Requires in depth training. Needs to perform the complete task on actual equipment or trainers to a high degree of proficiency.

Figure 3.8-1
Preliminary Flight Crew Training Requirements Summary

FLIGHT 1A
(Summarized from AAP Analysis)

Experiments (column codes):
T003 In-Flight Nephelometer; S017 X-Ray Astronomy; E00A Metric Cameras; E00B I. R. Imager; E00D Microwave Radiometer; S065 Multi-band Terrain Photo; S006 Synoptic Weather Photo; S005 Synoptic Terrain Photo; D017 CO_2 Reduction; S018 Micro Meteoroid Collect.; T002 Manual Navigation Sys.; S015 Influence of Zero "G" on a Human Cell

		TASK DESCRIPTION	T003	S017	E00A	E00B	E00D	S065	S006	S005	D017	S018	T002	S015
K	R	Layout Drawings	O	O								F		F
N	E	Displays and Controls	M		F	F	F		F	F	F	F		F
O	Q	Volume	F	F	F							F	F	
W	U	Hardware Mass	F	F	F							F		F
L	I	Performance Specification	M		M	M	M		M	M	F	M	F	M
E	R	Theory of Operation	M		M	M	M		M	M	F	F	M	M
D	E	Block Diagrams	M								F	F		F
G	M	Electrical Schematics	M											
E	E	Mechanical Schematics												
	N	Data Link Interfaces	M		M	M	M		M	M		M	F	M
	T	Hardwire Interfaces	F	F										
	S	Structural Interfaces		F	F	F						F	F	M
		Mechanical Interfaces		F										
		Test Points	M		M	M	M		M	M		M		M
		IVA Operation			M							M		
		Safety Precautions	M	F	M	F	F		F	F	F	M	M	M

REMARKS

O. Orientation Level - Provides a broad semi-technical treatment of the AAP systems and experiments.

F. Familiarization Level - Provides a technical description of the systems and equipment, including a description of hardware capabilities and a functional diagram analysis of each mode of operation.

M. Mechanization Level - Provides a detailed technical description of the AAP systems.

Figure 3.8-1
Preliminary Flight Crew Training Requirements Summary
(continued)

APPENDIX A

Sample AAP Training Summary for cluster, experiments now scheduled for 1A flight.

7. TRAINING AND TRAINING EQUIPMENT REQUIREMENTS FOR THE UV X-RAY SOLAR PHOTOGRAPHY (S020)

7.1 Experiment S020 as presently configured for AAP Flight 2 has been analyzed to identify training and training equipment requirements. Parameters used in the analysis are outlined in the following paragraphs:

7.1.1 Proficiency Requirements - The ultraviolet and soft X- ray Solar Photography experiment requires the astronaut to be proficient in the following activities: IVA translation from the Command Module to the MDA; operation of the CM and MDA airlocks; removal from storage, inspection, donning and operation of the EVA ensemble; operation, assembly, adjustment and checkout of the camera experiment airlock; removal from storage, installation, adjustment, checkout and operation of the UV X-ray camera; doffing, inspection, drying and storage of EVA ensemble; spacecraft orientation so that the camera is pointing toward the sun; operate the viewfinder and boresighter in conjunction with the attitude control system for target acquisition and tracking; maintain voice communication with the astronaut in the CM and with the Principal Investigator via mission control; operate the camera with camera control unit and camera display panel for UV X-ray spectrographic photography; operate the timer for spectrograph time exposure control; operate the data tape recorder, telemetry system and data interchange and control unit for experiment photographic data recording and transmission; entries recorded in the experiment data handbook; operation of the MDA lighting system; and operation of the portable lights as required. Subsequent to last film exposure, close camera vacuum valve; operation of the MDA camera experiment airlock for UV X-ray spectrograph removal; remove camera canister and place in camera storage box; replace outer hatch door on camera experiment airlock; translate camera to the CM and store in the film storage area.

Note: In the event that this experiment canister is relocated on the ATM rack, it will be mechanically aligned with the Hα telescope. A remote camera control unit and camera display panel will be located in the LM or CM. The Hα telescope on the ATM will be used for target acquisition and tracking in conjunction with the control moment gyros and the attitude control system since this experiment would be performed simultaneously with the appropriate solar ATM experiments. An EVA will be required to recover the camera canister containing the exposed film magazine.

7.1.2 Special Considerations - Targets of opportunity are selected by the Principal Investigator based on solar activity and communicated to the astronauts via mission control. The target acquisition and pointing control will be accomplished by attitude control system operation from the CM. The astronaut operating the viewfinder and boresighter mounted in the camera canister will have to give verbal instructions over the communications network to coordinate the target acquisition and pointing maneuver. This closely coordinated activity will require a high degree of proficiency and must be practiced by the two astronauts operating as a team until the skill proficiency is attained. The camera experiment equipment for this experiment is contained in a pressure sealed canister, therefore the data is obtained by retrieval of the entire camera canister.

7.1.3 Commonality - Tasks requiring training on this experiment that have commonality with other experiments are those associated with operating the camera experiment airlock in the MDA, attitude control system operation for target acquisition and tracking, timer operation, voice communication system operation, data tape recorder operation, telemetry system operation, data interchange and control unit operation, normal EVA/IVA and EVA ensemble functions, and normal photographic skills and knowledge.

7.2 Detailed Experiment Training Requirements - Figure 7-1 summarizes the training requirements analysis for each item of experiment hardware. It delineates the inflight crew task requirements for the transfer, setup, and operation of each hardware item and identifies the knowledge required to support the performance of these tasks.

7.2.1 Inflight Task Requirements - Figure 7-1 breaks down each inflight operation to be performed on each hardware item and assigns a level of training to be attained for each task. In determining the level of training, particular attention was given to personnel-equipment interfaces, personnel and equipment safety, and training equipment limitations. The level of training assigned each task will provide the degree of training required to accomplish the experiment objectives.

7.2.2 Knowledge Requirements - Figure 7-1 presents the analysis of the areas of knowledge that each astronaut must have to perform this experiment in a proficient manner and to make the proper assessment of the data to be obtained and returned for subsequent evaluation by experimenters. The required level of training assigned each knowledge area will assist in the preparation of detailed course descriptions and outlines.

7.3 Training Requirements Summary - Figure 7-2 summarizes the level of training for Experiment S020 in relation to the requirements of the overall mission. The code letters reflect the highest level of each skill or knowledge requirement identified in the individual Detailed Experiment Training Requirements Analyses.

7.4 Equipment and Task Commonality - Figure 7-3 lists the major equipment requirements for AAP Flight 2 and indicates the cross-utilization of equipment between experiments. This commonality assists in determining minimum requirements for training and training equipment.

7.5 Training Equipment Requirements - The following training equipment will be required to support flight crew training for Experiment S020:

a. Neutral Bouyancy Trainer - Mockup of the MDA with handholds, footholds, tethers, fasteners and attachment points, camera experiment airlock, camera canisters and mounts, and storage containers for practice of zero gravity IVA and operations.

b. Apollo Mission Simulator - To practice camera operations and control; target acquisition and pointing; display and control unit operation and monitoring; data tape recorder, telemetry system and data interchange and control unit operation; recording of experiment photographic data; voice communication system operation and coordinated ground data links; and film canister translation and storage.

c. Six degree of freedom simulator with MDA section mockup and camera experiment airlock - To practice zero gravity activities (IVA) and simulation associated with the camera experiment airlock operation, assembly and disassembly of camera canister in the camera experiment airlock, and the UV X-ray spectrographic camera operation including the target acquisition and pointing operation using the view-finder and bore-sighter in the camera canister.

d. Parts and Components - Figure 7-1 denotes the actual equipment and control units to be used for astronaut familiarization and operating procedural practice of all experiment operations performed in the Command Module, Multiple Docking Adapter and inter/intra-vehicular activities (IVA) associated with experiment operations, data retrieval, translation and storage.

EXPERIMENT S020 UV X-RAY SOLAR PHOTOGRAPHY	TASK REQUIREMENTS															KNOWLEDGE REQUIREMENTS															
EQUIPMENT	Transfer	Assemble	Checkout	Test	Fault Isolation	Adjust	Calibrate	Service/Repair	Operate	Data Transmission	Pointing and Tracking	EVA or IVA Activity	Store	Recovery/Data	Safety Practices	Layout Drawings	Displays and Controls	Volume	Hardware Mass	Performance Specification	Theory of Operation	Block Diagrams	Electrical Schematics	Mechanical Schematics	Data Link Interfaces	Hardwire Interfaces	Structural Interfaces	Mechanical Interfaces	Test Points	EVA or IVA Operation	Safety Precautions
Camera, UV X-Ray	C		B			C	A		C		C	B	C		A	F	M			M	M		F	F	F	F	F	F		M	O
Camera Control Unit									C	C					B	F	M			M	M		F	F	F	F	F	F		M	O
Boresighter & Viewfinder						C			C		C				A	F	M			F	M			F		F					O
Electrical Filter Unit																F				F	F		F	F				F			O
Slit and Filter																F				F	F			F				F			O
Diffraction Grating																F				F	F			F				F			O
Electronics Unit									C						B	F	F			F	F		F			F					F
Camera Power Supply									C						B	F	M			F	M		M		F	F			M		M
Display Panel									C						B	F	M				M		M		M				M		M
Film Transport									B						B	F	M				F	F				F					O
Camera Canister	C	C											C		B	F								F			F	F		M	F
Camera Storage Box & Packs	C	C											C		B	F								F			F	F		M	F
Film																		O		F	O							O			O
Camera Experiment Airlock - MDA		C	C			C			C			C			C	F				F	F			M		M	M	M		M	M
Timer									B								F			O	F										
Data Tape Recorder									B	B					A	F	M			F	F	F				F					F
Telemetry System									B	B					A	F	M			F	F	F			F	F					F
Data Interchange & Control Unit									C	C					C	F	M				M		M			F					M
Voice Communication System									C	B		C			C	F	M			F	F	F				F					M
Astronaut Display & Control Unit									C						C	F	M				M		M			F					M
Attitude Control System									C						C	F	M			F	F	F				F					F
Experiment Data Log Book										C				C											F						
O_2/Electrical/H_2O Umbilical	C		C	B								C	C		C					M			F				M		M	M	M
Oxygen Bottles & Supply	B		B												B		F	F			F									F	F
Flexible Hoses (Mask)						C									C			F									M		F		M
Oxygen Mask Regulator						C	C		B						C		F			F	M			F			M		F		M
Liquid Cooled Garment		B		B									B		C					M							O				M
Pressure Garment Assembly		B		B									B		C					M							O				M
Therm/Micrometeored Protect. Garment		B		B									B		C					F							O				M
Emergency Oxygen Supply	B												B		C		F				F									F	M
Radiation Dosimeter															C		O			M	O										M
Emergency Medical Kit															C						F										M
Suit Donning Jig									C						C	O								M				F		M	M
Suit Test Kit			C	C					C						C	O					M								M		M
Footholds															B	O					F										F
Handholds															B	O					F										F
Safety Lines	C											C	C		C					F							F			M	F
Personnel Anchoring Tethers															B												F			M	F
Anchoring Tether Eyebolts															B	F											F			M	F
Fasteners												B			C	O											F			M	F
MDA Lighting System									C						B	O	F					O	O						F		F
Portable Lights									C						B	O	F					O	O						F		F

A - Requires a general familiarization through discussion and/or demonstration.

B - Requires a briefing on the knowledge or tasks. Needs to perform on actual equipment or trainers.

C - Requires in-depth training. Needs to perform the complete task on actual equipment or trainers to a high degree of proficiency.

O - Orientation Level - Provides a broad semi-technical treatment of the AAP systems and experiments.

F - Familiarization Level - Provides a technical description of the systems and equipment, including a description of hardware capabilities and a functional diagram analysis of each mode of operation.

M - Mechanization Level - Provides a detailed technical description of the AAP systems.

FIGURE 7-1. DETAILED EXPERIMENT TRAINING REQUIREMENTS ANALYSIS

BRIEFING TITLE: UV X-Ray Solar Photography

BRIEFING NUMBER: AAP-2-S020

BRIEFING LENGTH: 2 HOURS

HOURS/DAY: 6 HOURS

SECURITY CLASSIFICATION: Unclassified

STUDENT LOAD

MINIMUM: 5
MAXIMUM: 15

BRIEFING OBJECTIVE:

To teach the flight crews the principles of operation, procedural performance requirements, hardware knowledge and safety precautions of the UV X-Ray Solar Photography experiment S020 in preparation for the Operations Training.

To acquaint Mission Control and Experiment Support personnel with experiment S020.

RECOMMENDED FOR:

1. Flight Crews
2. Mission Control Personnel
3. Experiment Support Personnel

BRIEFING SCOPE:

This briefing provides the description, purpose, function, location, identification, pertinent performance specifications and principles of operation of the experiment. Equipment to the familiarization and mechanization levels. It includes the knowledges, inorbit procedural performance requirements, safety precautions, performance hazards and the interfaces with other equipment and systems.

BRIEFING PREREQUISITE:

Background Training
- Basic Spectrography
- Basic Heliography
- Solar Astronomy

Subsystems Training
- Attitude Control System
- Communications System
- Telemetry/Instrumentation System
- EVA Ensemble & IVA

LOCATION OF TRAINING:

CONFIGURATION APPLICABILITY:

AAP Missions #2 and 4
Cluster Configuration Mission

METHOD OF PRESENTATION:

Formal Classroom Discussion
Laboratory Demonstrations

Figure 7-2 BRIEFING OUTLINE

BRIEFING TITLE: UV X-Ray Solar Photography
BRIEFING NUMBER: AAP-2-S020
BRIEFING LENGTH: 2 HOURS
HOURS/DAY: 6 HOURS

SECURITY CLASSIFICATION: Unclassified
STUDENT LOAD
MINIMUM: 5
MAXIMUM: 15

UNIT	OUTLINE	CODE LEVEL	TIME	TRAINERS, TRAINING AIDS, MATERIALS
I	INTRODUCTION A. Course Orientation 1. Course objectives 2. Desired trainee outcomes 3. Classroom procedures 4. Evaluation method B. Experiment Description 1. Heliography and characteristics of the sun 2. Grazing incidence spectrograph 3. Spectrographic program 4. Target acquisition, pointing and tracing 5. Functional flow block diagram 6. Film a. Characteristics b. Calibration c. Volume	0	0:15	Transparencies Training Manual
II	SPECTROGRAPH A. Grazing Incidence Optics 1. Protective vacuum valve a. Vacuum valve b. Valve actuating lever c. Solenoid 2. Filter 3. Slit	M	1:00	Transparencies Training Manual Grazing Incidence Spectrograph

Figure 7-3 BRIEFING OUTLINE

BRIEFING TITLE: UV X-Ray Solar Photography

BRIEFING NUMBER: AAP-2-S020

UNIT	OUTLINE	CODE LEVEL	TIME	TRAINERS, TRAINING AIDS, MATERIALS
II	4. Defraction grating			
	5. Canister & seals			
	B. UV X-Ray Camera			
	1. Shutter			
	2. Film transport and film advance			
	3. Camera canister and seals			
	C. Boresighter and Viewfinder			
	1. Solar ground observations			
	2. Ground communications link			
	3. Viewfinder operation			
	4. Boresighter operation			
	D. Electronics Unit			
	1. Electrical filter unit			
	2. Display panel			
	3. Film counter			
	E. Camera Power Supply			
	1. External cable			
	2. Power units and distribution			
	3. Consumption			
	F. Camera Control Unit			
	1. On-off switch			
	2. Timer			
	3. Exposure counter			

Figure 7-3 (Continued) BRIEFING OUTLINE

BRIEFING OUTLINE

BRIEFING TITLE: UV X-Ray Solar Photography

BRIEFING NUMBER: AAP-2-S020

UNIT	OUTLINE	CODE LEVEL	TIME	TRAINERS, TRAINING AIDS, MATERIALS
III	SPECTROGRAPH STORAGE A. Equipment Storage Bay 1. Stowage racks and bracketry 2. Stowage supports and latching bolts 3. Removal procedure 4. Restowing procedure B. Camera Storage Box C. IVA Translation to the Command Module D. Film Storage Area in CM	F	0:15	Transparencies Training Manual Spectrograph
IV	EXPERIMENT AIRLOCK 1. Outer hatch door 2. Inner hatch door 3. Retraction tool 4. Airlock hatch 5. Airlock hatch adapter 6. Spectrograph installation and removal 7. Pressure seals and checkout	M	0:10	Transparencies Training Manual Airlock Model
V	EXPERIMENT INTERFACES WITH OTHER SUBSYSTEMS AND EQUIPMENT A. Data Management 1. Data tape recorder 2. Timer	M	0:10	Transparencies Training Manual

Figure 7-3 (Continued) BRIEFING OUTLINE

BRIEFING TITLE: UV X-Ray Solar Photography

BRIEFING NUMBER: AAP-2-S020

UNIT	OUTLINE	CODE LEVEL	TIME	TRAINERS, TRAINING AIDS, MATERIALS
V	3. Voice communications system 4. Telemetry system 5. Data interchange and control unit 6. Experiment data log book			
	B. Target Acquisition, Pointing and Tracking 1. Attitude control system 2. Reaction contol system 3. Astronaut display and control unit			
	C. MDA and Equipment 1. Environmental control system 2. Lighting 3. Airlocks 4. IVA restraints, holds and techniques			
	D. EVA Ensemble 1. Donning 2. Doffing 3. Inspection and drying 4. Storage 5. Experiment airlock operation while in EVA ensemble			

Figure 7-3 (Continued) **BRIEFING OUTLINE**

BRIEFING TITLE: UV X-Ray Solar Photography

BRIEFING NUMBER: AAP-2-S020

UNIT	OUTLINE	CODE LEVEL	TIME	TRAINERS, TRAINING AIDS, MATERIALS
VI	EQUIPMENT CONSTRAINTS AND SAFETY A. Personnel Safety 1. Normal IVA safety techniques and precautions associated with spectrograph removal from storage, installation, operation, translation and storage after experiment completion. 2. EVA ensemble must be worn during experiment airlock operation in the MDA B. Equipment and Operations 1. Spectrograph a. Optical elements contamination - fingerprints and foreign materials b. Dropping, bumping and storage c. RCS firing - contamination of optical window d. Crew movements during experiment operation 2. MDA depressurization by airlock operation 3. Film a. Temperature b. MDA atmosphere (water vapor)	M	0:10	Transparencies Training Manual Airlock Model Spectrograph

Figure 7-3 (Continued) BRIEFING OUTLINE

PR-29-18

TRADE STUDY REPORT

LOGISTICS SUPPORT CRITERIA

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

28 August 1967

Prepared by D. G. Smeal
D. G. Smeal

Approved by J. T. Keeley
J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

Mission 1A maintenance and replacement level and criteria must be established early in the program to identify carrier system hardware characteristics and to support the program in the most efficient and cost effective manner.

The following trade off's were considered to establish recommended replacement data for the carrier and GSE:

1) Replacement Levels

   a) Black Box vs Component/Plug-In Module (Carrier)

   b) Chassis vs Component/Plug-In Module (GSE)

2) Replacement Location

   a) KSC vs Martin-Denver Factory

   b) Vendor vs KSC

   c) MSC vs Martin-Denver Factory

3) Repair Cycle Time vs Remaining Time to Launch

2.0 SUMMARY

Preventive and corrective maintenance performed on the 1A Carrier System must be accomplished with a minimum of down time. Considering the high cost of certain replacement items, inventories must be kept to a minimum quantity consistent with a high confidence level for mission success. Failed item(s) repair must be carefully considered as to repair turn-around time versus the remaining support activity time span, based on time-remaining-to-launch.

In consideration of the above facts and factors, a Maintenance and Replacement Items Criteria is recommended that will adequately support all program requirements and take into account such factors as cost effectiveness, schedule impact, personnel training requirements, turn around time, operator efficiency, reliability, and facilities requirements.

3.0 DISCUSSION

This criteria identifies the guidelines and constraints recommended for Mission 1A system hardware design and logistics planning

3.0 DISCUSSION (continued)

in order to support the program in the most efficient and cost effective manner.

The criteria is subdivided into:

I General
II 1A Carrier
III Ground Support Equipment (GSE)
IV Experiments
V Trainers
VI Maintenance Ground Equipment (MGE)

3.1 General

1) Three primary constraints play a major role in the establishment of the maintenance and replacement items criteria in the Mission 1A Program.

   These constraints are:

   a) A single launch mission with no resupply
   b) Three areas of support (Denver, KSC, MSC)
   c) Manned Mission - 14 days duration

2) Maintenance will consist of both preventive and corrective functions, and will be performed on deliverable Mission 1A hardware operated and/or stored at Denver, KSC and MSC Houston.

3) On-pad checkout of the flight article will be accomplished and maintenance activity will be performed. Preventive maintenance will be minimal. Corrective maintenance will consist of removal and replacement of failed items at the provisioned item level.

4) Corrective maintenance tasks associated with a malfunction or failure in the launch preparation and support GSE, experiments and flight hardware must be accomplished with a minimum of maintenance downtime.

5) There will be no mission dependent in-flight maintenance on the 1A carrier system hardware.

3.1 (continued)

6) Due to the single mission requirement and the relatively short duration of KSC support activity, failed items will only be judged repairable if the complete repair cycle can be accomplished within the remaining support activity time span. Generally, sufficient replacement items shall be initially provisioned to support the expected frequency of repair, based on a normal equipment operating schedule. The Martin-Denver factory rapid-reaction repair system shall be utilized for maintenance activities for which spares have not been provisioned or in the event all available spares have been utilized.

3.2 Mission 1A Carrier Maintenance Criteria - Preventive Maintenance

1) Preventive maintenance shall consist of visual inspection, adjustment, calibration and servicing.

2) P/M shall be accomplished at Martin Denver, and at KSC in the Manned Space Operation Building (MSOB) and Launch Complex 34 (LC-34).

Corrective Maintenance

1) Corrective maintenance shall be accomplished at location (Denver, MSOB, LC-34) by performing fault isolation (to the provisioned replacement item level), repair (remove and replace), inspection, service, and checkout (return to operation).

2) A system performance verification test shall be performed after each item replacement.

3) All removed items shall be reviewed by a material review board for repair/disposition status. (REF. Para. 6 of 1).

4) Considering the high cost of some items and the fact that there is to be only one mission, replacement item quantities shall be kept to a minimum quantity consistent with a high confidence level for mission success. The very minimum is considered to be one (1) each of all flight items replaceable at KSC.

3.2 (continued)

5) All flight hardware replacement items shall be designed for a minimum shelf life of two (2) years and shall have been subjected to acceptance testing as defined by Engineering.

6) To minimize replacement item quantities required to support the 1A mission, a single inventory of replacement items will be maintained in support of Denver, MSC and KSC. In the early phase of build and test the inventory of replacement items will be stored at Denver to support assembly and test. When the flight article and associated GSE is transported to KSC, all provisioned replacement items shall be transported to KSC to support pre-launch and launch activities.

7) One inventory of training equipment replacement items shall be provisioned to support Denver and MSC assembly, test, operational and maintenance activity.

8) Operating and maintenance instructions shall be provided to MSC in support of training equipment.

3.3 Ground Support Equipment Maintenance Criteria - Preventive Maintenance

1) Preventive maintenance of GSE shall consist of, before use visual inspection, periodic calibration of meters and gauges, self checks, servicing coolant and proof testing slings and hoisting equipment.

2) P/M shall be accomplished at Denver, MSOB and LC-34.

Corrective Maintenance

1) Corrective maintenance shall be accomplished at location by fault isolation (to the provisioned replacement item level), repair (remove and replace), inspection, servicing and checkout, (return to operation).

2) Chassis repair shall be accomplished by the replacement of plug-in modules, hardwired electrical parts/components and/or mechanical parts/components. Chassis will not generally be spared, however, detail

3.3 (continued)

2) (continued)

analysis based on criticality and complexity of chassis design may dictate sparing a selected few.

3) Performance of corrective maintenance shall require the subsequent successful completion of an operational verification check.

4) A GSE design goal shall be to fault isolate flight equipment to the provisioned replacement level.

5) All Ground Support Equipment design shall incorporate a method of conveniently fault isolating internal malfunctions to the replacement level.

6) Maintenance of that GSE provided with the trainers at MSC shall be accomplished by Contractor personnel. Replacement Items and Operating and Maintenance instructions shall be provided.

3.4 <u>Experiments Maintenance Criteria - Preventive Maintenance</u>

1) Preventive maintenance of the experiments shall consist of visual inspection, testing, and monitoring.

2) P/M shall be accomplished at Denver, MSOB and LC-34.

<u>Corrective Maintenance</u>

1) Individual experiment contractors shall provide special tools, test equipment, spare parts, operating and maintenance instructions for their experiment(s). Where complexity and criticality dictate, furnish necessary skilled personnel.

2) Maintenance support by the experiment contractor will be required from point of installation at Denver or KSC through launch.

3) Common requirements such as parts, tools, test equipment, etc., shall be coordinated by MMC with KSC and experiment contractor to ensure full utilization of existing capabilities and eliminate unnecessary duplication.

3.5 Trainers Maintenance Criteria - Preventive Maintenance

1) Preventive maintenance shall consist of periodic inspection, adjustment, lubrication, checkout and calibration.

2) P/M shall be accomplished at Denver, MSC and KSC.

Corrective Maintenance

1) Corrective maintenance will normally be accomplished at location by selected Martin or other MSC designated personnel, and consist of removal and replacement of failed items at the provisioned item replacement level. Martin will support MSC/KSC as defined for support of the Apollo Mission Simulators (AMS).

2) Replacement items and operating maintenance instructions shall be provided.

3) Trainer design goals shall be to provide fault isolation capabilities to the provisioned replacement item level.

4) Common requirements such as parts, tools, test equipment, etc., shall be coordinated by MMC with MSC to ensure full utilization of existing capabilities.

3.6 Maintenance Ground Equipment (MGE) Maintenance Criteria

1) MGE is additional ground support equipment which is used in support of maintenance operations for the 1A Carrier, GSE, Experiments, and Trainers.

2) MGE shall consist primarily of off the shelf electronic test equipment and standard mechanical test equipment.

3) MGE calibration and repair requirements shall be coordinated by MMC with MSC and KSC to ensure full utilization of existing test equipment and facilities.

3.7 Conclusion

The logistics support approach defined in this study is a realistic trade-off of the various constraints/peculiarities of the 1-A Mission. This approach of minimum spares inventory/cost versus maximum possible on-location maintenance support and the factory rapid-reaction repair system as secondary support shall be utilized in the development of the Logistics Support Plan and the Maintenance and Spares Policy.

PR 29-19

TRADE STUDY REPORT

REVISED GROUND TRACK, MSFN AND TRUTH SITE DATA

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

September 6, 1967

Prepared by: D. B. Cross

Approved by: J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

1.1 Purpose - The purpose of this report is the documentation of basic data from the TRACE digital program for use in definition of the final mission history.

1.2 Objectives - The objectives of the TRACE runs are to provide detailed time histories of orbital position relative to the earth's surface and to the solar position. These data are translated into day/night cycles, overstation time and experiment available time.

2. SUMMARY

The data presented in this report define the MSFN considered and the method of determining time over the Continental U.S. for experiments and truth site considerations. The mission data are presented in the form of a 14 day time-line and ground trace map. A sample TRACE output is shown.

3. DISCUSSION

3.1 MSFN - The MSFN utilized is shown in Fig. 1 and listed in Table 1. Additional stations are shown in Table 1 for the DSIF net and were not incorporated in the original TRACE data. These facilities improve station utilization and orbit coverage and will be considered for future studies.

3.2 Continental U.S. Simulation - The boundaries of the Continental U.S. represent the target zone and are simulated by three tracking stations to provide rise and set times for the TRACE timelines. These stations are identified by the call letters WE, CE, and EA and are located as shown in Fig. 2. The smaller circles are for 7.2 deg elevation angles and the larger circle is for a 2 deg elevation angle.

3.3 Truth Sites - Individual truth sites provide very little information unless related to specific experiments and experiment times. At this point in the study it is considered sufficient to provide significant coverage of the Continental U.S. Future efforts will be directed toward relating specific portions of the time-line to specific experiment activities and the associated truth sites.

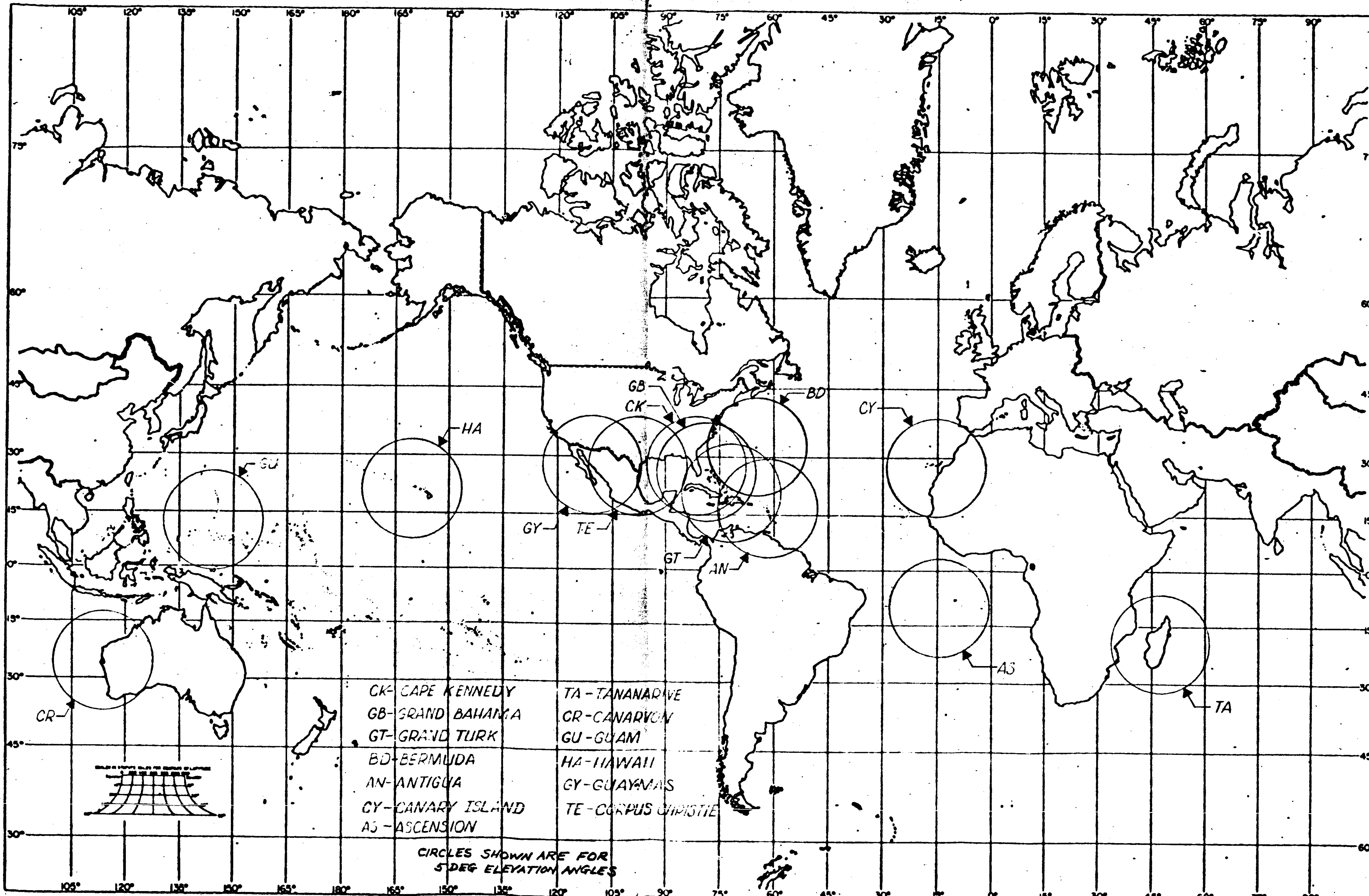
3.4 Time-line - Figure 3 presents fourteen days of mission time history with day/night cycles and overstation times. The call-letter definitions are noted in Fig. 1 and Fig. 2. These histories provide space for later integration of crew and experiment activities. The entire time-line can be provided by automatic machine plotting once co-ordinated inputs are available. Days are counted from the initial point or in this case from the launch time and therefore vary from the calendar days.

3.5 Trace Maps - Figure 4 presents fourteen days of ground trace in the area of the United States. The passes are numbered consecutively and the time of passage (GMT) into and out of the target area is noted. The earth day/night line is shown. For orbital conditions the spacecraft will pass into sunlight about 6 minutes or 24 deg earlier than the point shown. The western boundary is 8 hrs earlier than the GMT and the eastern boundary is 5 hrs earlier in terms of local time.

3.6 Sample TRACE Output - Figure 5 presents a sample output of the TRACE program with identifying code shown in Table 2. Time co-ordination between the time-lines and the print-out will provide latitude and longitude co-ordinates. An automatic map plotting routine is available and is being prepared for incorporation in the data handling and reduction capabilities of the current study.

4. CONCLUSIONS AND RECOMMENDATIONS

The basic tools and output data are presented. These data are the foundation for integrated mission activities to define crew and experiment operations and to insure compatibility of all mission elements. Launch dates other than 1 April 1969 (1500 GMT) would produce timelines and traces that vary from those shown.



FOLDOUT FRAME 1

FOLDOUT FRAME

FIG 1 MSFN DATA

FOLDOUT FRAME

FOLDOUT FRAME 2

Table 1. MSFN Stations and Capabilities

Station	Call Letters	Latitude (Geodetic)	Longitude	Unified S-band High Speed	Unified S-band Low Speed	C-band Tracking High Speed	C-band Tracking Low Speed	VHF Telemetry	VHF Voice	UHF Command
Merritt Island	MIL	28.508272	-80.693417	Yes	Yes					
Merritt Island	MLA	28.424861	-80.664404			Yes	Yes	Yes	Yes	Yes
Grand Bahama	GBM	26.632857	-78.237664	Yes	Yes					
Grand Bahama	GBI	26.636350	-78.267709			Yes	Yes	Yes	Yes	Yes
Bermuda	BDA	32.351286	-64.658331	Yes	Yes					
Bermuda	BDA	32.348102	-64.653800			Yes	Yes	Yes	Yes	Yes
Antigua	ANG	17.016916	-61.752849	Yes	Yes					
Antigua	ANT	17.144030	-61.792900			Yes	Yes	Yes	Yes	Yes
Grand Canary	CYI	27.764536	-15.634814	No	Yes					
Grand Canary	CYI	27.763205	-15.634814			No	Yes	Yes	Yes	Yes
Ascension	ACN	-7.955055	-14.327578	Yes	Yes					
Ascension	ASC	-7.972761	-14.401695			Yes	Yes	Yes	Yes	No
* Madrid	MAD	40.455358	-4.167395	Yes	Yes	No	No	No	No	No
* Pretoria	PRE	-25.943733	28.358488	No	No	Yes	Yes	Record	No	No
Tananarive	TAN	-19.018055	47.304444	No	No			Record	Relay	No
Carnarvon	CRO	-24.907591	113.724247	Yes	Yes					
Carnarvon	CRO	-24.897402	113.716077			Yes	Yes	Yes	Yes	Yes
Guam	GWM	13.309244	114.734413	Yes	Yes	No	No	Yes	Yes	No
* Canberra	CNB	-35.584738	148.976577	Yes	Yes	No	No	No	No	No
Hawaii	HAW	22.124897	-159.664989	No	Yes					
Hawaii	HAW	22.122091	-159.665384			Yes	Yes	Yes	Yes	Yes
* Port Arguello	CAL	34.582902	-120.561150	No	No	Yes	Yes	No	Relay	No
* Goldstone	GDS	35.341694	-116.873289	Yes	Yes	No	No	No	No	No
Guaymas	CYM	27.963205	-110.720850	Yes	Yes	No	No	Yes	Yes	No
* White Sands	WHS	32.358222	-106.369564	No	No	Yes	Yes	No	No	No
Texas	TE	27.65375	-97.37846944	Yes	Yes	No	No	Yes	Yes (?)	Yes

* Not at present being shown in MMC MSFN data

FOLDOUT FRAME

FOLDOUT FRAME 1

FOLDOUT FRAME

FOLDOUT FRAME 2

FIGURE 2 CONTINENTAL UNITED STATES SIMULATION

MARTIN MARIETTA CORPORATION

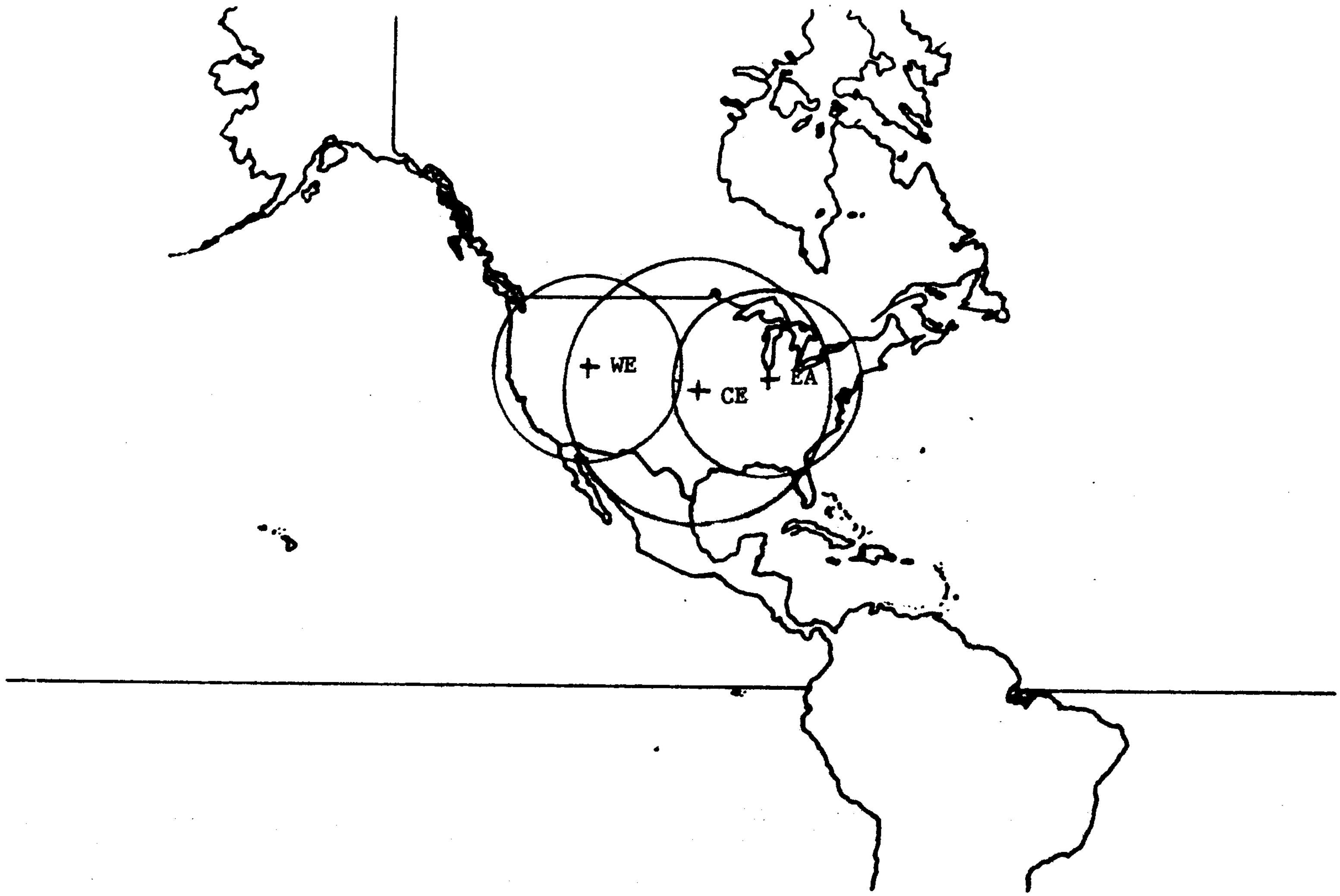


FIG 3

14 DAY TIME LINE

LAUNCH DATE 1 APRIL 1969

LAUNCH TIME 1500 GMT

FIGURE 1 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 1 OF 15 DAY MISSION

DAY/NIGHT

GROUND STATION COVERAGE

REVOLUTION: 1, 2

HOURS FROM L/O: 0, 1, 2, 3, 4

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 16, 17, 18, 19

DAY/NIGHT: DAY, DAY, DAY

GROUND STATION COVERAGE: HA, HE, CE, CY, HE, BD, GE, CA, AB, CR, GU, HE, CG

REVOLUTION: 3, 4, 5

HOURS FROM L/O: 4, 5, 6, 7, 8

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 20, 21, 22, 23

FIGURE 2 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 1 OF 15 DAY MISSION
DAY/NIGHT	DAY · DAY · DAY · DAY
GROUND STATION COVERAGE	GT, AN · CR · HE, CE, SY, CR, TE · GY · TA
REVOLUTION	5 · 7
HOURS FROM L/O	8 · 9 · 10 · 11 · 12
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	24 · 1 · 2 · 3

DAY/NIGHT	DAY · DAY · DAY
GROUND STATION COVERAGE	TA · HA
REVOLUTION	9 · 10
HOURS FROM L/O	12 · 13 · 14 · 15 · 16
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	4 · 5 · 6 · 7

FIGURE 3 AAP MISSION TIMELINE OF EVENTS

DAY 1 OF 15 DAY MISSION

DAY OF MISSION					
DAY/NIGHT		DAY		DAY	DAY
GROUND STATION COVERAGE		AS	AS	GU	CY
REVOLUTION		11	12		13
HOURS FROM L/O	16	17	18	19	20
CREW ACTIVITIES	1				
	2				
	3				
SPACECRAFT OPERATIONS					
GMT		8	9	10	11

DAY/NIGHT			DAY	DAY	DAY
GROUND STATION COVERAGE		AN	CR	CT GB BD	CR TE CA GR
REVOLUTION		14		15	16
HOURS FROM L/O	20	21	22	23	24
CREW ACTIVITIES	1				
	2				
	3				
SPACECRAFT OPERATIONS					
GMT		12	13	14	15

FIGURE 4 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 2 OF 1? DAY MISSION

DAY/NIGHT: DAY / NIGHT / DAY / NIGHT / DAY / NIGHT

GROUND STATION COVERAGE: CA, GB, EA, BD; GY, TE, CE, EA; TA; ME, GY, CD, CA; CY

REVOLUTION: 17, 18

HOURS FROM L/O: 24, 25, 26, 27, 28

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 16, 17, 18, 19

DAY/NIGHT: DAY / NIGHT / DAY / NIGHT / DAY

GROUND STATION COVERAGE: MA, ME, CA, AS; CE, BD, EA; AS; CR; GU; ME, CD, TE, EA, CK, GB, GY, AN

REVOLUTION: 19, 20, 21

HOURS FROM L/O: 28, 29, 30, 31, 32

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 20, 21, 22, 23

FIGURE 5 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 2 OF 18 DAY MISSION				
DAY/NIGHT		DAY		DAY	DAY
GROUND STATION COVERAGE			MC, CE, GY, TE	GY	TA
REVOLUTION	22		23		24
HOURS FROM L/O	32	33	34	35	36
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		24	1	2	3

DAY/NIGHT	DAY		DAY		DAY
GROUND STATION COVERAGE			HA		
REVOLUTION		25		26	
HOURS FROM L/O	36	37	38	39	40
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		4	5	6	7

FIGURE 6 AAP MISSION TIMELINE OF EVENTS

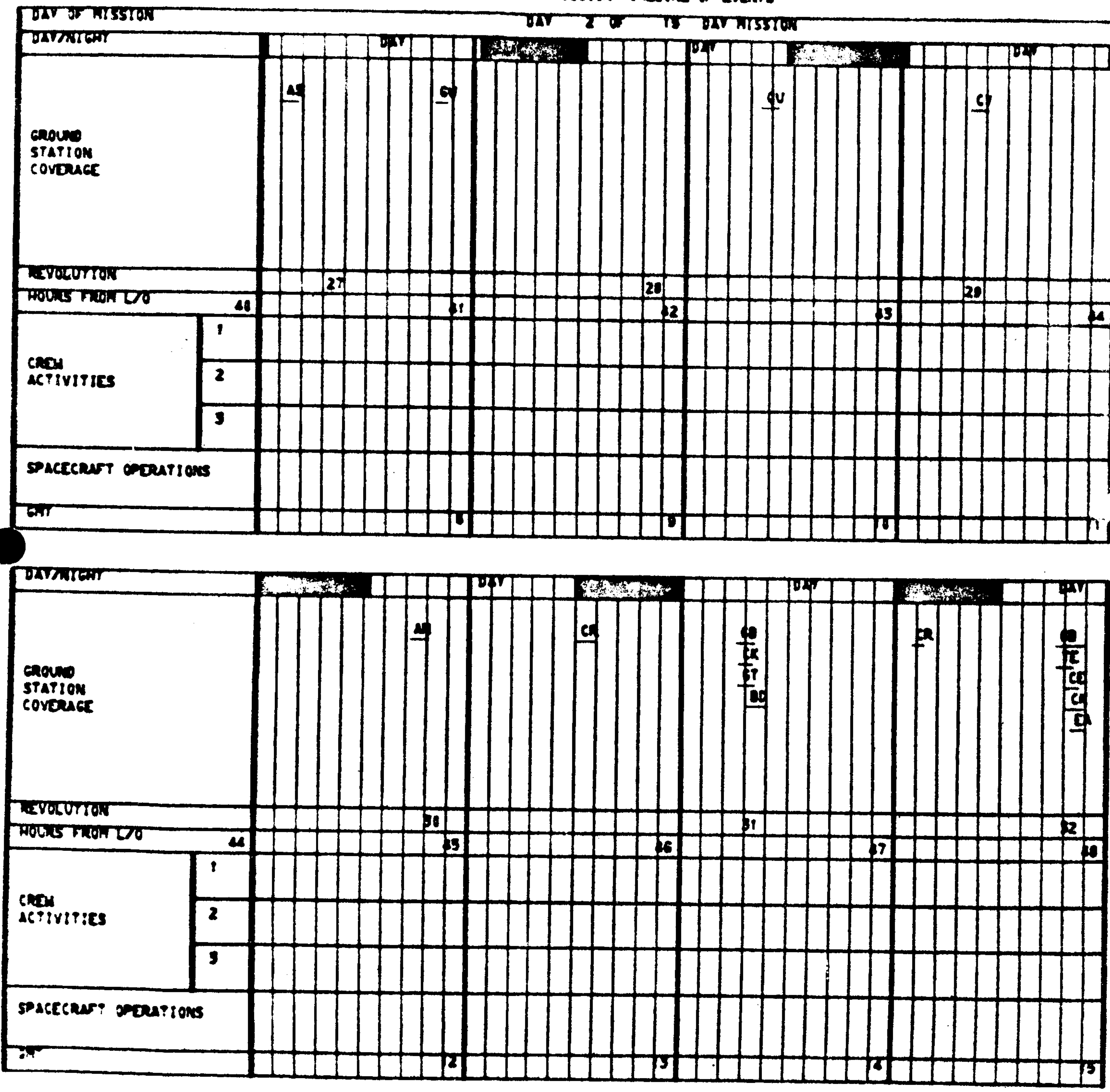


FIGURE 7 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 3 OF 15 DAY MISSION
DAY/NIGHT	DAY · DAY · DAY
GROUND STATION COVERAGE	CY, TC, HE, CE, EA · TA · HE, CE · CV
REVOLUTION	33 · 34
HOURS FROM L/O	48 · 49 · 50 · 51 · 52
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	16 · 17 · 18 · 19

DAY/NIGHT	DAY · DAY · DAY
GROUND STATION COVERAGE	HA · HE, CE · AS · HE, CE, EA, CK, GT, BD, AN · CR · GU · HE, CE, EA, TE, CK, GB, GT, AN
REVOLUTION	35 · 36 · 37
HOURS FROM L/O	52 · 53 · 54 · 55 · 56
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	20 · 21 · 22 · 23

FIGURE 8 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 3 OF 15 DAY MISSION
DAY/NIGHT	DAY, DAY, DAY
GROUND STATION COVERAGE	HS, GY, CE, TE, TA
REVOLUTION	38, 39, 40
HOURS FROM L/O	56, 57, 58, 59, 60
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	24, 1, 2, 3

DAY/NIGHT	DAY, DAY, DAY
GROUND STATION COVERAGE	MA, MA
REVOLUTION	41, 42
HOURS FROM L/O	60, 61, 62, 63, 64
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	4, 5, 6, 7

FIGURE 9 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 3 OF 15 DAY MISSION			
DAY/NIGHT	DAY		DAY	DAY
GROUND STATION COVERAGE	AS GU	CY	GU	CY
REVOLUTION	43	44		83
HOURS FROM L/O	64	65	66	67
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	8	9	0	1

Hours from L/O at right end: 68

DAY/NIGHT		DAY	DAY	DAY
GROUND STATION COVERAGE	AN	CR	GB GT CK BD	GY TE KE CR EA
REVOLUTION	46		47	48
HOURS FROM L/O	68	69	70	71
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	2	3	4	5

Hours from L/O at right end: 72

FIGURE 10 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 4 OF 18 DAY MISSION			
DAY/NIGHT	DAY / NIGHT	DAY / NIGHT	DA / NIGHT	DAY / NIGHT
GROUND STATION COVERAGE		CY, ME, CE, EA	TA, MA, ME, CE	CY
REVOLUTION		49	50	
HOURS FROM L/O	72–73	73–74	74–75	75–76
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	16	17	18	19

DAY/NIGHT	DAY / NIGHT	DA / NIGHT		DAY / NIGHT
GROUND STATION COVERAGE	MA, ME, CE, EA, BD, AS	CR	ME, CE, TA, CK, GB, BD, GT, AN, CR	GU, ME, CE, TC, EA, CK, GB, GT
REVOLUTION	51	52		53
HOURS FROM L/O	76–77	77–78	78–79	79–80
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	20	21	22	23

FIGURE 11 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 4 OF 15 DAY MISSION

DAY/NIGHT	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY
GROUND STATION COVERAGE		MC GY TE			TA	
REVOLUTION	54		55		56	
HOURS FROM L/O	80	81	82	83		84
CREW ACTIVITIES 1						
CREW ACTIVITIES 2						
CREW ACTIVITIES 3						
SPACECRAFT OPERATIONS						
GMT		24	1	2		3

DAY/NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
GROUND STATION COVERAGE	HA		HA			AS
REVOLUTION		57		58		
HOURS FROM L/O	84	85	86	87		88
CREW ACTIVITIES 1						
CREW ACTIVITIES 2						
CREW ACTIVITIES 3						
SPACECRAFT OPERATIONS						
GMT		4	5	6		7

FIGURE 12 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 4 OF 15 DAY MISSION			
DAY/NIGHT	DAY	DAY	DAY	
GROUND STATION COVERAGE	GU	GY		
REVOLUTION	59	60	61	
HOURS FROM L/O	88 / 89	90	91	92
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	8	9	10	11

DAY/NIGHT	DAY	DAY	DAY	
GROUND STATION COVERAGE	GT AN / CR	CK CD CT BD	GY TE CE EA CA	
REVOLUTION	62	63	64	
HOURS FROM L/O	92 / 93	94	95	96
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	12	13	14	15

FIGURE 15 AAP MISSION TIMELINE OF EVENTS

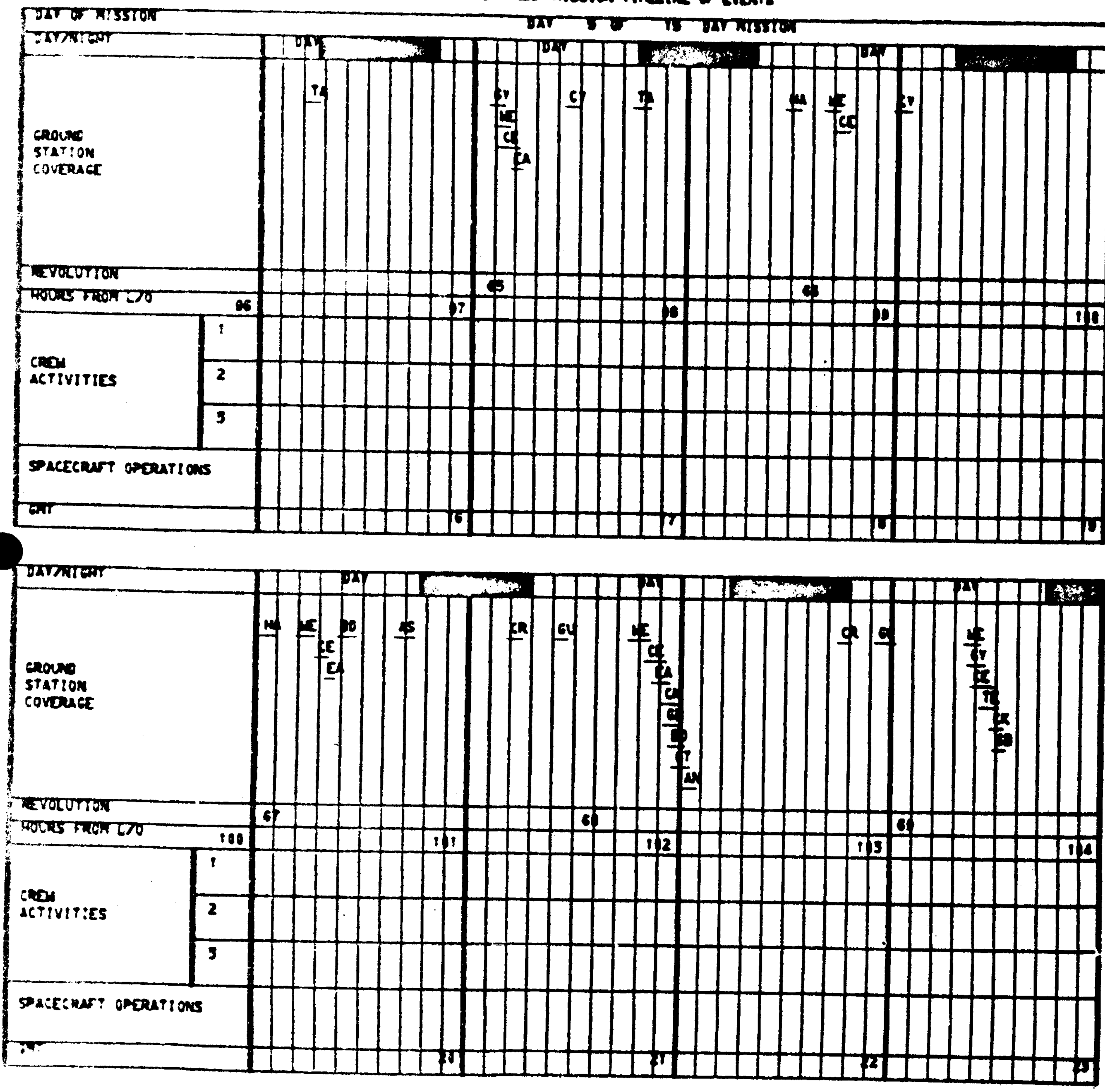


FIGURE 14 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 5 OF 75 DAY MISSION				
DAY/NIGHT	DAY		DAY		DAY
GROUND STATION COVERAGE	GY	TA		TA	HW
REVOLUTION	70		71	72	
HOURS FROM L/O	104	105	106	107	108
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		24	1	2	3

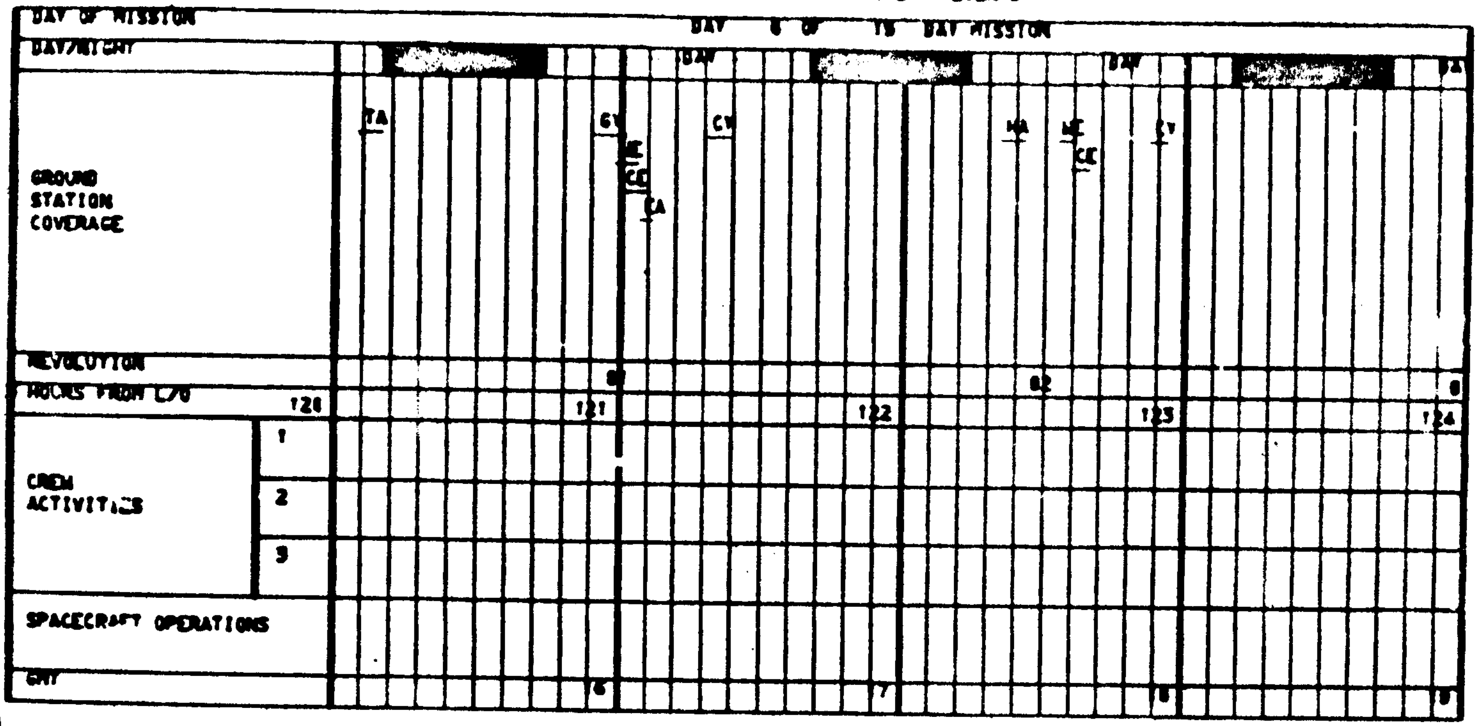
DAY/NIGHT	DAY	DAY		DAY	DAY
GROUND STATION COVERAGE	HAW				AS
REVOLUTION		73		74	
HOURS FROM L/O	108	109	110	111	112
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		4	5	6	7

FIGURE 18 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 5 OF 15 DAY MISSION
DAY/NIGHT	DAY · DAY · DAY
GROUND STATION COVERAGE	SU · CY · CR
REVOLUTION	76 · 77
HOURS FROM L/O	112 · 113 · 114 · 115 · 116
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	8 · 9 · [illegible] · [illegible]

DAY/NIGHT	DAY · DAY · DAY
GROUND STATION COVERAGE	ST HN BD · CR · CA GC BD · GY TX CE EA
REVOLUTION	78 · 79 · [illegible]
HOURS FROM L/O	116 · 117 · 118 · 119 · 120
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	12 · 13 · 14 · 15

FIGURE 16 AAP MISSION TIMELINE OF EVENTS



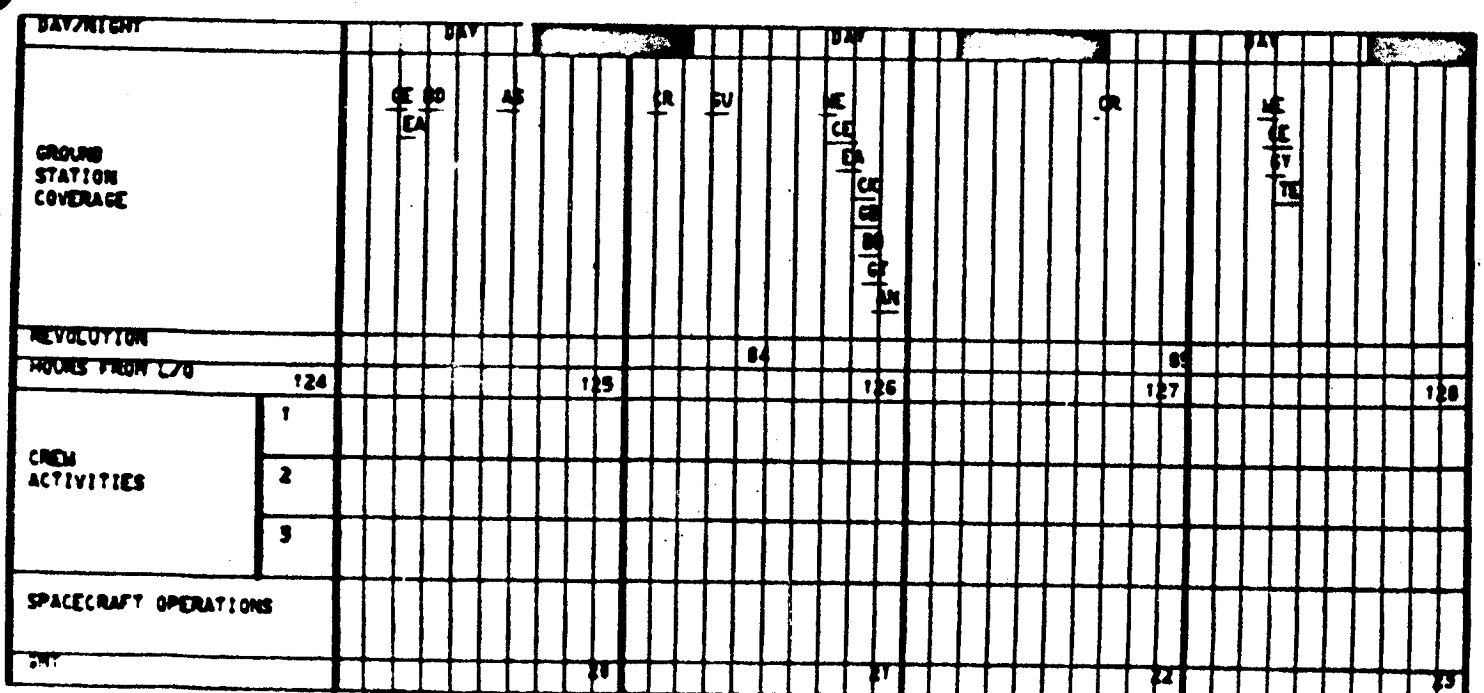


FIGURE 17 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 6 OF 15 DAY MISSION			
DAY/NIGHT	DAY	DAY	DAY	
GROUND STATION COVERAGE	GY	TA	TA	MA
REVOLUTION	86	87	88	
HOURS FROM L/O 128	129	130	131	132
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	24	1	2	3

DAY/NIGHT	DAY	DAY	DAY	
GROUND STATION COVERAGE		AS		
REVOLUTION	89	90	91	
HOURS FROM L/O 132	133	134	135	136
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	4	5	6	7

FIGURE 18 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION: DAY 6 OF 15 DAY MISSION

	136–137	137–138	138–139	139–140
DAY/NIGHT	DAY	DAY		DAY
GROUND STATION COVERAGE	GU	CY	AN	CR
REVOLUTION		92		93
HOURS FROM L/O	136	137	138	139 (140)
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	8	9	10	11

	140–141	141–142	142–143	143–144
DAY/NIGHT	DAY		DAY	DAY
GROUND STATION COVERAGE	GD GT AN BD	CR TE GD CR CA BD		GY TE CR CA
REVOLUTION	94	95		96
HOURS FROM L/O	140	141	142	143 (144)
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	12	13	14	15

FIGURE 10 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION: DAY 7 OF 15 DAY MISSION

DAY/NIGHT: DAY, DAY, DAY

GROUND STATION COVERAGE: TA, WE, CE, CV, MA, CE, AS, M

REVOLUTION		97		98		99
HOURS FROM L/O	144	145	146	147	148	
CREW ACTIVITIES 1						
CREW ACTIVITIES 2						
CREW ACTIVITIES 3						
SPACECRAFT OPERATIONS						
GMT	16	17	18	19		

DAY/NIGHT: DAY, DAY, DAY

GROUND STATION COVERAGE: WE, CE, CA, BD, AN, AS, CR, GU, WE, CE, CA, TE, CK, GD, GY, AN, WE, GY, CE, TE

REVOLUTION		100		101	
HOURS FROM L/O	148	149	150	151	152
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT	20	21	22	23	

FIGURE 28 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 7 OF 18 DAY MISSION				
DAY/NIGHT	DAY		DAY		DAY
GROUND STATION COVERAGE	GY	TA			MA
REVOLUTION	102		103		104
HOURS FROM L/O	152	153	154	155	156
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT	24	1	2	3	

DAY/NIGHT	DAY		DAY		DAY
GROUND STATION COVERAGE		AS	CU		
REVOLUTION	105		106		107
HOURS FROM L/O	156	157	158	159	160
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT	4	5	6	7	

FIGURE 21 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 7 OF 18 DAY MISSION

DAY/NIGHT	DAY		DAY		DAY	
GROUND STATION COVERAGE	GU	CY		AN	CR	
REVOLUTION		108		109		
HOURS FROM L/O	160	161	162	163	164	
CREW ACTIVITIES 1						
CREW ACTIVITIES 2						
CREW ACTIVITIES 3						
SPACECRAFT OPERATIONS						
GMT	8	9	10	11		

DAY/NIGHT	DAY		DAY		DAY	
GROUND STATION COVERAGE	GY, GB, CE, BD	CR	TE, CE, TK, GB, EA, BD		GY, TE, CE, EA	TA
REVOLUTION	110		111		112	
HOURS FROM L/O	164	165	166	167	168	
CREW ACTIVITIES 1						
CREW ACTIVITIES 2						
CREW ACTIVITIES 3						
SPACECRAFT OPERATIONS						
GMT	12	13	14	15		

FIGURE 22 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 8 OF 15 DAY MISSION

DAY/NIGHT — DAY · DAY · DAY

GROUND STATION COVERAGE — ME CE · CY · MA · ME · CE · BD · AS · ME CE B

REVOLUTION — 113 · 114 · 115

HOURS FROM L/O — 168 · 169 · 170 · 171 · 172

CREW ACTIVITIES — 1 · 2 · 3

SPACECRAFT OPERATIONS

GMT — 16 · 17 · 18 · 19

DAY/NIGHT — DAY · DAY · DAY

GROUND STATION COVERAGE — EA CK BD AN GT · CR · GU · ME CE EA TE CK GB GT AN · ME GY CE ME

REVOLUTION — 116 · 117

HOURS FROM L/O — 172 · 173 · 174 · 175 · 176

CREW ACTIVITIES — 1 · 2 · 3

SPACECRAFT OPERATIONS

GMT — 20 · 21 · 22 · 23

FIGURE 23 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 8 OF 15 DAY MISSION

DAY/NIGHT		DAY · DAY · DAY
GROUND STATION COVERAGE		TA · HA · HA
REVOLUTION		118 · 119 · 120
HOURS FROM L/O		176 · 177 · 178 · 179 · 180
CREW ACTIVITIES	1	
	2	
	3	
SPACECRAFT OPERATIONS		
GMT		24 · 1 · 2 · 3

DAY/NIGHT		DAY · DAY · DAY
GROUND STATION COVERAGE		AS · GU · CY
REVOLUTION		121 · 122 · 123
HOURS FROM L/O		180 · 181 · 182 · 183 · 184
CREW ACTIVITIES	1	
	2	
	3	
SPACECRAFT OPERATIONS		
GMT		4 · 5 · 6 · 7

FIGURE 34 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 8 OF 15 DAY MISSION				
DAY/NIGHT		DAY	DAY	DAY	
GROUND STATION COVERAGE			GY	GY, AN	CR
REVOLUTION			124	125	
HOURS FROM L/O	104	105	106	107	108
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		8	9	10	11

DAY/NIGHT		DAY	DAY	DAY	
GROUND STATION COVERAGE	GB, CK, GT, BD		GY, TE, CR, GB, CK, EA	GY, ME, CE, EA	TA
REVOLUTION	126		127	128	
HOURS FROM L/O	108	109	110	111	112
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		12	13	14	15

FIGURE 25 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 9 OF 15 DAY MISSION

DAY/NIGHT: DAY — DAY — DAY

GROUND STATION COVERAGE: HA, ME, CE, CY, BA, ME, CE, CA, BD, AS, CR, ME, CE, CA, CR, GB, BD, GT

REVOLUTION: 129, 130, 131

HOURS FROM L/O: 192, 193, 194, 195, 196

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 16, 17, 18, 19

DAY/NIGHT: DAY — DAY — DAY

GROUND STATION COVERAGE: AN, CR, GU, ME, CE, TE, CA, CR, GB, GT, ME, GY, TE

REVOLUTION: 132, 133

HOURS FROM L/O: 196, 197, 198, 199, 200

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 20, 21, 22, 23

FIGURE 26 AAP MISSION TIMELINE OF EVENTS

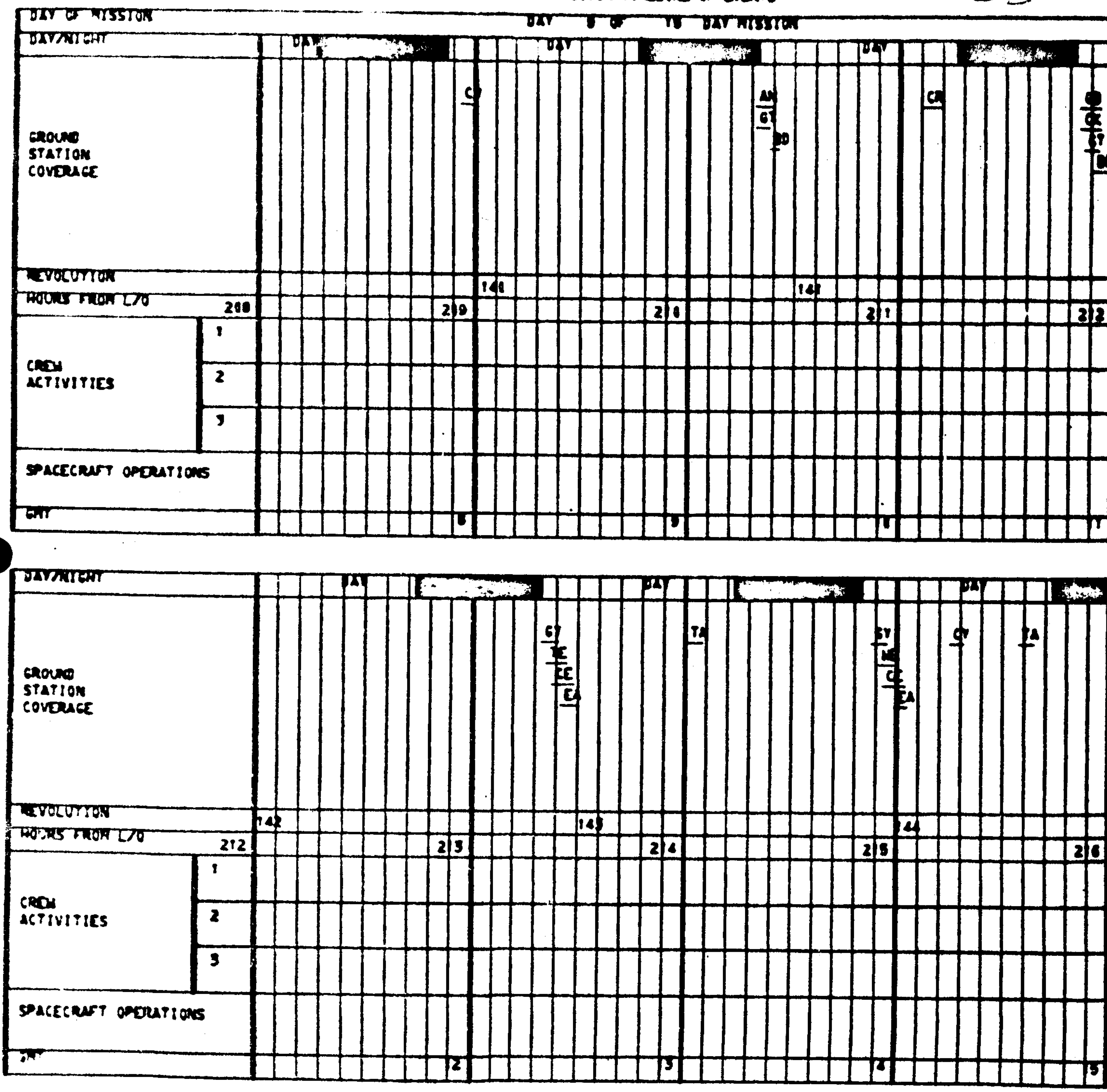
DAY OF MISSION — DAY 9 OF 15 DAY MISSION

DAY/NIGHT	DAY	DAY	DAY
GROUND STATION COVERAGE	TA	HA	HA
REVOLUTION	134	135	136
HOURS FROM L/O	200 · 201	202	203 · 204
CREW ACTIVITIES 1			
CREW ACTIVITIES 2			
CREW ACTIVITIES 3			
SPACECRAFT OPERATIONS			
GMT	24	1	2 · 3

DAY/NIGHT	DAY	DAY	DAY
GROUND STATION COVERAGE	AS	GU	CV
REVOLUTION	137	138	139
HOURS FROM L/O	204 · 205	206	207 · 208
CREW ACTIVITIES 1			
CREW ACTIVITIES 2			
CREW ACTIVITIES 3			
SPACECRAFT OPERATIONS			
GMT	4	5	6 · 7

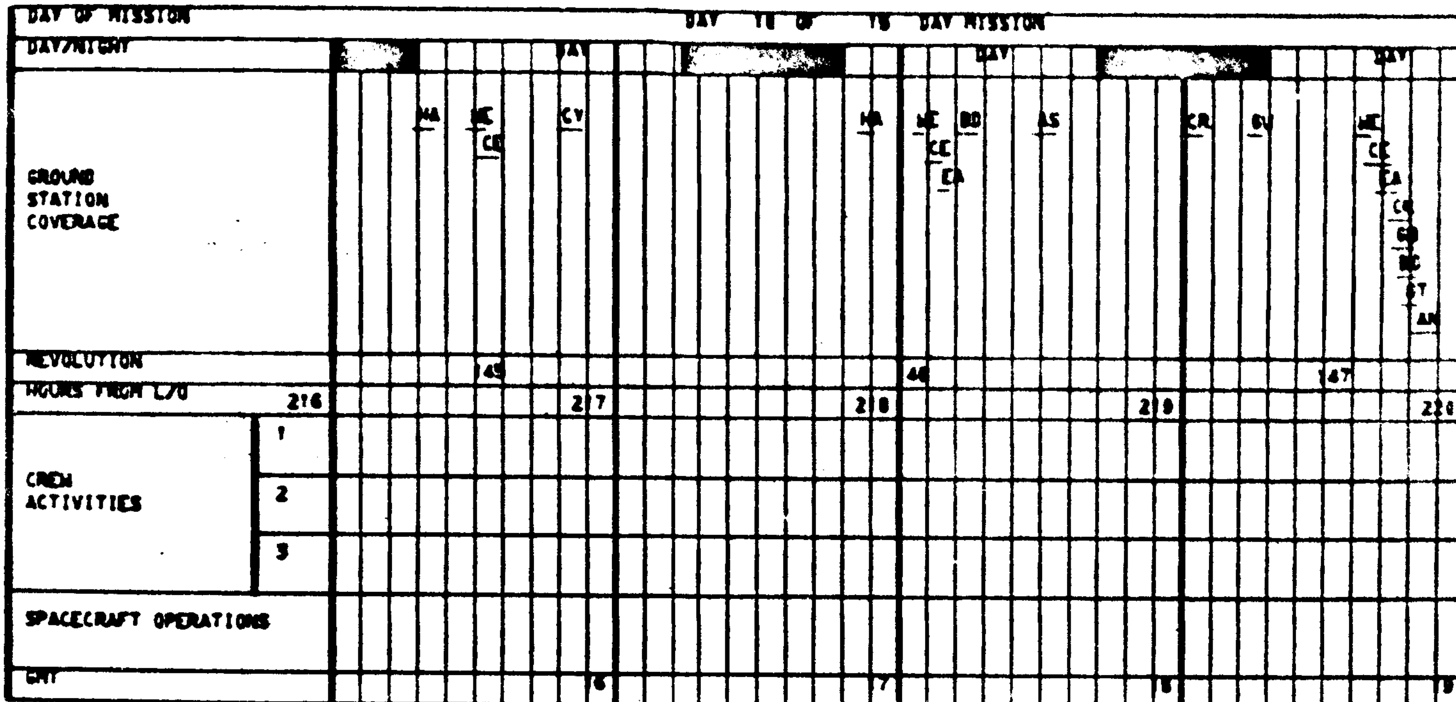
33

FIGURE 27 AAP MISSION TIMELINE OF EVENTS



34

FIGURE 28 AAP MISSION TIMELINE OF EVENTS



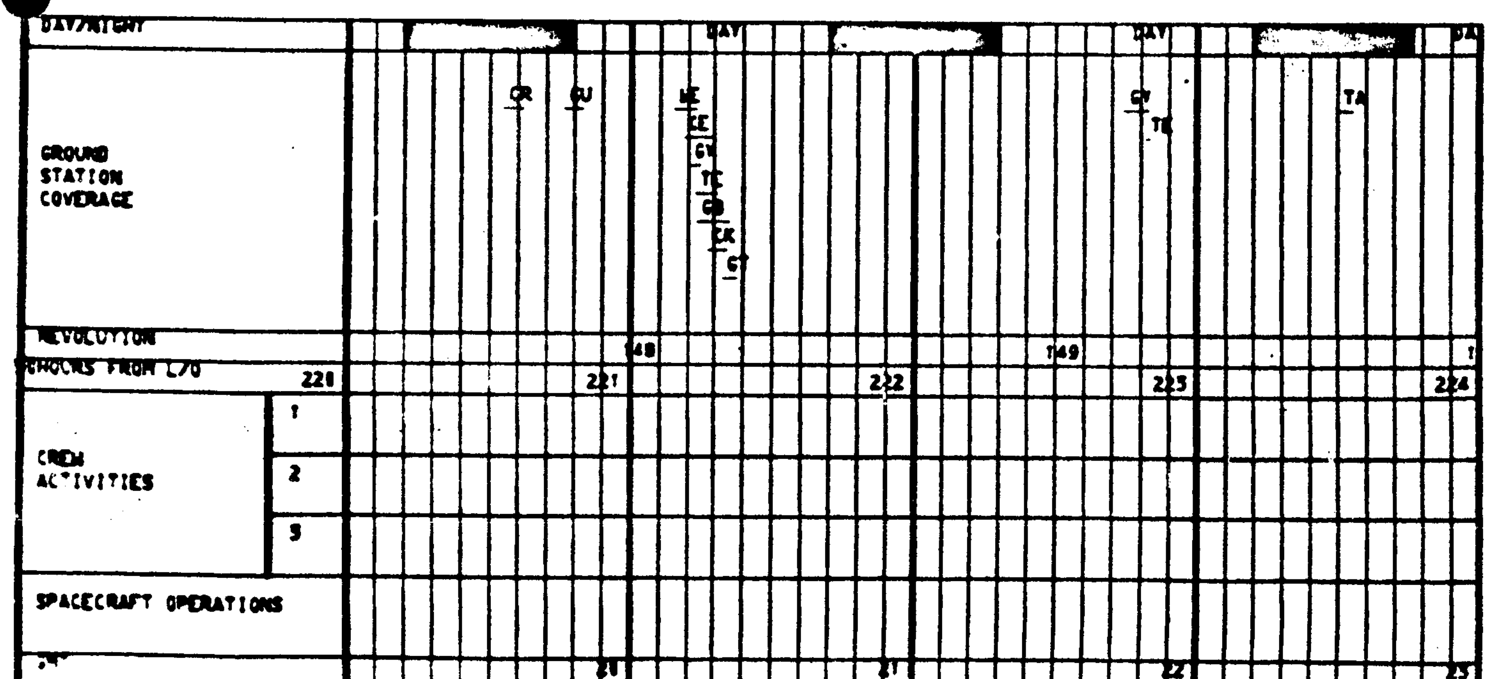


FIGURE 28 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 10 OF 10 DAY MISSION

DAY/NIGHT		DAY		DAY		DAY			
GROUND STATION COVERAGE			TA	MA					
REVOLUTION				151		152			
HOURS FROM L/O	224	225		226		227		228	
CREW ACTIVITIES	1								
	2								
	3								
SPACECRAFT OPERATIONS									
GMT		24		1		2		3	

DAY/NIGHT		DAY		DAY		DAY			
GROUND STATION COVERAGE			AS	GU		CY			
REVOLUTION		153		154		155			
HOURS FROM L/O	228	229		230		231		232	
CREW ACTIVITIES	1								
	2								
	3								
SPACECRAFT OPERATIONS									
GMT		4		5		6		7	

FIGURE 34 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 10 OF 15 DAY MISSION			
DAY/NIGHT		DAY	DAY	DAY
GROUND STATION COVERAGE		GY, AN, BD	CR	CR, GR, GY, BD
REVOLUTION	156		157	15
HOURS FROM L/O 232	233	234	235	236
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	8	9	10	11

DAY/NIGHT	DAY	DAY		DAY
GROUND STATION COVERAGE		GY, TE, CE, EA, TA	GY, HE, CE, EA	CY, TA
REVOLUTION		159		160
HOURS FROM L/O 236	237	238	239	240
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	12	13	14	15

37

FIGURE 31 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 11 OF 18 DAY MISSION
DAY/NIGHT	DAY / DAY / DAY
GROUND STATION COVERAGE	HA, MC, CE, CY, MD, CE, EA, BD, AS, CR, GU, MC, CE, EA, CK, SB, BD, GY, AN
REVOLUTION	161, 162, 163
HOURS FROM L/O	240, 241, 242, 243, 244
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	16, 17, 18, 19

DAY/NIGHT	DAY / DAY / DAY
GROUND STATION COVERAGE	CR, GY, GB, ME, CE, TE, CK, GY, TA
REVOLUTION	164, 165, 166
HOURS FROM L/O	244, 245, 246, 247, 248
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	20, 21, 22, 23

FIGURE 32 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 11 OF 18 DAY MISSION			
DAY/NIGHT	DAY	DAY		DAY
GROUND STATION COVERAGE	TA	MA		
REVOLUTION		167	168	
HOURS FROM L/O 248	249	250	251	252
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	24	1	2	3

DAY/NIGHT	DAY		DAY	DAY
GROUND STATION COVERAGE		AS	CY	CY
REVOLUTION	169	170		171
HOURS FROM L/O 252	253	254	255	256
CREW ACTIVITIES 1				
CREW ACTIVITIES 2				
CREW ACTIVITIES 3				
SPACECRAFT OPERATIONS				
GMT	4	5	6	7

FIGURE 33 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION: DAY 11 OF 13 DAY MISSION

DAY/NIGHT	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY
GROUND STATION COVERAGE	AN	CR	GY, GD, AN, BD	CR	TC, CR, GD, EA, BD	
REVOLUTION		172		173		174
HOURS FROM L/O	256	257	258	259		260
CREW ACTIVITIES 1						
CREW ACTIVITIES 2						
CREW ACTIVITIES 3						
SPACECRAFT OPERATIONS						
GMT		8	9	10		11

DAY/NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
GROUND STATION COVERAGE	EA	GY, FE, CE, EA	TA	ME, CE	GY	
REVOLUTION		175		176		
HOURS FROM L/O	260	261	262	263		264
CREW ACTIVITIES 1						
CREW ACTIVITIES 2						
CREW ACTIVITIES 3						
SPACECRAFT OPERATIONS						
GMT		12	13	14		15

43

FIGURE 34 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 12 OF 15 DAY MISSION

DAY/NIGHT: DAY — DAY — DAY

GROUND STATION COVERAGE: HAW, ME, CZ, GYAB, CE, BO, CA, AS, CR, GY, ME, CZ, CA, TE, CK, BD, ST, AN

REVOLUTION: 177, 178, 179

HOURS FROM L/O: 264, 265, 266, 267, 268

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 16, 17, 18, 19

DAY/NIGHT: DAY — DAY — DAY

GROUND STATION COVERAGE: ME, CE, GY, TE, GY, TA

REVOLUTION: 180, 181, 182

HOURS FROM L/O: 268, 269, 270, 271, 272

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 20, 21, 22, 23

4/

FIGURE 35 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION: DAY 12 OF 15 DAY MISSION

DAY/NIGHT	DAY — DAY — DAY
GROUND STATION COVERAGE	HA — AS
REVOLUTION	183 — 184
HOURS FROM L/O	272 — 273 — 274 — 275 — 276
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	24 — 1 — 2 — 3

DAY/NIGHT	DAY — DAY — DAY
GROUND STATION COVERAGE	CU — CY
REVOLUTION	185 — 186 — 187
HOURS FROM L/O	276 — 277 — 278 — 279 — 280
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	4 — 5 — 6 — 7

FIGURE 38 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 12 OF 15 DAY MISSION

DAY/NIGHT		DAY			DAY			DAY	
GROUND STATION COVERAGE	AN	CR		ST GD AN BD		CR	BD TE GD CR CR CA		
REVOLUTION		188			189			190	
HOURS FROM L/O	280	281		282		283		284	
CREW ACTIVITIES 1									
CREW ACTIVITIES 2									
CREW ACTIVITIES 3									
SPACECRAFT OPERATIONS									
GMT		8		9		10		11	

DAY/NIGHT	DAY			DAY			DAY		
GROUND STATION COVERAGE		SY TX CE GE CA		TA		HE CE	CY		MA
REVOLUTION			191			192			
HOURS FROM L/O	284	285		286		287		288	
CREW ACTIVITIES 1									
CREW ACTIVITIES 2									
CREW ACTIVITIES 3									
SPACECRAFT OPERATIONS									
GMT		12		13		14		15	

FIGURE 37 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 13 OF 15 DAY MISSION				
DAY/NIGHT	DAY		DAY		DAY
GROUND STATION COVERAGE	ME, CE, AS		ME, CE, EA, BD, AN	CR, GU	ME, CE, EA, TE, CK, EB, GY, AN
REVOLUTION	193		194		195
HOURS FROM L/O	288	289	290	291	292
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		16	17	18	19

DAY/NIGHT		DAY		DAY	DAY
GROUND STATION COVERAGE		ME, GY, CE, TE		TA	
REVOLUTION		196	197		198
HOURS FROM L/O	292	293	294	295	296
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		20	21	22	23

FIGURE 38 AAP MISSION TIMELINE OF EVENTS

47

DAY OF MISSION	DAY 13 OF 13 DAY MISSION				
DAY/NIGHT	DAY	DAY		DAY	
GROUND STATION COVERAGE		HA			AS
REVOLUTION		199		200	
HOURS FROM L/O	296	297	298	299	300
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		24	1	2	3

DAY/NIGHT	DAY		DAY		DAY
GROUND STATION COVERAGE	GV	CV	GV	CV	
REVOLUTION	201		202		203
HOURS FROM L/O	300	301	302	303	304
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		4	5	6	7

FIGURE 30 AAP MISSION TIMELINE OF EVENTS

45

DAY OF MISSION — DAY 13 OF 19 DAY MISSION

DAY/NIGHT	DAY · DAY · DAY
GROUND STATION COVERAGE	AN · AR · GE GT CK BD · TE CK CA
REVOLUTION	204 · 205 · 206
HOURS FROM L/O	304 · 305 · 306 · 307 · 308
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	8 · 9 · 10 · 11

DAY/NIGHT	DAY · DAY · DA
GROUND STATION COVERAGE	GY NE CE EA · TA · HA NE CR · CY · NA · C
REVOLUTION	207 · 208
HOURS FROM L/O	308 · 309 · 310 · 311 · 312
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	12 · 13 · 14 · 15

FIGURE 48 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 14 OF 15 DAY MISSION

DAY/NIGHT	DAY	DAY	DAY
GROUND STATION COVERAGE	BD, AS	CE, EA, GD, CR, BD, GT, AN, CR, GU	WE, CE, TE, EA, CR, GD, GT
REVOLUTION	209	210	211
HOURS FROM L/O	312, 313	314	315, 316
CREW ACTIVITIES 1			
CREW ACTIVITIES 2			
CREW ACTIVITIES 3			
SPACECRAFT OPERATIONS			
GMT	6	7	8, 9

DAY/NIGHT	DAY	DAY	DAY
GROUND STATION COVERAGE	WE, GY, CE, TE	TA	MA
REVOLUTION	212	213	214
HOURS FROM L/O	316, 317	318	319, 320
CREW ACTIVITIES 1			
CREW ACTIVITIES 2			
CREW ACTIVITIES 3			
SPACECRAFT OPERATIONS			
GMT	20	21	22, 23

FIGURE 41 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY 14 OF 16 DAY MISSION				
DAY/NIGHT		DAY		DAY	DAY
GROUND STATION COVERAGE		MA			AS
REVOLUTION		215		216	
HOURS FROM L/O	320	321	322	323	324
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		24	1	2	3

DAY/NIGHT		DAY		DAY	DAY
GROUND STATION COVERAGE		GU	CY	CY	
REVOLUTION		217	218	219	
HOURS FROM L/O	324	325	326	327	328
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT		4	5	6	7

FIGURE 42 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 14 OF 18 DAY MISSION

DAY/NIGHT	DAY — DAY — DAY
GROUND STATION COVERAGE	AN, CR, GY, CR, GY, BD, GY, HE, CE, EA, CR, TA
REVOLUTION	220, 221, 222
HOURS FROM L/O	328, 329, 330, 331, 332
CREW ACTIVITIES	1, 2, 3
SPACECRAFT OPERATIONS	
GMT	8, 9, 10, 11

DAY/NIGHT	DAY — DAY — DAY
GROUND STATION COVERAGE	CY, HE, CR, EA, GY, TA, HA, HE, CE, CY, HA, HE, BD, CE, EA
REVOLUTION	223, 224, 2
HOURS FROM L/O	332, 333, 334, 335, 336
CREW ACTIVITIES	1, 2, 3
SPACECRAFT OPERATIONS	
GMT	12, 13, 14, 15

FIGURE 43 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION — DAY 15 OF 15 DAY MISSION

DAY/NIGHT: DAY | NIGHT | DAY | NIGHT | DAY | NIGHT

GROUND STATION COVERAGE: AS, CR, CE, CA, GB, CR, BD, GY, AN, CR, GU, ME, CE, TE, CA, TE, BD, GY

REVOLUTION: 226, 227

HOURS FROM L/O: 336, 337, 338, 339, 340

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 16, 17, 18, 19

DAY/NIGHT: DAY | NIGHT | DAY | NIGHT | DAY

GROUND STATION COVERAGE: ME, GY, TE, TA, HA

REVOLUTION: 228, 229, 230

HOURS FROM L/O: 340, 341, 342, 343, 344

CREW ACTIVITIES: 1, 2, 3

SPACECRAFT OPERATIONS

GMT: 20, 21, 22, 23

FIGURE 44 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION	DAY __ TO __ OF __ DAY MISSION				
DAY/NIGHT		DAY		DAY	DAY
GROUND STATION COVERAGE		MA			AS
REVOLUTION	23[illegible]		232		23
HOURS FROM L/O	344	345	346	347	348
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT	24	1	2	3	

DAY/NIGHT	DAY		DAY	DAY	
GROUND STATION COVERAGE	CU	CY		CY	GY AN BD
REVOLUTION		234		235	
HOURS FROM L/O	348	349	350	351	352
CREW ACTIVITIES 1					
CREW ACTIVITIES 2					
CREW ACTIVITIES 3					
SPACECRAFT OPERATIONS					
GMT	4	5	6	7	

FIGURE 46 AAP MISSION TIMELINE OF EVENTS

DAY OF MISSION: DAY 15 OF 15 DAY MISSION

DAY/NIGHT	DAY — DAY — DAY
GROUND STATION COVERAGE	CR; GB, CK, GT, BD; GY, TC, CA, BA; TA
REVOLUTION	236, 237, 238
HOURS FROM L/O	352, 353, 354, 355, 356
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	[illegible]

DAY/NIGHT	DAY — DAY — DAY
GROUND STATION COVERAGE	GY, HE, CE, EA; CY; TA; HA; HE, CE; CY; HA, HE, BD, CE, EA
REVOLUTION	239, 240, 241
HOURS FROM L/O	356, 357, 358, 359, 360
CREW ACTIVITIES 1	
CREW ACTIVITIES 2	
CREW ACTIVITIES 3	
SPACECRAFT OPERATIONS	
GMT	2, 3, 4, 5

FIG 4

14 DAY GROUND TRACE MAPS

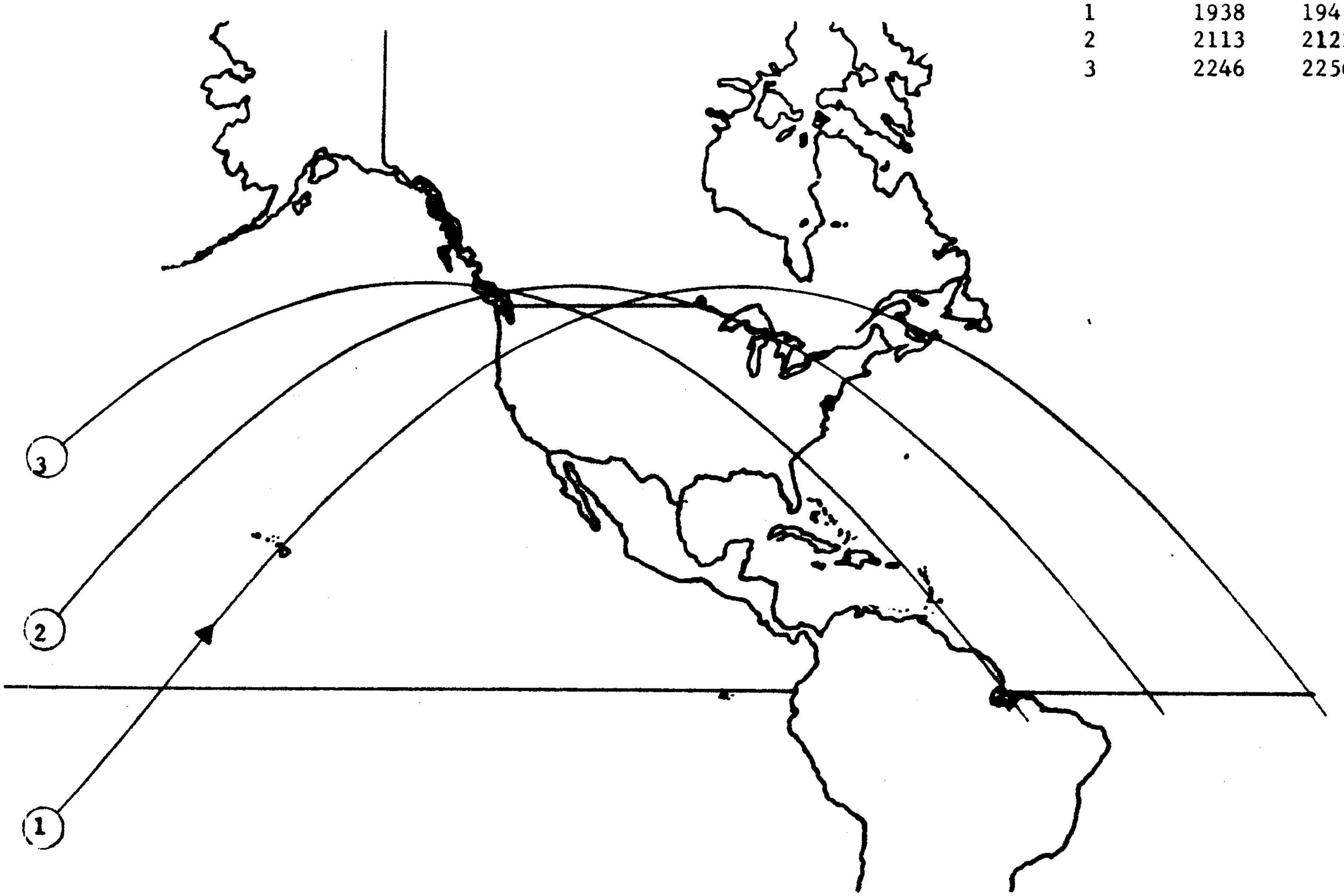
LAUNCH DATE 1 APRIL 1969

LAUNCH TIME 1500 GMT

DATE - FIRST OF MONTH, LAUNCH ON FIRST OF MONTH

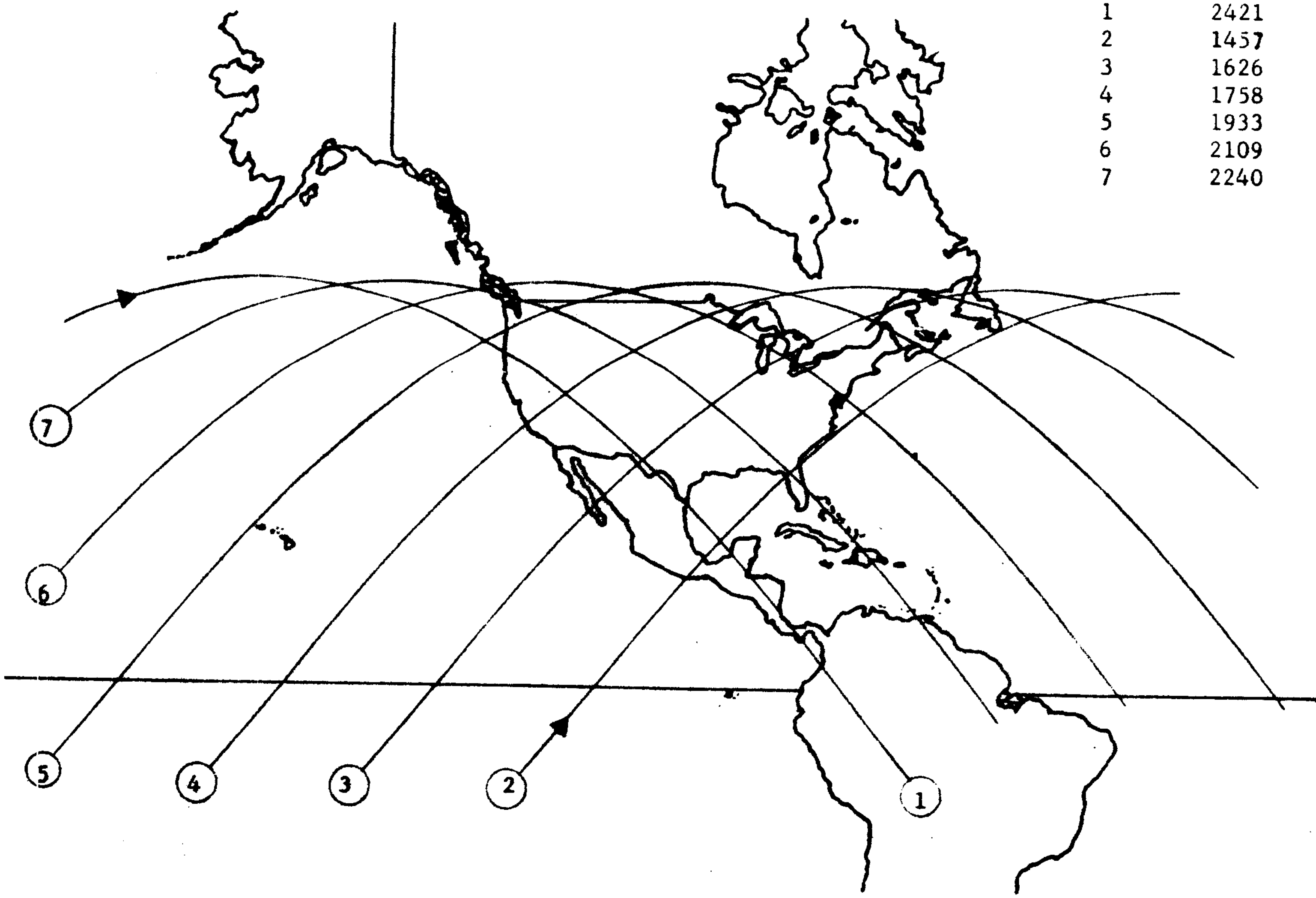
MARTIN MARIETTA CORPORATION

ZI-GMT		
TRACE	IN	OUT
1	1938	1945
2	2113	2122
3	2246	2256



DATE - SECOND OF MONTH, LAUNCH ON FIRST OF MONTH

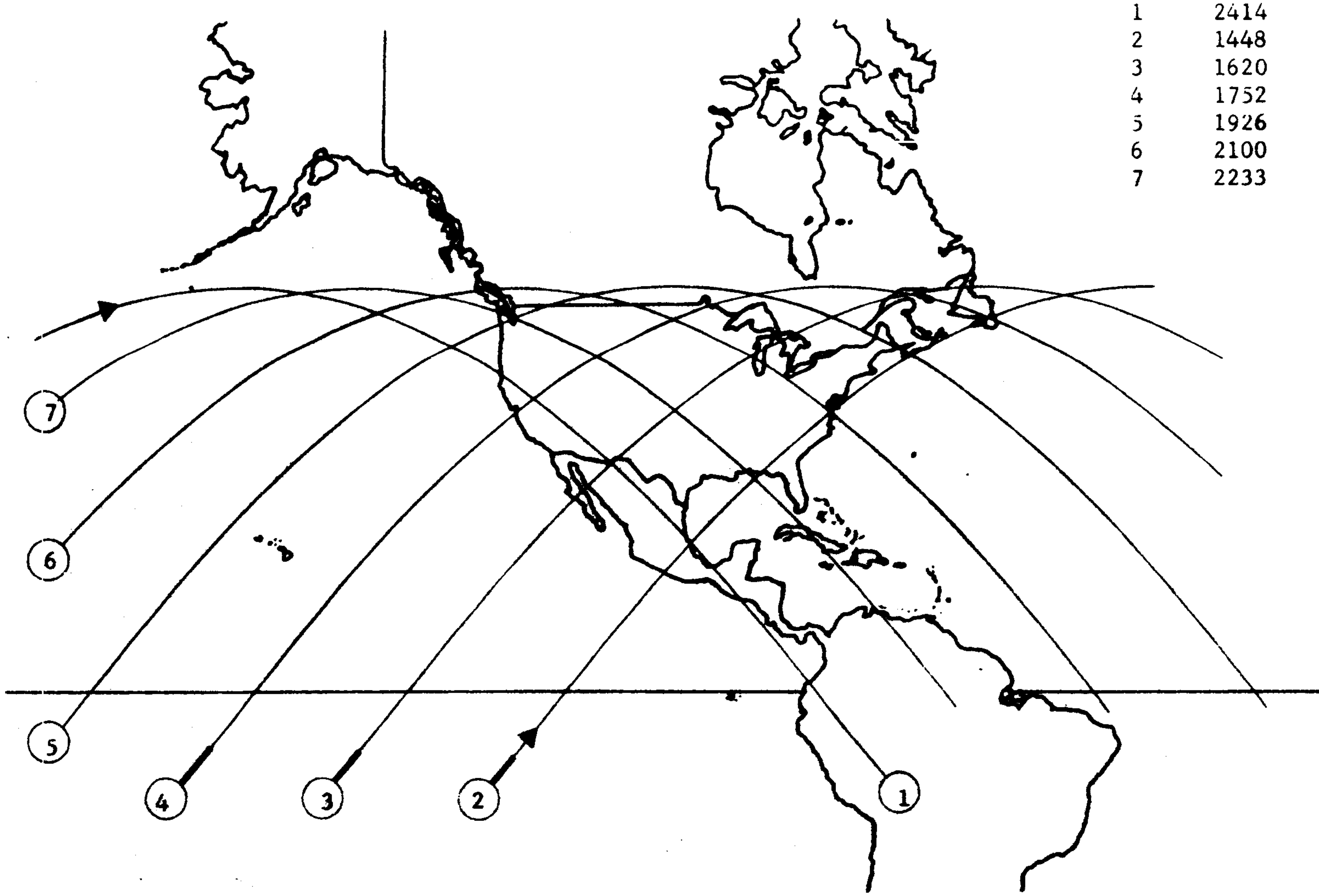
TRACE	ZI-GMT IN	ZI-GMT OUT
1	2421	2427
2	1457	1500
3	1626	1634
4	1758	1806
5	1933	1939
6	2109	2116
7	2240	2250



DATE - THIRD OF MONTH, LAUNCH ON FIRST OF MONTH

ZI-GMT

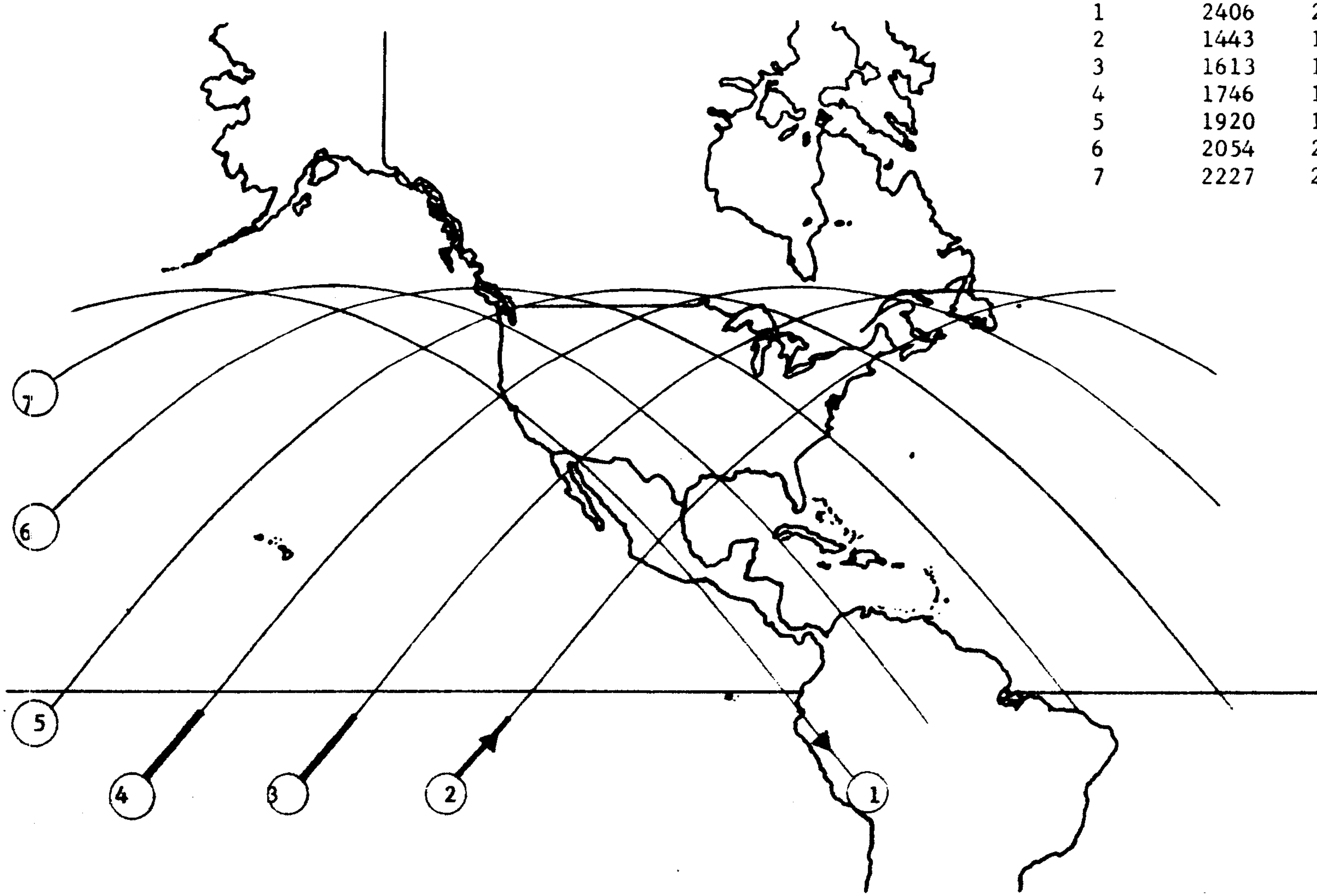
TRACE	IN	OUT
1	2414	2422
2	1448	1454
3	1620	1628
4	1752	1800
5	1926	1933
6	2100	2110
7	2233	2243



DAY - FOURTH OF MONTH, LAUNCH ON FIRST OF MONTH

MARTIN MARIETTA CORPORATION

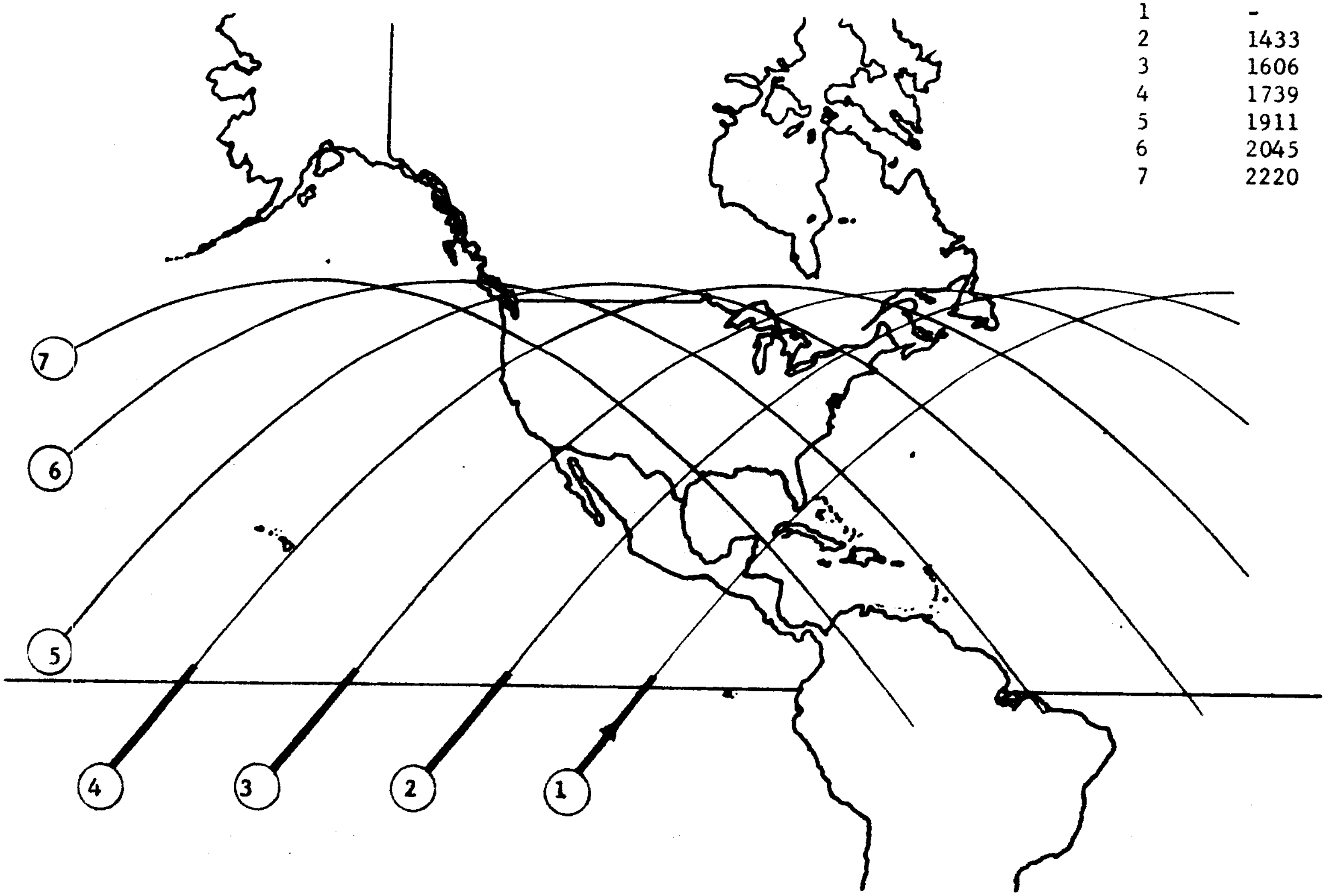
TRACE	ZI-GMT IN	ZI-GMT OUT
1	2406	2412
2	1443	1448
3	1613	1621
4	1746	1753
5	1920	1928
6	2054	2104
7	2227	2236



DATE - FIFTH OF MONTH, LAUNCH ON FIRST OF MONTH

ZI-GMT

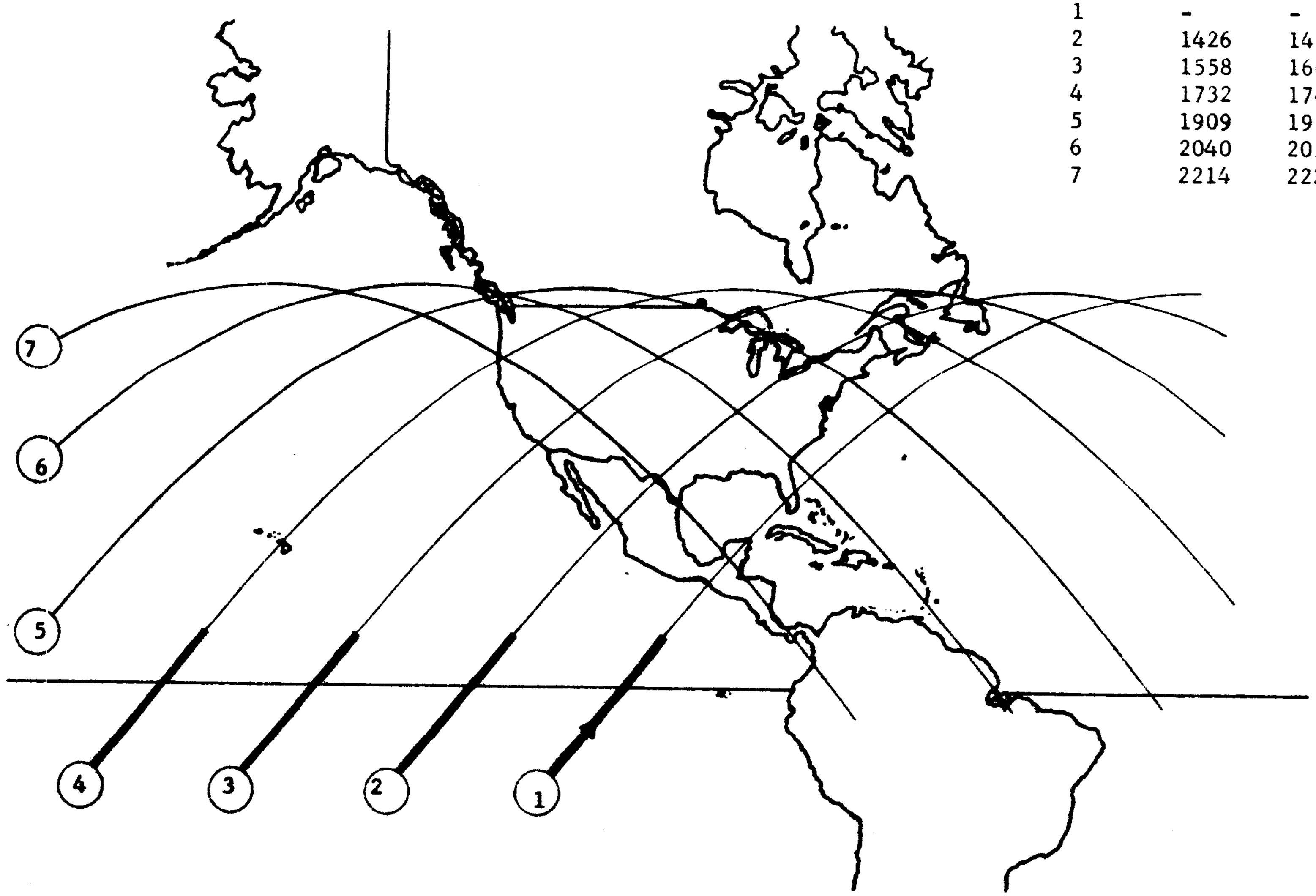
TRACE	IN	OUT
1	-	-
2	1433	1441
3	1606	1614
4	1739	1746
5	1911	1922
6	2045	2057
7	2220	2230



DATE - SIXTH OF MONTH, LAUNCH ON FIRST OF MONTH

ZI-GMT

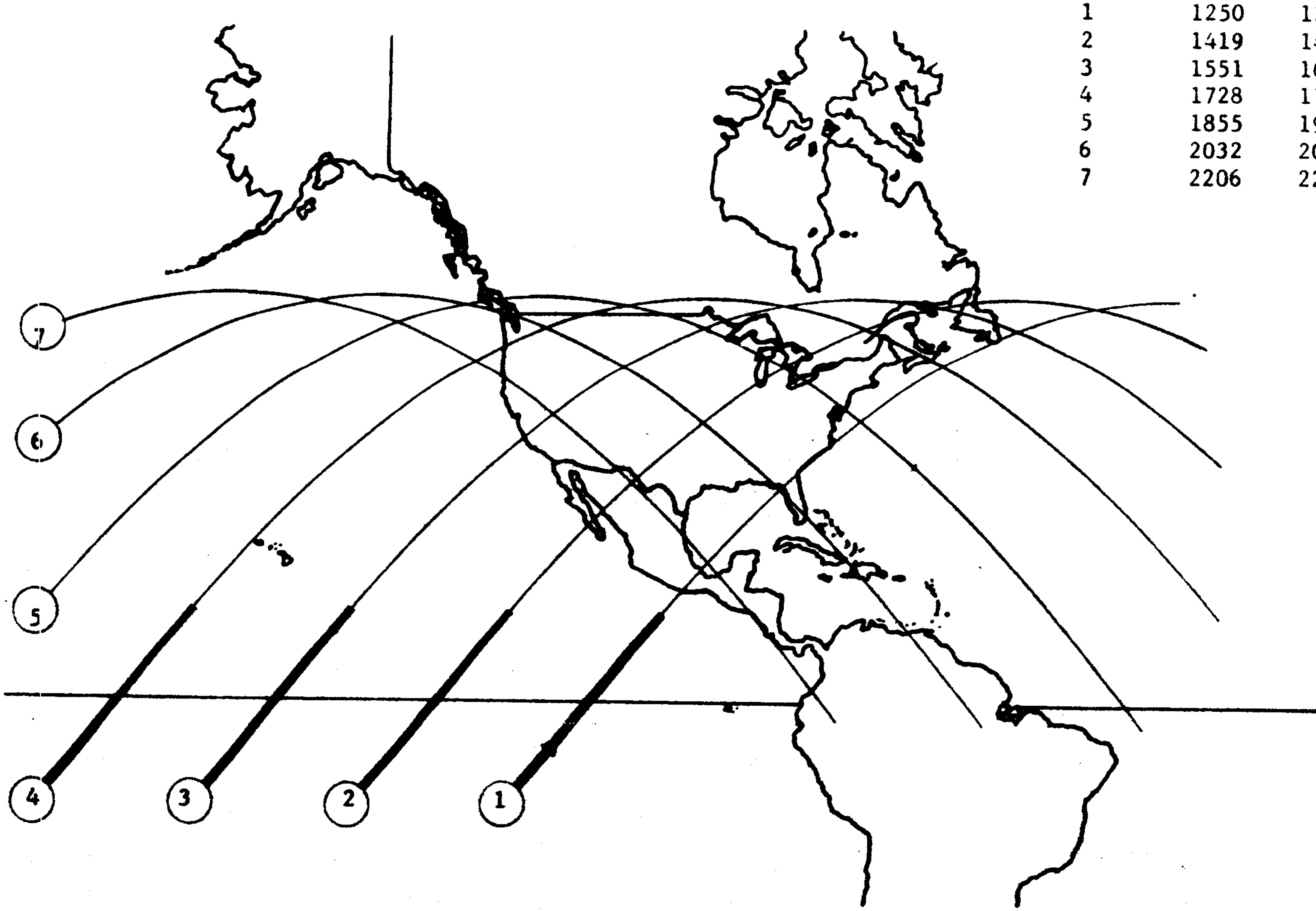
TRACE	IN	OUT
1	-	-
2	1426	1434
3	1558	1606
4	1732	1740
5	1909	1915
6	2040	2050
7	2214	2222



DATE - SEVENTH OF MONTH, LAUNCH ON FIRST OF MONTH

MARTIN MARIETTA CORPORATION

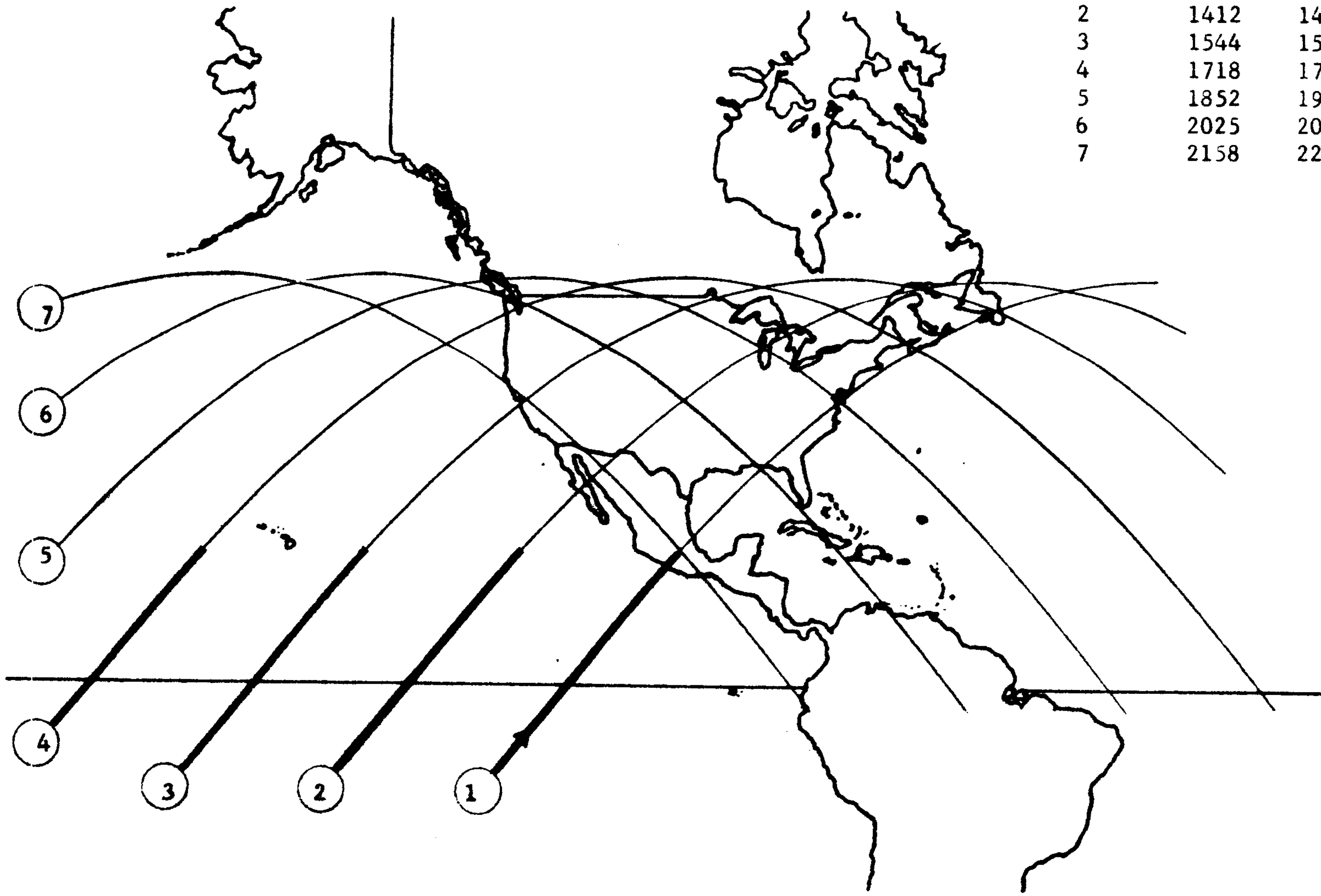
ZI-GMT		
TRACE	IN	OUT
1	1250	1253
2	1419	1427
3	1551	1600
4	1728	1733
5	1855	1909
6	2032	2042
7	2206	2214



DATE - EIGHTH OF MONTH, LAUNCH ON FIRST OF MONTH

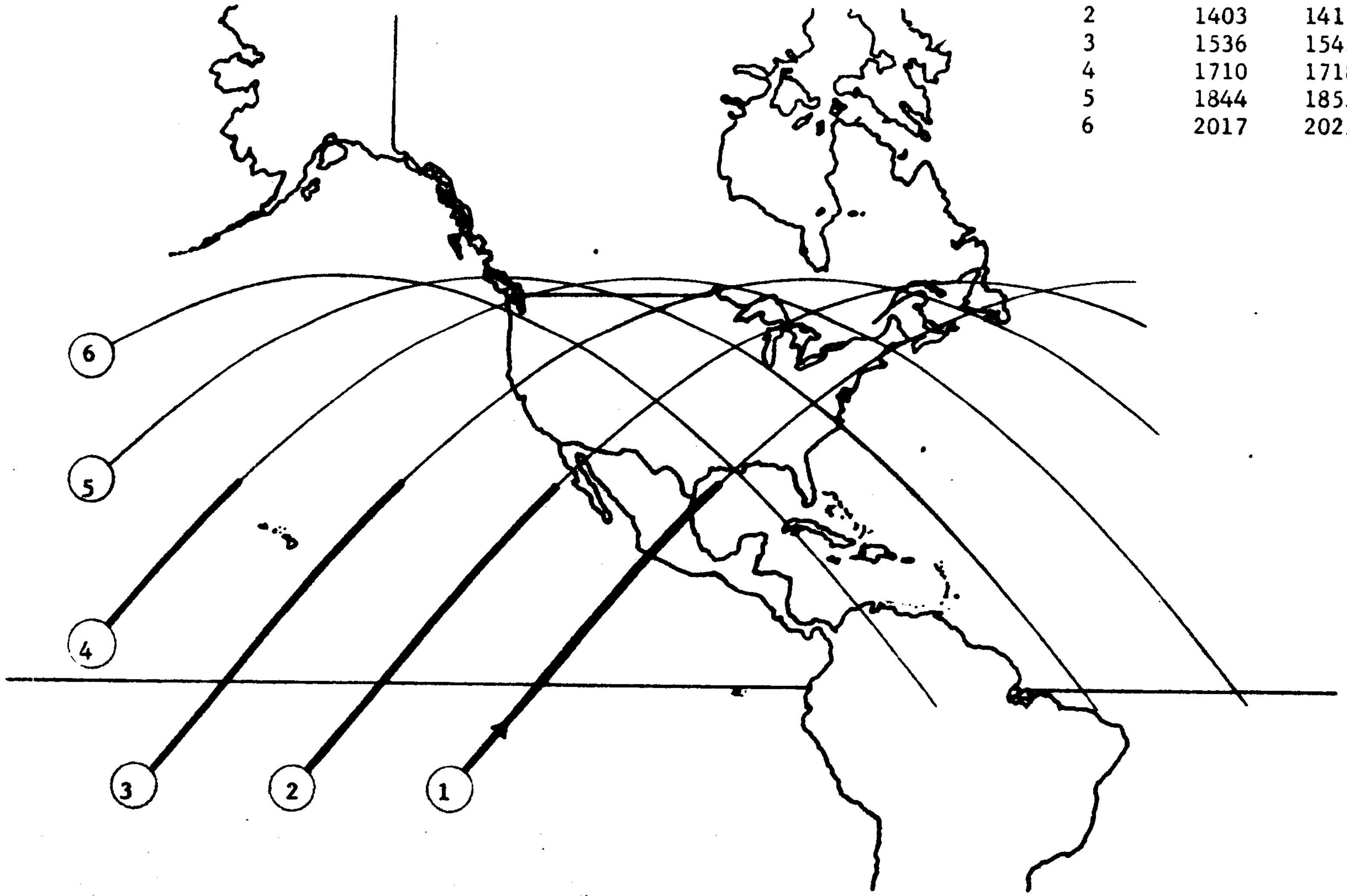
MARTIN MARIETTA CORPORATION

TRACE	ZI-GMT IN	ZI-GMT OUT
1	1239	1246
2	1412	1419
3	1544	1552
4	1718	1724
5	1852	1901
6	2025	2033
7	2158	2205



DATE - NINTH OF MONTH, LAUNCH ON FIRST OF MONTH

MARTIN MARIETTA CORPORATION



ZI-GMT

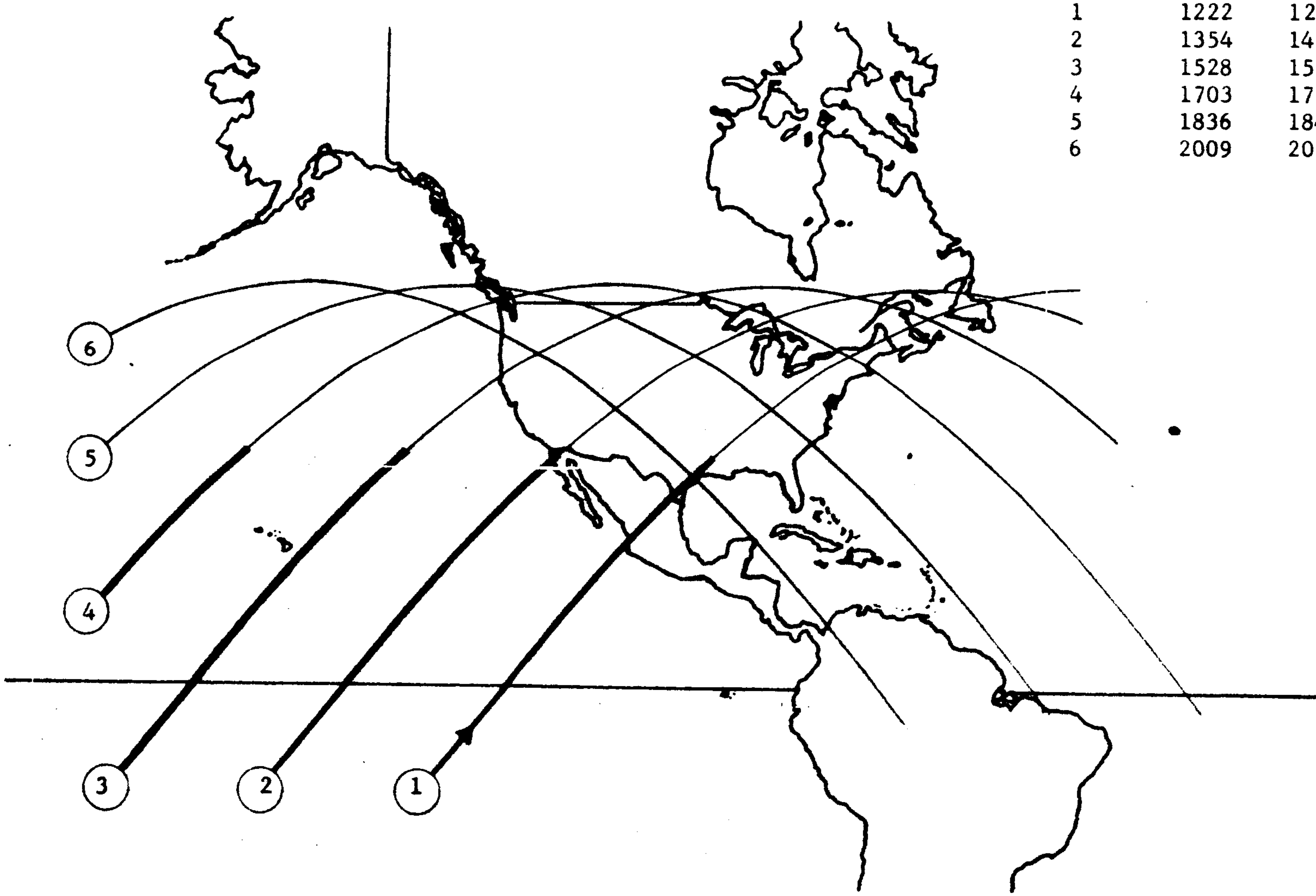
TRACE	IN	OUT
1	1230	1238
2	1403	1411
3	1536	1543
4	1710	1718
5	1844	1853
6	2017	2025

DATE - TENTH OF MONTH, LAUNCH ON FIRST OF MONTH

MARTIN MARIETTA CORPORATION

ZI-GMT

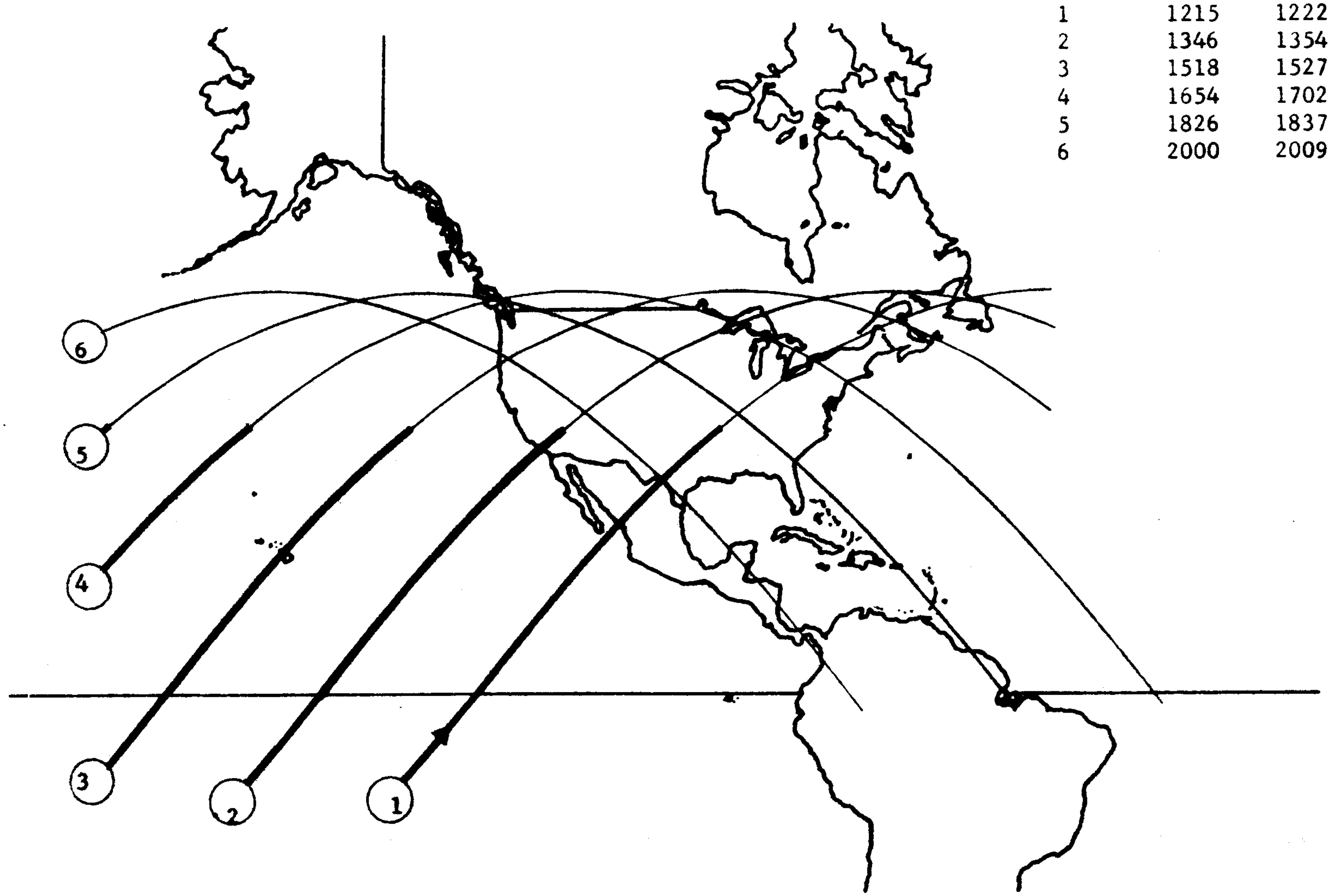
TRACE	IN	OUT
1	1222	1230
2	1354	1403
3	1528	1535
4	1703	1710
5	1836	1846
6	2009	2018



DATE - ELEVENTH OF MONTH, LAUNCH ON FIRST OF MONTH

ZI-GMT

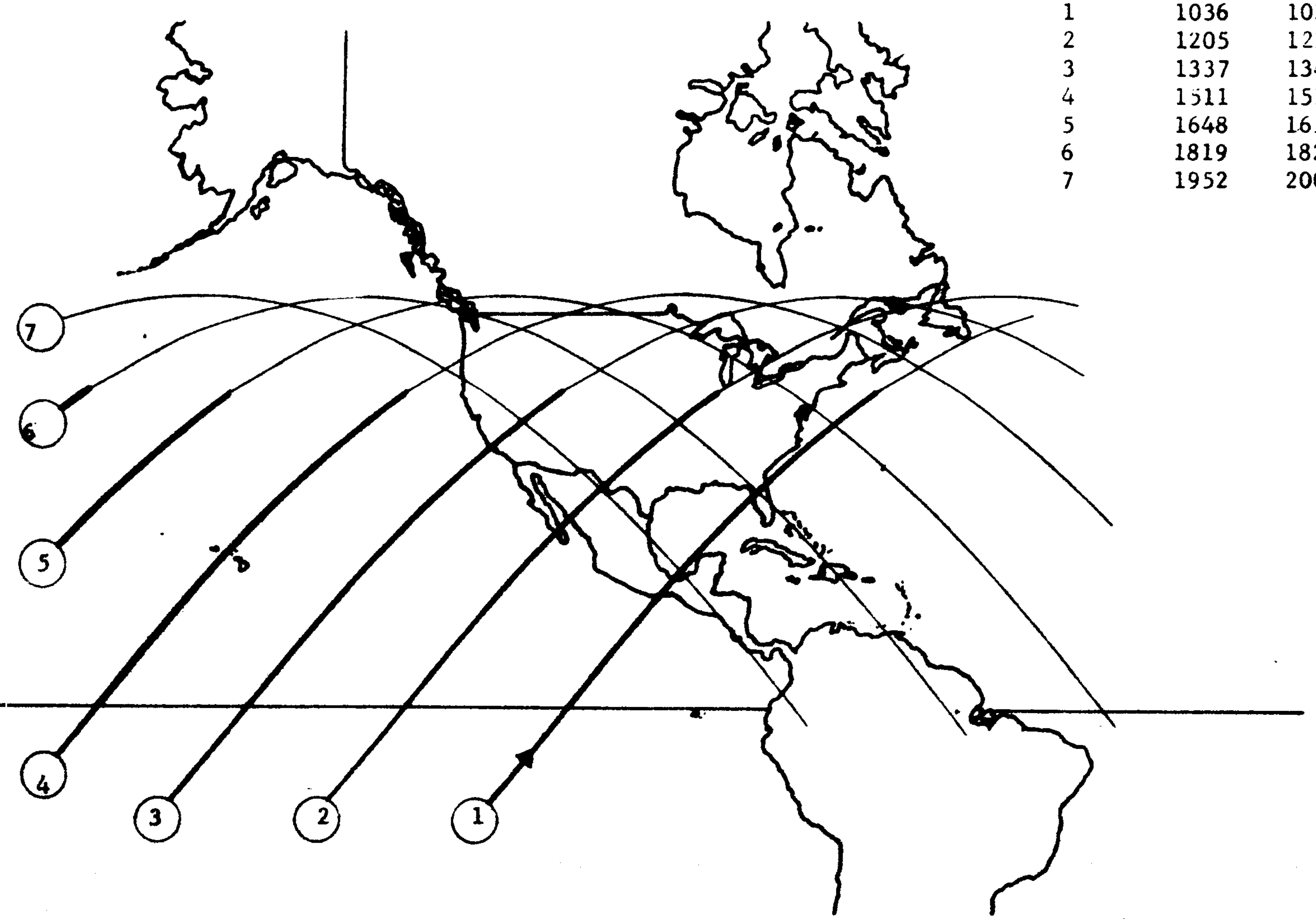
TRACE	IN	OUT
1	1215	1222
2	1346	1354
3	1518	1527
4	1654	1702
5	1826	1837
6	2000	2009



DATE - TWELFTH OF MONTH, LAUNCH ON FIRST OF MONTH

ZI-GMT

TRACE	IN	OUT
1	1036	1039
2	1205	1213
3	1337	1345
4	1511	1518
5	1648	1654
6	1819	1828
7	1952	2000

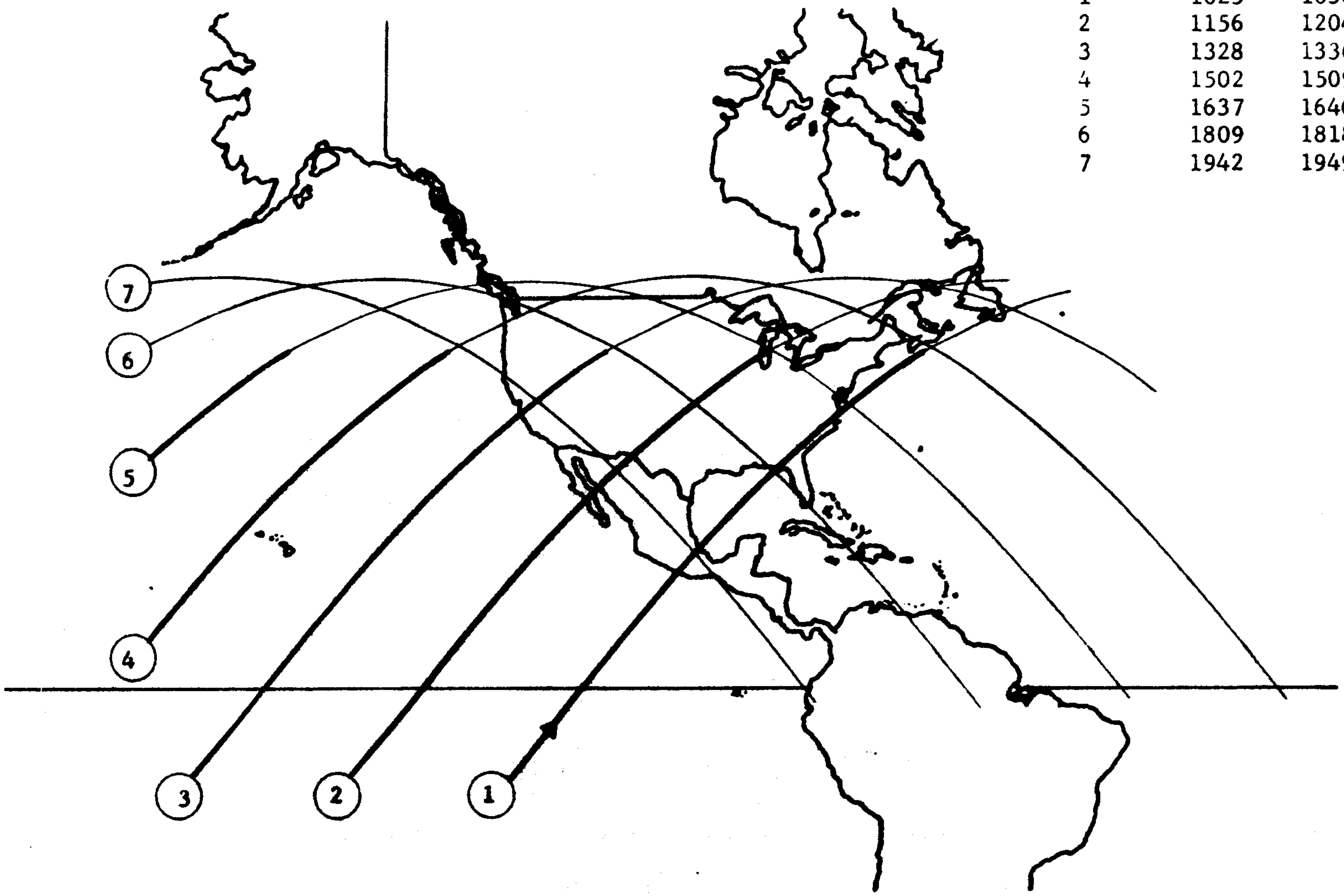


DATE - THIRTEENTH DAY OF MONTH, LAUNCH ON FIRST OF MONTH

MARTIN MARIETTA CORPORATION
DENVER

ZI-GMT

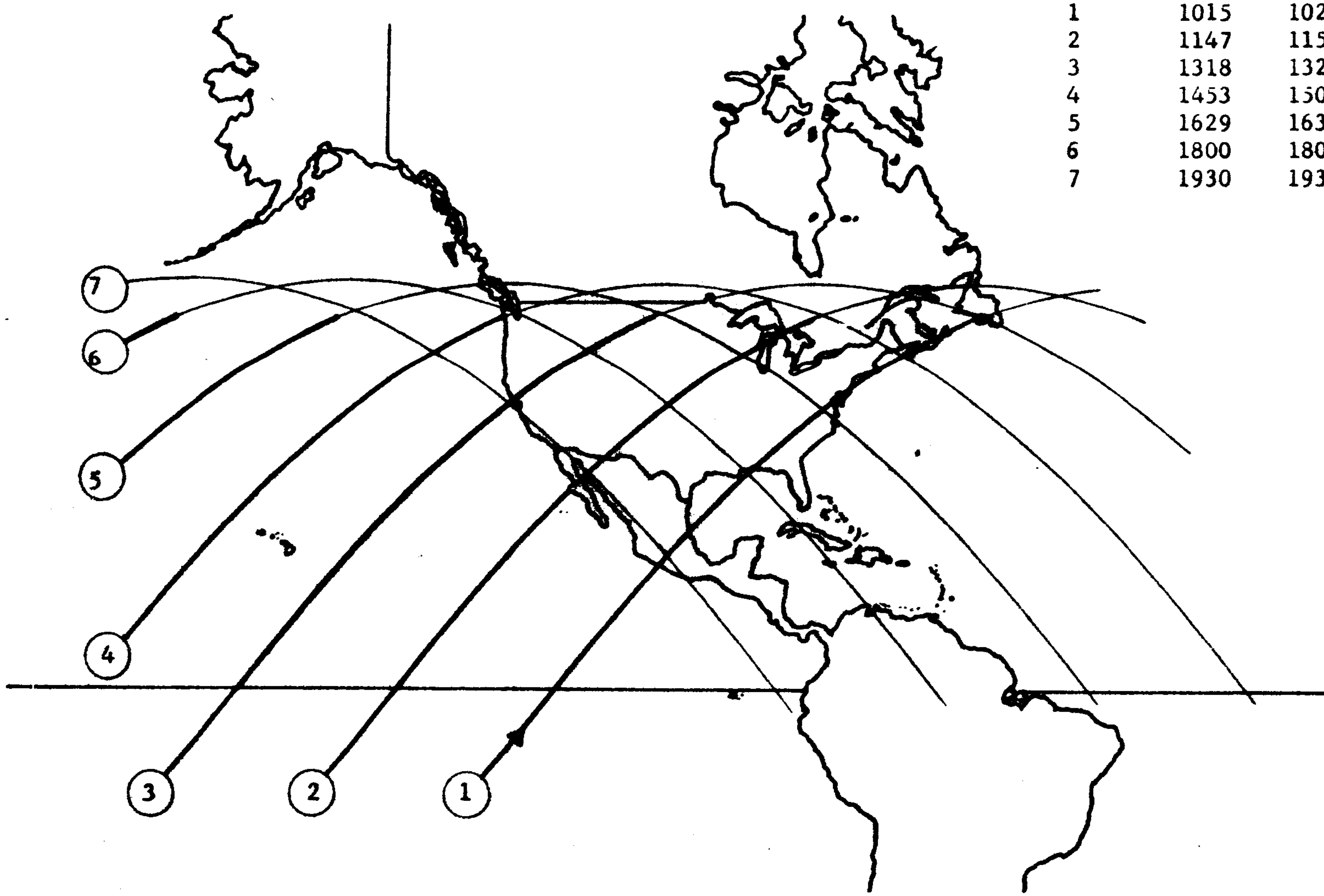
TRACE	IN	OUT
1	1025	1030
2	1156	1204
3	1328	1336
4	1502	1509
5	1637	1646
6	1809	1818
7	1942	1949



65

DATE - FOURTEENTH OF MONTH, LAUNCH ON FIRST OF MONTH

MARTIN MARIETTA CORPORATION



ZI-GMT

TRACE	IN	OUT
1	1015	1021
2	1147	1154
3	1318	1326
4	1453	1502
5	1629	1636
6	1800	1809
7	1930	1939

DATE - FIFTEENTH OF MONTH, LAUNCH ON FIRST OF MONTH

MARTIN MARIETTA CORPORATION

ZI-GMT

TRACE	IN	OUT
1	1004	1012
2	1136	1145
3	1310	1316
4	1439	1452
5	1619	1626
6	1750	1758

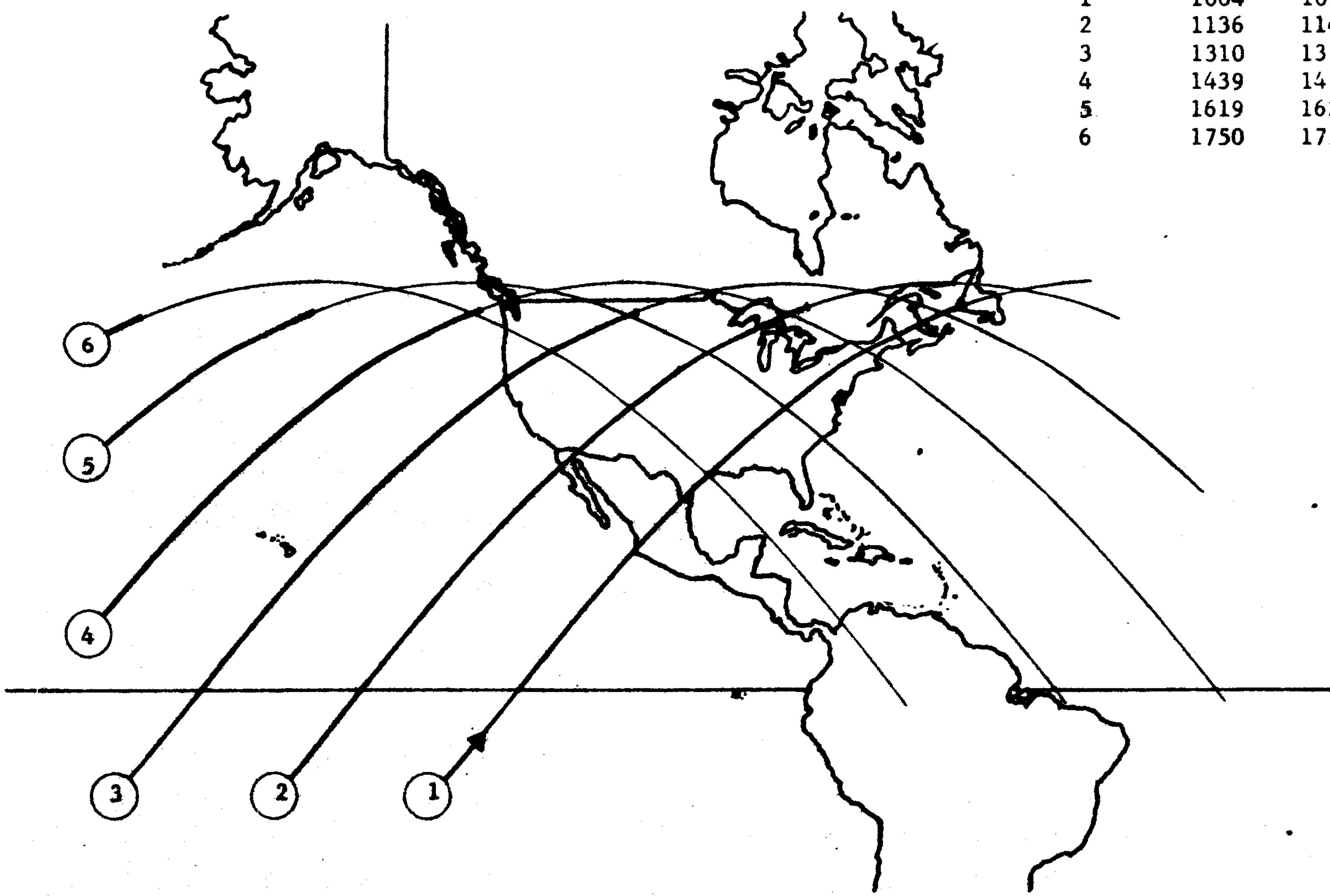


FIGURE 5 TRACE SAMPLE OUTPUT

```
    4/ 5/69
 ME,MM,ST,DT           X,R                XDOT,V          LAT,LONG,H,SBV   ALPHA,DELTA,BETA,A    REV
   5926.838    -0.90752884E 07     0.13347644E 05        -42.25616          235.81899            0
   1298.000    -0.13363406E 08    -0.19445589E 05         77.31178          -42.06471
  77879.994    -0.14577909E 08     0.95090627E 04        142.34463           89.98930
      2.000     0.21759065E 08     0.25430549E 05        -42.24854           59.74537
                                                                                         ECLIPSE
   A,E,I,O,U,T           MEAN ANM= 150.61892       APOGEE= 3581.25674
 0.21751846E 08          TRUE ANM= 150.64032         HT   =  139.18831
 0.38079646E-03              ODOT=  -5.57815      PERIGEE= 3578.53040
 0.50113307E 02              UDOT=   4.59348         HT   =  136.46196
 0.28477539E 03                                  PERIOD(K)=   89.54161
 0.14853456E 03                                  PERIOD(A)=   89.58319
 0.70205370E 04                                  PERIOD(N)=   89.51846

    4/ 5/69
 ME,MM,ST,DT           X,R                XDOT,V          LAT,LONG,H,SBV   ALPHA,DELTA,BETA,A    REV
   5928.838    -0.73898260E 07     0.14697479E 05        -37.85492          244.59326            0
   1300.000    -0.15558216E 08    -0.17074446E 05         85.58468          -37.66864
  77999.995    -0.13297197E 08     0.11801229E 05        141.57195           89.98832
      2.000     0.21759666E 08     0.25432688E 05        -37.84755           54.10045
                                                                                         ECLIPSE
   A,E,I,O,U,T           MEAN ANM= 123.71172       APOGEE= 3581.57092
 0.21756705E 08          TRUE ANM= 123.73509         HT   =  137.66266
 0.24513099E-03              ODOT=  -5.57316      PERIGEE= 3579.81546
 0.50118735E 02              UDOT=   4.58787         HT   =  135.90720
 0.28476454E 03                                  PERIOD(K)=   89.57161
 0.18348259E 03                                  PERIOD(A)=   89.58778
 0.70292191E 04                                  PERIOD(N)=   89.51812
```

FIGURE 5 TRACE SAMPLE OUTPUT (Continued)

CK

APRIL 5, 1969

```
RISE (   5.00 DEGREES ELEV.)     13. HOURS  32.25 MINUTES    AZIMUTH 211.087 DEGREES
SET  (   5.00 DEGREES ELEV.)     13. HOURS   7.60 MINUTES    AZIMUTH  54.790 DEGREES
RISE (   5.00 DEGREES ELEV.)     14. HOURS  36.92 MINUTES    AZIMUTH 298.123 DEGREES
SET  (   5.00 DEGREES ELEV.)     14. HOURS  39.79 MINUTES    AZIMUTH  -1.918 DEGREES
RISE (   5.00 DEGREES ELEV.)     20. HOURS  54.56 MINUTES    AZIMUTH 338.702 DEGREES
SET  (   5.00 DEGREES ELEV.)     20. HOURS  59.61 MINUTES    AZIMUTH 101.597 DEGREES
RISE (   5.00 DEGREES ELEV.)     22. HOURS  29.05 MINUTES    AZIMUTH 282.362 DEGREES
SET  (   5.00 DEGREES ELEV.)     22. HOURS  32.38 MINUTES    AZIMUTH 186.103 DEGREES
```

Table 2 Symbol Definitions - Trajectory and Trace Data

4/5/69	calendar date for data following
ME	minutes from epoch
MM	minutes from midnight, Greenwich mean time
ST	seconds from midnight, Greenwich mean time
DT	computing interval, seconds
X	three space coordinates, feet; first is X, second is Y, third is Z
R	distance from center of earth, feet ($R^2 = X^2 + Y^2 + Z^2$)
XDOT	three velocity components, ft/sec; first is rate of change of X, second is rate of change of Y, third is rate of change of Z
V	magnitude of velocity vector, ft/sec ($V^2 = VDOT^2 + YDOT^2 + ZDOT^2$)
LAT	geodetic latitude, degrees north
LONG	longitude, degrees east
H	altitude above sea level on oblate earth, nautical miles
SBV	plumbline latitude, degrees
ALPHA	right ascension, degrees east of vernal equinox
DELTA	declination (or geocentric latitude), degrees
BETA	angle between position vector and velocity vector, degrees
A	azimuth, degrees from north in local horizontal plane
REV	a revolution counter not used in this printout
ECLIPSE	indicates spacecraft is in earth's shadow when printed, otherwise omitted

Keplerian Orbit Data

A	semimajor axis
E	eccentricity
I	inclination, degrees
O	right ascension of ascending node, degrees
U	argument of perigee
T	time of perigee passage, Greenwich mean time, minutes
MEAN ANM	mean anomaly, degrees
TRUE ANM	true anomaly, degrees
ODOT	rate of change of O, deg/day
UDOT	rate of change of U, deg/day
Apogee	apogee radius from center of earth, n m
HT	apogee altitude, n m
Perigee	perigee radius from center of earth, n m
HT	perigee altitude, n m
Period (K)	Keplerian period, min
Period (A)	Anomalistic period, min
Period (N)	Nodal period, min

PR 29-20

TRADE STUDY REPORT

ELECTRICAL POWER, FUEL CELLS
vs BATTERIES

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

31 August 1967

Prepared by: J. E. Rink
J. E. Rink

Approved by: A. B. Huff
A. B. Huff

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

1.1 Purpose - The purpose of this trade study report is to determine what type of power source should be used on Flight AAP-1A.

1.2 Objectives - The objective of this trade study is to compare various characteristics of a fuel cell power system and a battery power system and based on this comparison, determine which type of system should be used on Flight AAP-1A.

2. SUMMARY

This trade study report compares cost, weight, and simplicity of a fuel cell system with that of a battery system. The study shows that for an energy requirement of 54 kilowatt-hours, the battery system is simpler and costs approximately $1,349,430 less than the fuel cell system. The battery system weighs approximately 230.5 pounds less than the fuel cell system. From this information, it is concluded that a battery power system should be used on Flight AAP-1A.

3. MAIN BODY OF REPORT

3.1 Ground Rules and Assumptions

3.1.1 General - Due to the mission duration, weight limitations and launch schedule, solar array and radioisotape thermoelectric generators were not considered as candidates for Flight AAP-1A power sources. This trade study report considers only batteries and fuel cells as potential power sources. Since fuel cell system and battery system cost and weight are effected by energy requirements, a specific energy requirement must be used in any comparison. The energy requirement used for the comparisons herein is 54 kilowatt-hours. This is approximately the total energy required for the Flight AAP-1A mission. Information on Flight AAP-1A total energy requirements may be found in Trade Study Report No. PR29-21, entitled "Power Profile".

3.1.2 Components Considered - For purposes of this trade study, it is assumed that the Allis-Chalmers 2 kilowatt fuel cell module would be used with Apollo tanks if a fuel cell system were used. The battery used in this trade study report is a modification of the Eagle-Picher battery used on the LM descent module. The battery is rated at 400 ampere hours and presently contains 20 cells. It is anticipated that a tap output on the nineteenth cell will be required in order to provide a nominal 28 volts DC on the Flight AAP-1A mission. Therefore, some qualification cost has been added to the battery cost.

3.1.3 Redundancy Considerations - The total energy requirement of 54 KWH includes the energy required from the Main Bus and the energy required from the EMI Sensitive Equipment Bus. It is not known at the time of writing this report what the load on the EMI Sensitive Equipment Bus will be, but for purposes of this report, it is assumed that this load will be 10 KWH. This assumption results in the following energy requirement on the two types of busses:

Main Bus	44.0 KWH
EMI Sensitive Equipment Bus	10.0 KWH

If batteries are used as the main power source, it is assumed that one spare battery on each bus would satisfy redundancy requirements. If fuel cells are used as the main power source, it is assumed that two fuel cells would be used on the main bus and batteries would be used on the EMI Sensitive Equipment Bus with one spare battery satisfying redundancy requirements.

3.1.4 Battery Quantity Calculation - Since the batteries to be used are 400 ampere hour batteries, they are each capable of delivering approximately (400 AH x 28 volts) 11.2 kilowatt-hours (KWH). The main bus would therefore require four (4) batteries plus one spare or five (5) batteries. The EMI Sensitive

3.1.4 (Cont'd.)

Equipment Bus would require one (1) battery plus one spare or two (2) batteries.

3.2 Comparison of Fuel Cell and Battery Systems

3.2.1 Cost Comparison

3.2.1.1 Fuel Cell System Cost

Fuel Cell	2 @ $400,000	800,000
Oxygen Tank		100,000
Hydrogen Tank		110,000
Peaking Battery	2 @ $1,500	3,000
Hydrogen Valve Package		36,800
Oxygen Valve Package		27,250
Radiator		190,000
Hand Valves		9,000
Lines and Fittings		1,000
Regenerative Heater		90,000
Temperature Control Valves		49,000
Ground Heat Exchangers		12,700
Quick Disconnects		8,180
EMI Sensitive Bus Batteries	2 @ $6,000	12,000
Battery Cold Plates	2 @ $1,000	2,000
	Total*	$1,450,930

*This total does not include cost of oxygen, hydrogen, water glycol coolant, or water disposition equipment.

3.2.1.2 Battery System Cost

Batteries	7 @ $6,000	42,000
Qualification Costs		50,000
Cold Plates	7 @ $1,000	7,000
Lines and Fittings		1,000
Diodes and Circuit Breakers		1,500
	Total	$101,500

3.2.2 Weight Comparison

3.2.2.1 Fuel Cell System Weight

Fuel Cell	2 @ 165 lbs	330.00
Oxygen Tank		90.00
Hydrogen Tank		90.00
Peaking Battery	2 @ 30 lbs	60.00
Hydrogen Valve Package		17.00
Oxygen Valve Package		10.00
Radiator		70.00
Regenerative Heater		6.00
Temperature Control Valves		2.60
Ground Heat Exchangers		2.70
Quick Disconnects		0.90
Oxygen		238.00**
Hydrogen		23.80**
Hand Valves		0.50
EMI Sensitive Bus Batteries	2 @ 140 lbs	280.00
Battery Cold Plates	2 @ 1.6 lbs	3.20
Lines and Fittings		0.50
	Total lbs	1,225.20

**Minimum hydrogen and oxygen usage based on specification leakage rates on Apollo hydrogen and oxygen tanks for a 14 day mission.

3.2.2.2 Battery System Weight - Battery system weight is completely dependent on energy requirement. Each 400 ampere hour battery can deliver a total energy of 400 ampere hours x 28 volts = 11.2 kilowatt-hours. Therefore, battery system weight is as follows:

Batteries	7 @ 140 lbs	980.0
Cold Plates	7 @ 1.6 lbs	11.2
Isolation Diodes and Circuit Breakers		3.0
Lines and Fittings		0.5
	Total lbs	994.7

3.2.3 System Simplicity Comparison - Paragraph 3.2.1.1 lists the components necessary for a fuel cell system and paragraph 3.2.1.2 lists the components necessary for a battery system. Comparison of these lists shows the fuel cell system to be considerably more complicated than a battery system.

4. CONCLUSIONS AND RECOMMENDATIONS

Table 1 summarizes the cost and weight comparisons between a battery system and a fuel cell system. Based on the information contained in Table I and paragraph 3.2.3 herein, the conclusion of this study is that batteries should be used as the power source on the Flight AAP-1A mission.

TABLE I

Comparison of
Power Source Characteristics

Type of Source	Cost	Weight for 56 KWH
Battery System	$ 101,500	994.7 lbs
Fuel Cell System	$1,450,930	1,225.2 lbs

PR 29-21

TRADE STUDY REPORT

POWER PROFILE

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

6 September 1967

Prepared by: N. E. Sitter
N.E. Sitter

J. E. Rink
J.E. Rink

Approved by: A.B. Huff
A.B. Huff

MARTIN MARIETTA CORPORATION
DENVER DIVISION

I. INTRODUCTION

1.1 Purpose - The purpose of this report is to define the carrier electrical load profile and to verify the adequacy of the power system selected.

1.2 Objective - The objective of this report is to present the electrical load profile and substantiating data.

2. SUMMARY

This report presents the carrier electrical load profile based on the "AAP Mission 1A 14 Day Experiment Time Lines", dated 28 August 1967. The total energy required is 58.989 KWH. Minimum and maximum steady state loads are 89 and 1367 watts respectively. The average load is approximately 190 watts. Experiment and subsystem loads are tabulated. Based upon the use of seven (7) batteries rated at 12 KWH/unit, the electrical system has approximately a 30% reserve capacity.

3. MAIN BODY OF REPORT

3.1 Electrical Loads

3.1.1 Subsystems

3.1.2	Electrical Power & Distribution	20 Watts DC
3.1.3	Display and Control	
	a) Sequencer	8 Watts DC
	b) Display & Control Panel	2 Watts DC
3.1.4	Stabilization & Control	75 Watts DC
3.1.5	Lighting	100 Watts DC
3.1.6	Data Management	
	a) Signal Conditioner	30 Watts DC
	b) Recorder	10 Watts DC
	c) PCM Encoder	10 Watts DC
	d) VHF Transmitter "A"	84 Watts DC
	e) VHF Transmitter "B"	84 Watts DC
	f) VHF Transmitter "C"	84 Watts DC
	g) VCO's	57 Watts DC
	h) Recorder	47 Watts DC
	i) S-Band Power Amplifier	120 Watts DC
	j) S-Band Transmitter	11 Watts DC

3.1.7 Thermal Control — 43 Watts DC

3.1.8 Experiments

Experiments	Warm Up (watts)	Operate (watts)
D017 CO_2 Reduction	280.0 DC	200.0 DC
S017 X-Ray Astronomy	2.0 DC	30.0 DC
S020 UV X-Ray Solar Photography	7.0 DC	7.0 DC
S039 Day Night Camera	10.0 DC	43.0 DC
S040 Dielectric Tape Camera	25.0 DC	27.0 DC
**S043 I.R. Temperature Sounding	55.0 DC	85.0 DC
**S044A E.S Microwave Radiation	20.0 DC	20.0 DC
**S048 UHF Sferics	5.28 DC	5.28 DC
*E06-1 Metric Camera	250.0 DC	250.0 DC
*E06-7 IR Imager	34.0 DC	150.0 DC
*E06-11 Microwave Radiometer	100.0 DC	100.0 DC
*E06-9a IR Radiometer	30.0 DC	60.0 DC
*E06-9b IR Spectrometer	25.0 DC	40.0 DC
T004 Frog Otolith	5.0 DC	20.0 DC

3.2 Subsystem Kilowatt Hour Requirements (KWH)

3.2.1

Electrical Power & Distribution	20 x 312 Hr.	=	6.24
Display & Control	10 x 312 Hr.	=	3.12
Stabilization & Control	75 x 67 Hr.	=	5.0
Lighting	100 x 10 Hr.	=	1.0
Data Management & Experiment Loads			
a) D017 Experiment			1.320
D017 Data Record	50 x 6 hr.	=	0.300
D017 Data Dump	94 x 1.5 hr.	=	0.141
b) S017 Experiment			0.342
S017 Data Record	104 x 11.4 hr.	=	1.185
S017 Data Dump	131 x 2.85 hr.	=	0.374
c) S020 Experiment			0.032
S020 Data Record	50 x 4.4 hr.	=	0.220
S020 Data Dump	94 x 1.1 hr.	=	0.104
d) S039 Experiment & Data Record		=	0.942
e) S040 Experiment & Data Record		=	0.438
f) S039 & S040 Data Dump		=	1.254
g) Group I Experiments & Data (See Table II)		=	3.907
h) Group II Experiments & Data (See Table II)		=	12.492
i) T004 (see Table IV)		=	2.170
j) Time Generator	16 x 312 hr.	=	4.992

*Group I Experiments
**Group II Experiments

EXPERIMENT	WARM UP-HR	OPERATE-HR	KILOWATTS	KILOWATT HOURS
D017	0.0		0.28	0.0000
		6.0	0.22	1.3200
TOTAL				1.3200
S017	0.167		0.002	0.0002
		5.2	0.03	0.1560
	0.167		0.002	0.0002
		6.2	0.03	0.1860
TOTAL				0.3424
S020	0.167		0.007	0.0012
		4.4	0.007	0.0308
TOTAL				0.0320

3.2.2 Thermal Control 43 x 312 hr. = 13.416

3.2.3 Total Energy Requirement 58.989

3.2.4 Standard Day Power Profile - The load data for the standard day power profile is tabulated in Table I. This profile represents total carrier load for a typical standard day. A plot of the data is shown in figures 1 and 2.

3.2.5 Standard Day Power Profile load data for group I and group II experiments are tabulated in tables II and III respectively.

3.3.0 Individual Experiment Data - Experiment and data management loads for S039, S040 and T004 are tabulated in table IV.

3.4.0 AC Power Requirements - Presently AC power is required only for the S-Band power amplifier, S-Band transmitter and experiment E06-7. The total power required is 100 watts 3 phase 400 HZ. The loads are as follows:

E06-7	2.0	Watts
S-Band Power Amplifier	90.0	Watts
S-Band Transmitter	8.0	Watts

TABLE I

Typical Standard Day Power Profile

TIME	WATTS
0-0756	89.0
0756-0811	144.0
0811-0821	244.0
0821-0825	333.0
0825-0826	583.0
0826-0834	913.0
0834-0849	313.0
0849-0850	323.0
0850-0856	356.0
0856-0906	389.0
0906-0926	356.0
0926-0935	386.0
0935-0936	353.0
0936-0943	323.0
0943-0945	423.0
0945-0953	448.0
0953-0956	537.0
0956-0957	567.0
0957-0958	1189.0
0958-1000	1359.0
1000-1005	1361.0
1005-1006	980.0
1006-1008	950.0
1008-1010	350.0
1010-1017	323.0
1017-1021	356.0
1021-1029	737.0
1029-1039	356.0
1039-1105	220.0
1105-1116	356.0
1116-1120	481.0
1120-1122	448.0
1122-1126	604.0
1126-1130	693.0
1130-1131	787.0
1131-1140	950.0
1140-1150	353.0
1150-1158	704.0
1158-1210	323.0
1210-1220	353.0
1220-1240	356.0
1240-1250	386.0

TABLE I (continued)

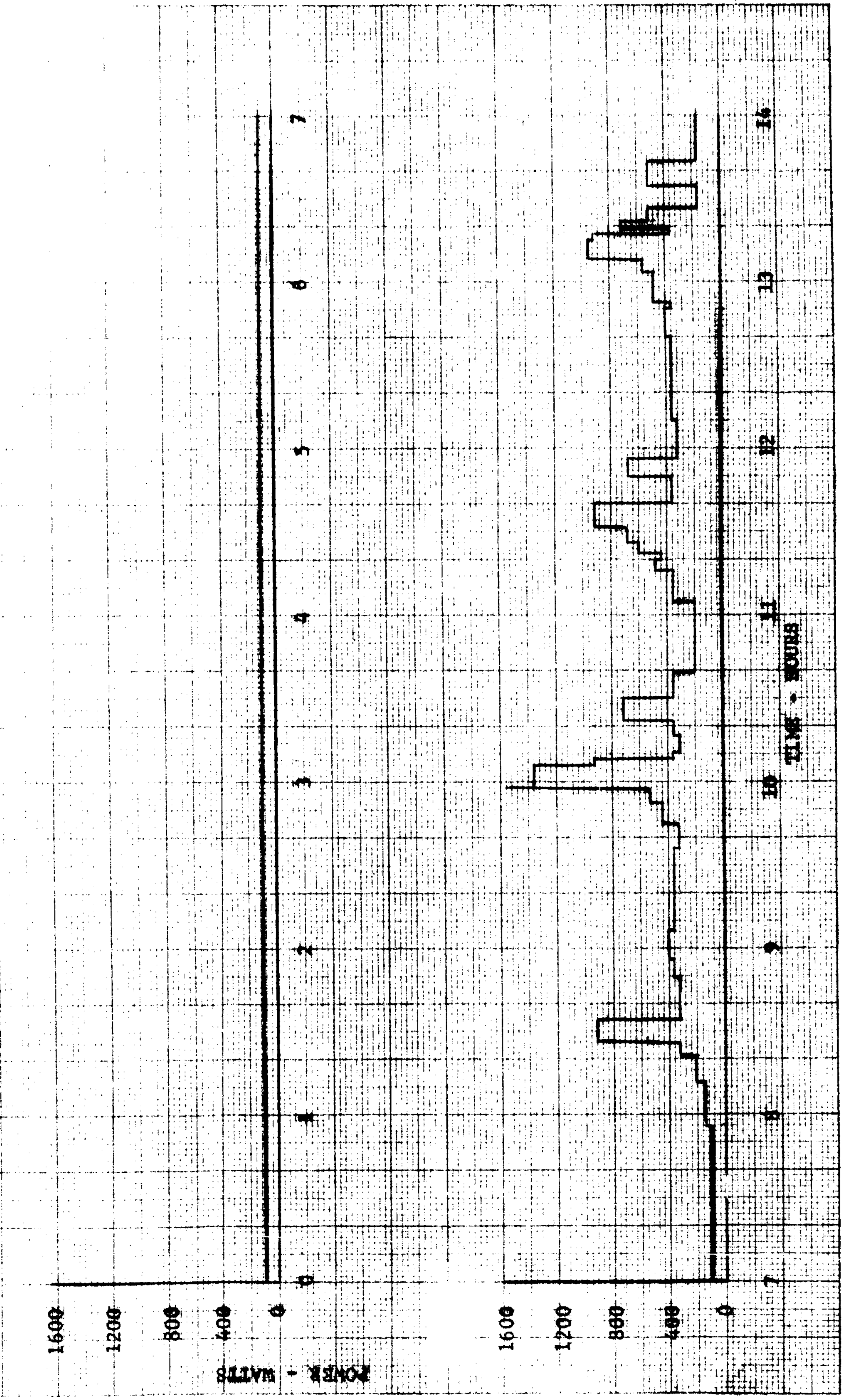
TIME	WATTS
1250-1252	356.0
1252-1253	381.0
1253-1303	481.0
1303-1307	570.0
1307-1308	822.0
1308-1315	983.0
1315-1317	940.0
1317-1318	340.0
1318-1322	721.0
1322-1326	536.0
1326-1335	155.0
1335-1343	536.0
1343-1406	155.0
1406-1414	536.0
1414-1419	155.0
1419-1423	536.0
1423-1424	639.0
1424-1427	764.0
1427-1428	383.0
1428-1434	438.0
1434-1438	527.0
1438-1439	777.0
1439-1451	940.0
1451-1453	340.0
1453-1500	313.0
1500-1510	343.0
1510-1524	313.0
1524-1525	323.0
1525-1540	356.0
1540-1548	767.0
1548-1550	386.0
1550-1559	356.0
1559-1609	456.0
1609-1613	445.0
1613-1614	695.0
1614-1618	956.0
1618-1620	1337.0
1620-1622	1367.0
1622-1626	542.0
1626-1630	386.0
1630-1635	356.0
1635-1655	323.0
1655-1700	356.0
1700-1710	386.0
1710-1715	356.0
1715-1752	313.0
1752-1800	694.0

TABLE I (continued)

TIME	WATTS
1800-2053	129.0
2053-2100	510.0
2100-2101	470.0
2101-2400	89.0

TYPICAL STANDARD DAY LOAD PROFILE

Figure 1



TYPICAL STANDARD DAY LOAD PROFILE

Figure 2

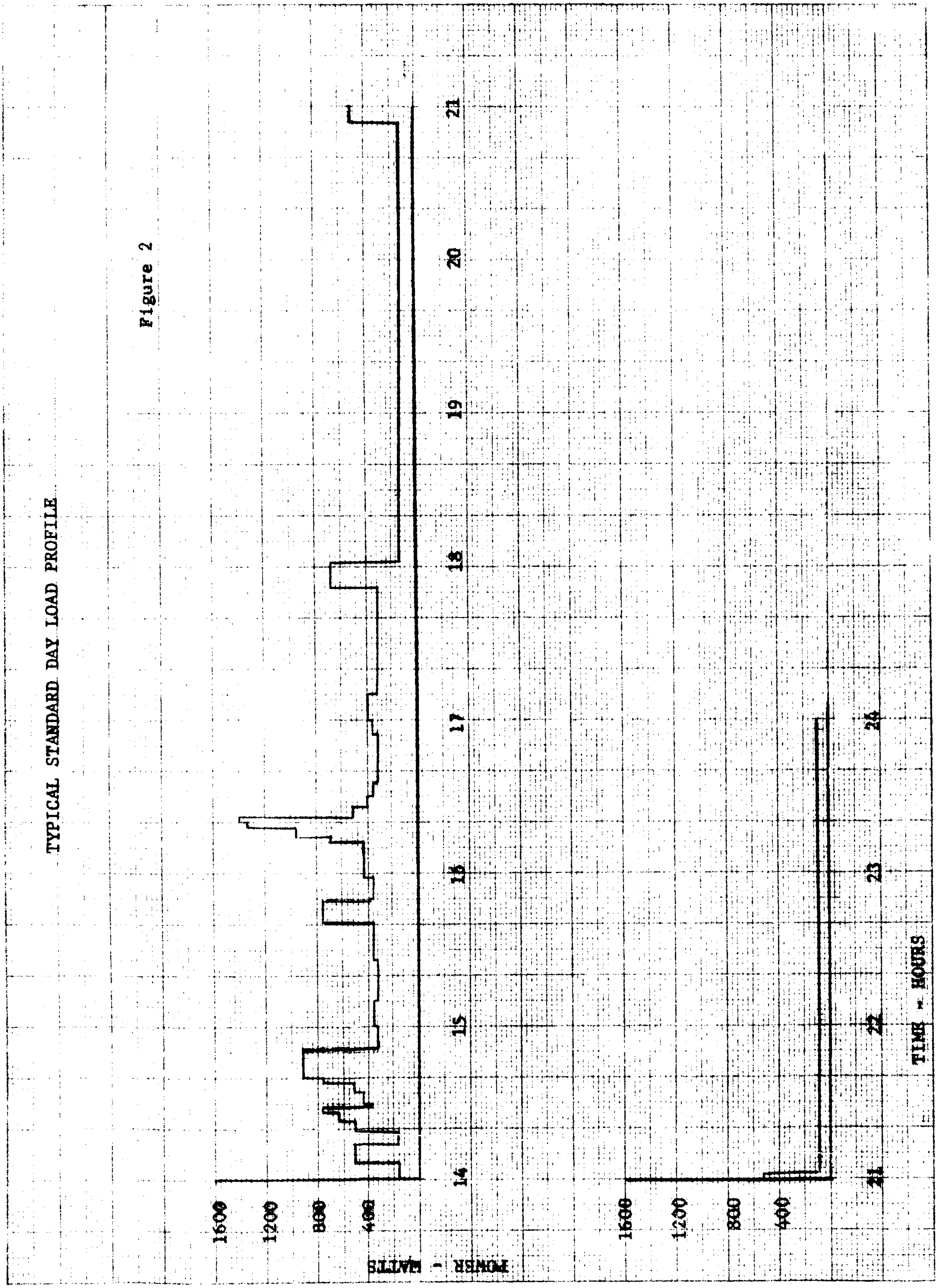


TABLE II

Typical Standard Applications Day Power Profile for Group I Experiments

0811 Turn on E06-11 (15 min. warmup)
0821 Turn on E06-7, E06-9a and E06-9b (5 min. warmup)
0825 Turn on E06-1 (1 min. warmup)

TIME PERIOD	HOURS	KILOWATTS	KWH
0811-0821	0.167	0.100	0.0167
0821-0825	0.067	0.189	0.0127
0825-0826	0.017	0.439	0.0075
0826-0834	0.134	0.600	0.0800
0943-0953	0.167	0.100	0.0167
0953-0957	0.067	0.189	0.0127
0957-0958	0.017	0.439	0.0075
0958-1008	0.167	0.600	0.1000
1116-1126	0.167	0.100	0.0167
1126-1130	0.067	0.189	0.0127
1130-1131	0.017	0.439	0.0075
1131-1140	0.150	0.600	0.0900
1253-1303	0.167	0.100	0.0167
1303-1307	0.067	0.189	0.0127
1307-1308	0.017	0.439	0.0075
1308-1317	0.150	0.600	0.0900
1424-1434	0.167	0.100	0.0167
1434-1438	0.067	0.189	0.0127
1438-1439	0.017	0.439	0.0075
1439-1451	0.200	0.600	0.1200
1559-1609	0.167	0.100	0.0167
1609-1613	0.067	0.189	0.0127
1613-1614	0.017	0.439	0.0075
1614-1622	0.134	0.600	0.0800
Group I Total Energy for Standard Day			0.7814
Group I Total Energy for 5 Standard Days			3.9070

Typical DMS Power Profile for Standard Applications Day.

Group I Experiments

TIME PERIOD	HOURS	KILOWATTS*	KWH*
0826-0834	0.134	0.0	0.0
0958-1008	0.167	0.0	0.0
1131-1140	0.150	0.0	0.0
1308-1317	0.150	0.0	0.0
1439-1451	0.200	0.0	0.0
1614-1622	0.134	0.0	0.0
Group I Total for Standard Day			0.0
Group I Total for 5 Standard Days			0.0

* All data loads are included under Group II data loads.

TABLE III

Typical Standard Applications Day Power Profile for Group II Experiments

0756 Turn on S043 (30 min. warmup)
0826 Turn on S044A & S048 (no warmup)
0856 Operate S043 for 10 minutes
0926 Operate S043 for 10 minutes
0956 Operate S043 for 10 minutes
1140 Operate S043 for 10 minutes
1210 Operate S043 for 10 minutes
1240 Operate S043 for 10 minutes
1322 Turn off S043
1428 Turn on S043 (30 min. warmup)
1500 Operate S043 for 1C minutes
1540 Operate S043 for 10 minutes
1620 Operate S043 for 10 minutes
1700 Operate S043 for 10 minutes

TIME PERIOD	HOURS	KILOWATTS	KWH
0756-0826	0.50	0.055	0.0275
0826-0856	0.50	0.081	0.0405
0856-0906	0.167	0.111	0.0186
0906-0926	0.334	0.081	0.0270
0926-0936	0.167	0.111	0.0186
0936-0956	0.334	0.081	0.0270
0956-1006	0.167	0.111	0.0186
1006-1140	1.567	0.081	0.1270
1140-1150	0.167	0.111	0.0186
1150-1210	0.334	0.081	0.0270
1210-1220	0.167	0.111	0.0186
1220-1240	0.334	0.081	0.0270
1240-1250	0.167	0.111	0.0186
1250-1322	0.532	0.081	0.0432
1322-1428	1.10	0.026	0.0286
1428-1500	0.532	0.081	0.0432
1500-1510	0.167	0.111	0.0186
1510-1540	0.50	0.081	0.0405
1540-1550	0.167	0.111	0.0186
1550-1620	0.50	0.081	0.0405
1620-1630	0.167	0.111	0.0186
1630-1700	0.50	0.081	0.0405
1700-1710	0.167	0.111	0.0186
1710-1800	0.833	0.081	0.0675
Group II Total Energy for Standard Day			0.7930
Group II Total Energy for 5 Standard Days			3.9650

Typical DMS Power Profile for Standard Applications Day

Group II Experiments

Data Record

TIME PERIOD	HOURS	KILOWATTS	KWH
0826-1039	2.216	0.143	0.3186
1105-1322	2.284	0.143	0.3270
1423-1800	3.619	0.143	0.5200
Group II Per Standard Day			1.1650
Group II Per 5 Standard Days			5.8250
1039-1105	0.434	0.040	0.0174
1322-1423	1.017	0.040	0.0431
1800-2100	3.0	0.040	0.1200
Per Standard Day			0.1805
Per 5 Standard Days			0.9025
Data Record Total			6.7275
Data Dump (12 dumps x 8 min. x 5 days x 225)		=	1.8000
Data Total			8.5273

Loads:

Signal Conditioner	30
PCM Encoder	10
Recorder	10
VCO's	46
Recorder	47
	143 Watts

TABLE IV

Typical Standard Applications Day Power Profile

Day-Night Camera (S039)

0849	Turn on camera (warmup)
0850	Operate Camera
0935	Camera to Standby
1017	Operate Camera
1039	Camera to Standby
1105	Operate Camera
1120	Camera to Standby
1220	Operate Camera
1315	Camera Off
1524	Warm-up Camera
1525	Operate Camera
1635	Camera to Standby
1655	Operate Camera
1715	Camera Off

TIME PERIOD	HOURS	KILOWATTS	KWH
0849-0850	0.017	0.010	0.0002
0850-0935	0.75	0.043	0.0323
0935-1017	0.70	0.010	0.0070
1017-1039	0.367	0.043	0.0158
1039-1105	0.434	0.010	0.0044
1105-1120	0.25	0.043	0.0108
1120-1220	1.0	0.010	0.0100
1220-1315	0.92	0.043	0.0395
1524-1525	0.017	0.010	0.0002
1525-1635	1.167	0.043	0.0503
1635-1655	0.334	0.010	0.0034
1655-1715	0.334	0.043	0.0144
Total Energy per Standard Day			0.1883
Total Energy per 5 Standard Days			0.9415

Dielectric Tape Camera (S040)

0945	Warm-up Camera
1000	Operate Camera
1010	Turn off Camera
1116	Warm-up Camera
1131	Operate Camera
1140	Turn off Camera
1252	Warm-up Camera
1307	Operate Camera
1322	Turn off Camera
1424	Warm-up Camera
1439	Operate Camera
1453	Turn off Camera

TIME PERIOD	HOURS	KILOWATTS	KWH
0945-1000	0.25	0.025	0.0063
1000-1010	0.167	0.027	0.0452
1116-1131	0.25	0.025	0.0063
1131-1140	0.150	0.027	0.0041
1252-1307	0.25	0.025	0.0063
1307-1322	0.25	0.027	0.0068
1424-1439	0.25	0.025	0.0063
1439-1453	0.234	0.027	0.0063
Total Energy per Standard Day			0.0876
Total Energy per 5 Standard Days			0.4380

Day-Night Camera & Dielectric Tape Camera
(Recorder (25W) plus Data Dump.)

TIME PERIOD	HOURS	KILOWATTS	KWH
0957-1005	0.134	0.156	0.0209
1021-1029	0.134	0.156	0.0209
1122-1130	0.134	0.156	0.0209
1150-1158	0.134	0.156	0.0209
1318-1326	0.134	0.156	0.0209
1335-1343	0.134	0.156	0.0209
1406-1414	0.134	0.156	0.0209
1419-1427	0.134	0.156	0.0209
1540-1548	0.134	0.156	0.0209
1618-1626	0.134	0.156	0.0209
1752-1800	0.134	0.156	0.0209
2053-2101	0.134	0.156	0.0209
Total Energy per Standard Day			0.2508
Total Energy per 5 Standard Days			1.2540

T004 Frog Otolith Power Profile

0600 (T-3 hrs) - Turn on 5 watt load (install frog)
1630 - Start frog test sequence

TIME PERIOD	HOURS	KILOWATTS	KWH
0600-1630	10.5	0.005	0.0525
1630-1638	0.134	0.020	0.0027
1638-1700	0.367	0.005	0.0019
1700-1708	0.134	0.020	0.0027
1708-1730	0.367	0.005	0.0019
1730-1738	0.134	0.020	0.0027
1738-1800	0.367	0.005	0.0019
1800-1808	0.134	0.020	0.0027
1808-1830	0.367	0.005	0.0019
1830-1838	0.134	0.020	0.0027
1838-1900	0.367	0.005	0.0019
1900-1908	0.134	0.020	0.0027
1908-2000	0.967	0.005	0.0049
2000-2008	0.134	0.020	0.0027
2008-2100	0.87	0.005	0.0044
2100-1500 Day II			0.1278
1500-1508	0.134	0.020	0.0027
1508-0130 of Day III	10.367	0.005	0.0519
0130-0138	0.134	0.020	0.0027
0138-0330	1.87	0.005	0.0094
0330-0130 of Day V (46 hours)			0.2783

Frog Otolith (T004) Total Energy Req. 0.5630

DMS Power Profile for T004 Frog Otolith

A. Data Record Power Profile

TIME PERIOD	HOURS	KILOWATTS	KWH
1630-1638	0.134	0.104	0.0140

Typical for 51 cycles:

51 x 0.0140 = 0.7140

B. Data Dump Power Profile

Load

Recorder	47
Transmitter	84
	131 Watts

51 dumps x 8 min. x 0.131 Kw = 0.8930

1.6070
.5630

Total Energy Requirement= 2.1700

PR 29-22

STUDY REPORT

GROUND SERVICING SYSTEMS

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

28 August 1967

Prepared by: C B Westfall
C. B. Westfall

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D. E. Callahan

MARTIN MARIETTA CORPORATION
DENVER DIVISION

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to analyze all requirements for fluid and mechanical servicing for the AAP/PIP Early Applications Program (Flight IA) and to define the equipment to meet the requirements.

1.2 Objectives - The objectives of the study are (1) to define all functional and technical GSE requirements, (2) to identify, analyze, and trade off possible design approaches and (3) to establish a baseline list and description of equipment.

2. SUMMARY

The IA Carrier subsystems require leak checking, coolant servicing, freon servicing, vacuum servicing, and thermal simulators. The IA Experiments require liquid nitrogen, vacuum, gaseous helium, gaseous nitrogen, gaseous carbon dioxide, air conditioning, leak checking, and black body calibrators. The gaseous requirements are minor and will be furnished as Program Support Requirements. The thermal simulators will be supplied as test tooling. All other requirements will be met by servicing Ground Support Equipment. Some of the servicing functions are performed during more than one ground operation.

The result of the analysis is the selection of the following end items of servicing GSE: Coolant Service Unit, Liquid Nitrogen Service Unit, Mass Spectrometer Leak Tester, Vacuum Service Unit, Freon Supply Unit, SLA Air Conditioner, Carrier Umbilical Set, Experiment Black Body Calibration Unit, Leak Check Unit, and Freon Distribution Unit.

Some of these items have already been provided for the mainline Apollo program, but it is assumed that no existing equipment will be available for this program; therefore, all new equipment is proposed. In order to minimize cost, existing engineering will be used for several end items. Lead times for all servicing GSE are compatible with the present flight schedule, although approximately half of the end items are considered long lead items and will require an early start of about two months.

No major problem areas have been identified during this study.

3. SERVICING ANALYSIS

3.1 Functional Requirements - The primary analytical tool used in this study is a function/equipment matrix (see Table II). The keystone parameter used in this matrix is the functional requirement. The carrier, its subsystems, and the experiments all have functional requirements for fluid services. The basic functional requirements exist for various ground operations at both Denver and Kennedy Space Center (KSC). All ground operations (see Study Reports PR 29-26 and 27) have been analyzed to determine when and where each service is needed. Figure 1 is a Ground Servicing Functional Flow Chart derived from the basic ground operations flow. The gross functions to be performed for each operation/location are listed on the chart and summarized below in the order in which they first appear on the chart.

a. Leak check Thermal Control Subsystem

b. Provide calibrators for experiments

c. Service experiments with fluids

d. Leak check Carrier

e. Service TCS with fluids

f. Provide thermal simulators

g. Leak check Carrier - CSM

h. Air condition adapter (SLA) interior

3.1.1 Carrier Subsystems - The Carrier consists of five basic subsystems: (1) Structures Subsystem, (2) Electrical Power Subsystem, (3) Display and Control Subsystem, (4) Data Management Subsystem, and (5) Thermal Control Subsystem. Of these, only the Structures Subsystem and the Thermal Control Subsystem have fluid servicing requirements.

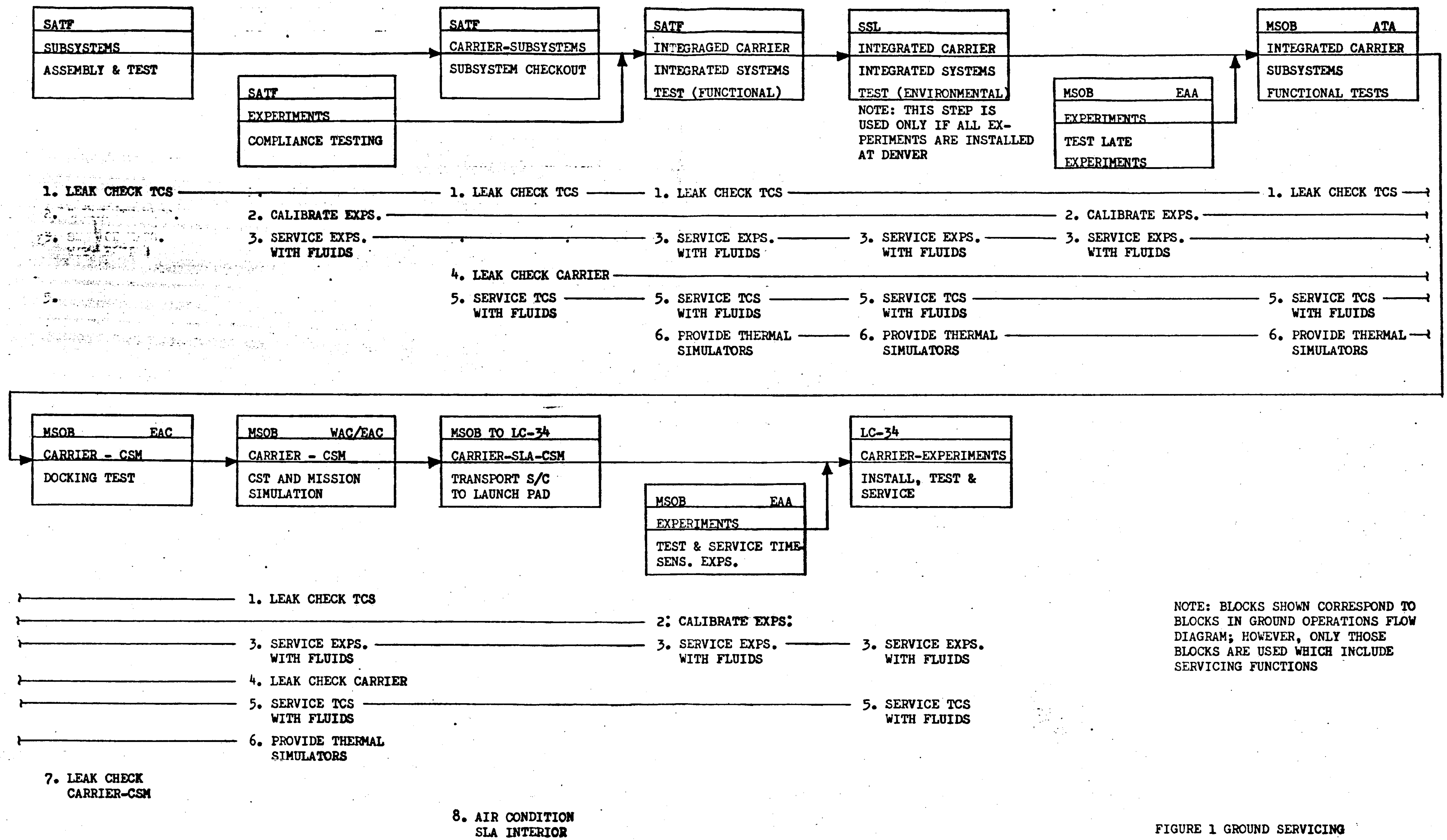

FIGURE 1 GROUND SERVICING FUNCTIONAL FLOW CHART

FOLDOUT FRAME 1

FOLDOUT FRAME 2

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3.1.1.1 Structures Subsystem - The Carrier is a conical shaped vehicle which when in space will be pressurized with oxygen to 5 psia. It will have welded joints and a bolted-on lower dome. It requires leak checking. There are two phases to this: (1) the Carrier itself must be leak tight, and (2) the Carrier when docked with the Apollo Command and Service Module (CSM) must be leak tight. This second requirement is to verify the integrity of the docking mechanism so that after docking no undue depletion of the pressurization system will occur.

3.1.1.2 Thermal Control Subsystem (TCS) - The TCS is a closed loop liquid coolant system which uses Freon-21 as the coolant. Airborne pumps circulate the freon through a cold-plate system, where the heat load is picked up, and then through a radiator system, where the heat load is dissipated. Since the radiators are designed for heat dissipation to a space environment, they are not effective on the ground; therefore, for ground operations a freon boiler is included in the airborne loop. Also included are accumulators to accommodate expansion and contraction of the coolant. The functional servicing requirements for the TCS are as follows:

a. Leak Checking - The fluid portion of the TCS must be checked for leakage to assure that no leakage of coolant will occur during ground operations and flight.

b. Coolant Servicing - The fluid system must be completely filled with Freon-21 coolant. Associated with this service, the capability must be provided to flush the system with coolant, to evacuate the system prior to filling to assure complete filling, to drain the coolant from the system, to purge and dry the system, and to blanket the system with nitrogen.

3.1.1.2 Thermal Control Subsystem (TCS) - (Continued)

c. Freon Boiler Servicing - The freon boiler dissipates the TCS heat load by boiling off Freon-12 to atmosphere. The boiler operates at atmospheric pressure. The freon supply to the boiler will be controlled in response to signals from an airborne temperature transducer located in the coolant line downstream of the freon boiler.

d. Accumulator Servicing - The airborne accumulators are spring loaded. The spring compartments will be open to the space environment during flight. For ground operation of the TCS, the spring compartments must be evacuated to an absolute pressure of 0.5 mm of mercury to simulate the space environment.

e. Thermal Simulators - The heat load on the TCS is produced by experiments, batteries, and inverters. For ground performance checkout of the TCS, some of the experiments and possibly the batteries and inverters will not be available. The heat loads from the missing items must be simulated in order to check out the subsystem performance.

3.1.2 Experiments - There are twenty-three experiments scheduled for the IA flight. Of these, twenty will be located in or on the Carrier during launch; the other three will be in the Command Module. The servicing requirements have been derived from writeups of the individual experiments prepared by MMC Experiment Integration personnel and also from contacts with experimenters themselves. The detailed requirements are defined in Table I and are summarized below.

a. Liquid Nitrogen - Five experiments require liquid nitrogen to service airborne dewars or ground calibrators.

TABLE I SERVICING REQUIREMENTS FOR EXPERIMENTS

EXPERIMENT IDENTIFICATION	SURVIVAL TEMPERATURE LIMITS (°F)	SURVIVAL REL. HUMID. LIMITS (%)	CRYOGENIC REQUIREMENTS	VACUUM REQUIREMENTS	CALIBRATION REQUIREMENTS	BOCST LOC. CARRIER	BOCST LOC. CM	REMARKS
Radiation Measurement (D008)							X	No servicing required
Simple Navigation (D009)						X		No servicing required
Solid Electrolyte Carbon Dioxide Reduction (D017)	0-1300			Vac. pump req'd to evac. insul. chamber of electrolysis cell		X		Charging of 20.4 cubic inch A/B CO_2 cylinder req'd. Cylinder is removable for servicing at existing CO2 facility.
Metric Camera (E06-1)	-148 to 104	0-95				X		No servicing req'd.
Multispecial Camera (E06-4)	14 to 95	0-90				X		No servicing req'd.
Wide Range Imager (E06-7)	-58 to 104	0-95		Small vacuum pump provided with exp. to evacuate Malaker Cooler	Ambient temperature black body furnished by experiment contractor	X		Helium tank (gas) req'd. to fill refrigerator - pressure 250 psi (Provide K-Bottle or other source) (PSRD item)
IR Radiometer (E06-9A)	-58 to 167	0-95	25 liters liquid nitrogen req'd. to service exp. cryo flask (See Remarks)	Vacuum pump req'd to evacuate jacket of cryo flask	Liquid nitrogen black body furnished by experiment contractor	X		Cryo flask furnished with experiment
IR Spectrometer (E06-9B)	-58 to 167	0-95	25 liters liquid nitrogen req'd. to service exp. cryo flask (See Remarks)	Vacuum pump req'd. to evacuate jacket of cryo flask	Liquid nitrogen black body furnished by experiment contractor	X		Cryo flask furnished with experiment
Multifrequency Microwave Radiometer (E06-11)	-85 to 212	0-100	100 liters liquid nitrogen req'd. to cool black body	Vacuum pump req'd.	Liquid nitrogen black body required (See Remarks)	X		Black body will probably be furnished by experiment contractor, but until this is firm, assumption is that MMC will provide.
Zero-G Effect on Human Cells (S015)	52 to 95	0-95					X	No servicing required
Trapped Particle Assymetry (S016)						X		No servicing required
X-Ray Astronomy (S017)	0 to 150					X		No servicing required
Micrometerorite Collection (S018)	40 to 85	10-60				X		No servicing required
UV Stellar Astronomy (S019)	100 Max			Vac. pump req'd. for pre-flight evac. of film and objective canisters		X		

FOLDOUT FRAME

FOLDOUT FRAME

FOLDOUT FRAME 2

FOLDOUT FRAME

TABLE I (Continued)

EXPERIMENT IDENTIFICATION	SURVIVAL TEMPERATURE LIMITS (°F)	SURVIVAL REL. HUMID. LIMITS (%)	CRYOGENIC REQUIREMENTS	VACUUM REQUIREMENTS	CALIBRATION REQUIREMENTS	BOOST CARRIER	LOG. CM	REMARKS
X-Ray/UV Solar Photography (S020)	100 Max	0-40	10 liters/day liquid nitrogen req'd in lab			X		One cylinder helium gas req'd for leak test in lab (PSRD item)
Day-Night Camera (S039)	23 to 131	0-100				X		No servicing required
Dielectric Tape Camera (S040)	23 to 131	0-100		Vacuum pump req'd to evac. experiment during checkout		X		
IR Temperature Sounding (S043)	-85 to 185	0-50 (See Remarks)		Vacuum pump req'd but provided with GSE by exp. contractor		X		Radiometer purged & pressurized with dry nitrogen at all times. GN_2 K-Bottle or other source required. 50% RH for electronics questionable.
Electrically Scanned Microwave Radiometer (S044A)	-85 to 185	0-100	60 liters liquid nitrogen req'd to cool black body	Vacuum pump required	Liquid nitrogen black body required (See Remarks).	X		Black body will probably be furnished by experiment contractor, but until this is firm, assumption is that MMC will provide.
UHF Sferics (S048)	32 to 140	0-100.				X		No servicing required
Manual Navigation Sightings (T002)						X		No servicing required. Instrument normally kept in shipping container until installation in spacecraft.
Aerosol Particle Analyzer (T003)	0-120	0-85					X	No servicing required
Frog Otolith Function (T004)						X		No servicing required

3.1.2 Experiments - (Continued)

b. Vacuum - Five experiments require the use of a vacuum pump to evacuate various parts of the experiments.

c. Black-body Calibrators - Four experiments require black-bodies at liquid nitrogen temperature, and one requires an ambient temperature black-body. Preliminary indications are that all calibrators will be provided by the experiment contractors, but because this is not firmly established, calibration is considered an integrating contractor responsibility.

d. Gaseous Helium - Two experiments have small gaseous helium requirements which can be satisfied by K-bottle-type gas cylinders with standard gauge and regulator controls.

e. Gaseous Nitrogen - One experiment must be purged and pressurized with dry nitrogen gas at all times. Only a small quantity is required.

f. Gaseous Carbon Dioxide - One experiment contains a small CO_2 cylinder which is removed for servicing at a CO_2 facility.

g. Air Conditioning - Survival temperature limits have been established for twenty-two of the experiments and survival relative humidity limits for fifteen of the experiments.

h. Leak Checking - One experiment is contained in a canister which is evacuated during ground operations. It must be leak tight and therefore requires leak checking prior to flight using helium gas.

3.2 Design Approaches - Table II contains the design approach analysis which leads to the recommended equipment which forms the servicing GSE baseline. To avoid duplicating the analysis of each operation/location shown in Figure 1, the gross functional requirements listed above have been used as a starting point. Each function has been listed only once, and all of the operations during which that function is performed have been shown in the first column. Then the functional requirement has been expanded as described in the following paragraphs.

3.2.1 Technical Requirements - These are the engineering requirements which form the basis for the actual equipment which fulfills the functional requirements. Such parameters as commodity quantity, leakage rate, flow-rate, temperature, and pressure are defined.

3.2.2 Possible Approaches - This section presents one or more approaches to satisfying each set of functional and technical requirements. Not all the possibilities are presented and discussed, but only those that from previous experience or obvious logic appear most worthy of consideration. For instance, leak checking of a thermal control system was analyzed during the AEP Program, in Study Report ACO 301-001, "Fluid Servicing GSE Requirements and Concepts", dated 20 April 1966, performed under Contract No. NAS 9-5452. In this study it was determined that the optimum method for leak checking the fluid system was to pressurize the system with helium gas, monitor pressure decay, and, if leakage was out of limits, locate leak points with a mass spectrometer. This approach has been adopted here without further analysis.

3.2.3 Comparison of Approaches - The design and build status and the cost of the equipment associated with each approach have been used as prime bases for comparison. The costs shown are engineering estimates and are presented for comparative purposes rather than as absolute values. Other considerations used to compare the approaches are presented in the Remarks column.

GROUND SUPPORT FUNCTION/EQUIPMENT MATRIX

BY ______ DATE ______ SUBJECT SERVICING GSE SHEET NO. 1 OF 6
CHKD. BY ______ DATE ______ JOB NO. ______

TABLE II GROUND SUPPORT FUNCTION/DQUIPMENT MATRIX

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
Sub-systems Assembly and Test at SATF Carrier - Subsystems Sub-system Checkout at SATF Integrated Carrier Integ. Systems Test (Functional) at SATF Integrated Carrier Subsystem (Functional) Test at MSOB A & T Area Carrier - CSM CST and mission simulation at MSOB WAC/EAC	Leak Check Fluid Portion of Thermal Control System	Leakage from the TCS cannot exceed (TBD) SCC/SEC when the system is pressurized with helium to 75 psig(15 psi above the maximum operating pressure of 60 psig)	MSE Cl. I	1. Pressurize system with helium and monitor pressure decay to determine leak rate							Use the following two end items: 1. Leak Check Unit MMC Code No. 3110 2. Mass Spectrometer Leak Tester NAA Model No. S14-003 MMC Code No. 3103	1. Alternate methods of leak testing were investigated on AEP Program and the basic method used here was selected. No further trade-off of methods was made. 2. NAA Model C14-075 is a more complex unit than is required and is therefore not recommended; however, if a unit is available it can be used.
				a. New leak check unit					X	15 K		
				b. NAA Fluid Checkout Unit Model C14-075			X			20 K		
				2. If leak rate is out of tolerance, isolate leakage points using Mass Spectrometer								
				a. New unit					X	25 K		
				b. NAA Leak Tester Model S14-003			X			20 K		
Experiment Compliance Testing at SATF Late Experiment Testing at MSOB Time-sensitive Experiment Testing at MSOB	Provide "black-body" calibrators for ground calibration of certain experiments	1. Ambient temperature black body required for Exp. E06-7 2. Liquid nitrogen black body comes as part of Exp. E06-9A 3. Liquid nitrogen black body comes as part of Exp. E06-9B 4. Liquid nitrogen black body required for Exp. E06-11 5. Liquid nitrogen black body required for Exp. S044A	MSE Cl.I	1. Use calibrators provided by Experiment Contractors							Provide one unit as follows: Experiment Black-Body Calibration Unit MMC Code No. 3109 (See Remarks)	Calibrators are built into Exps. E06-9A and E06-9B. Calibrators for E06-7, E06-11, and S044A may be provided with experiments, but until this is confirmed it is assumed that MMC has the requirement to furnish the calibration equipment
				2. Provide individual calibrators					X			
				3. Provide a unit that contains all required black bodies together with the temperature control and monitor equipment required.					X			

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MARTIN DENVER

GROUND SUPPORT FUNCTION/EQUIPMENT MATRIX

BY ______ DATE ______ SUBJECT SERVICING GSE SHEET NO. 2 OF 6
CHKD. BY ______ DATE ______ JOB NO. ______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
Experiments Compliance Testing at SATF Integ. Carried IST (Functional) at SATF Integ. Carrier IST (Environmental) at SSL Late Experiments Compliance Testing at MSOB Exp. Accom. Area Carrier-CSM CST and Mission Simulation at MSOB WAC/EAC Time-Sensitive Experiments Test and Service at MSOB Exp. Accom. Area	Provide fluid services for experiments and experiment-associated GSE for ground checkout	1. 25 liters liquid nitrogen required to service experiment Cryo flask for E06-9A IR Radiometer 2. 25 liters liquid nitrogen required to service experiment cryo flask for E06-9B IR Spectrometer 3. 100 liters liquid nitrogen required to cool black body calibrator for E06-11 Microwave Radiometer. 4. 10 liters/day for 10 days (est.) liquid nitrogen required for lab checkout of Exp S020 X-Ray/UV Solar Photography 5. 60 liters liquid nitrogen required to cool black body for Exp S044A Microwave Radiometer 6. It is assumed that to fill all of the above requirements a single unit with a storage capacity of 100 gallons will be required.	MSE Cl.I	1. For transporting liquid nitrogen from source (tank farm or supply trailer) to usage point and supplying it to the experiments or GSE as required:							1. Provide new Liquid Nitrogen Service Unit MMC Code No. 3102 Use it first at Denver and then ship it to KSC.	1. Facility Equipment may be available at Denver and KSC but availability has not been established 2. NAA uses a GFP LN_2 Storage and Transfer Unit No. S-083 but availability for this program has not been established.
				a. Use facility equipment	X					—		
				b. Use GFE	X					—		
				c. Provide new service unit					X	5 K (Est)		
		Vacuum source required for ground checkout of Experiments E06-9A, E06-9B, S019, D017, and S040. Equipment must be capable of producing an absolute pressure of 0.5 MM of mercury		1. For vacuum supply:							1. Provide new Vacuum Service Unit MMC Code No. 3104 using existing design for NAA Servicing Vacuum Unit Model No. S14-113	1. Labs may have built-in vacuum service but this has not been determined. 2. Availability of existing NAA units (GFE) is not known.
				a. Use facility source	X					—		
				b. Use GFE	X					—		
				c. Provide new service unit			X			7 K		
		(continued next page)										

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MARTIN MARIETTA CORPORATION
DENVER DIVISION

GROUND SUPPORT FUNCTION/EQUIPMENT MATRIX

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
		1. Helium gas at 250 psig required to fill refrigerator of Exp E06-7 Wide Range Imager. Small quantity required in laboratory 2. One cylinder of helium gas required in lab for leak testing of Exp. S020 Solar Photography		Provide K-bottle-type helium tank as PSRD item	X					—	Provide K-bottle-type helium tank as PSRD item	This is the normal way a requirement of this type is handled, so no alternate approaches are suggested.
		Exp. S043 IR Temperature Sounding requires purging and pressurizing with dry nitrogen at all times. After purging, pressure is sealed in. Only small quantities of GN_2 required.		1. Provide K-bottle-type nitrogen cylinder as PSRD item.	X						Provide K-bottle-type nitrogen cylinder as PSRD item	This is the normal way a requirement of this type is handled.
				2. Provide outlet from facility nitrogen supply				X		2 K (Est.)		
		Exp. D017 CO_2 Reduction contains small CO_2 cylinder. Cylinder is removable for servicing.		1. Charge at existing CO_2 facility. Cover requirement in PSRD	X					—	Charge at existing CO_2 facility as PSRD item	Easier to take small cylinder to facility than to take large cylinder to lab
				2. Provide CO_2 charging cylinder as PSRD item.	X					—		
Carrier - Subsystems Checkout at SATF Integ. Carrier IST(Functional) at SATF Integ. Carrier IST (Environmental) at SSL (continued next page)	Provide fluid services for Thermal Control System (TCS)	1. Flush fluid portion of TCS prior to filling with coolant 2. Evacuate fluid portion of TCS to (TBD) mm of Hg. 3. Fill TCS with approx. 100 lbs. of coolant 4. Drain coolant from TCS 5. Dry TCS and blanket with nitrogen at 5 psig (continued next page)	MSE Cl.I	1. Provide new-design unit to perform all required functions					X		Provide new-design Coolant Service Unit MMC Code No. 3101. This unit will provide flush, evacuate, fill, drain, dry and blanket functions. Flex lines and connectors will be included with the unit.	1. Unit will be similar in concept and size to 80801C10900 2. Providing a vacuum unit separate from coolant unit would complicate the servicing operations and also cost more.
				2. Modify Titan III Propellant Servicing Unit 80801C10900 design and build new unit				X				
				3. Provide new-design coolant unit and separate vacuum unit					X			

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GROUND SUPPORT FUNCTION/EQUIPMENT MATRIX

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROACHES	COMPARISON OF APPROACHES: EXIST. EQUIP NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
Integ. Carrier Subsystem Functional Tests at MSOB A & T Area Carrier CSM CST & Mission Simulation at MSOB Alt. Ch. Integ. Carrier Preflight Checkout and Servicing at LC-34		Supply approx. 70 lb/hr of Freon-12 (or possibly F-114) to Freon Boiler. Incorporate flow control based on appropriate airborne signal (from float valve, temperature sensor, or some other device)		1. Provide new unit built to Grumman design for Freon Supply Unit Part No. 430-54600			X			35 K (est.)	Provide new Grumman Freon Supply Unit Part No. 430-54600 MMC Code No. 3105	1. Grumman unit was designed for just this service.
				2. Provide new-design unit					X	50 K (est.)		2. Grumman unit may be available as GFE but availability has not been determined.
				3. Use existing GFE item	X							
		Connect supply unit to Freon Boiler; filter and sample Freon upstream of ground/airborne interface; provide shutoff capability.		1. Provide GSE fluid distribution system					X		Provide as GSE Fluid Distribution System MMC Code No. 3111	Cost would be about same for each approach but GSE approach will give best control.
				2. Provide facility system					X			
				3. Provide system as part of installation engrg. pkg.					X			
		Evacuate spring sides of airborne accumulators to 0.5 mm of Hg.		1. Provide new vacuum unit specifically for this service					X	3 K (est.)	Use vacuum unit provided for experiments (see MMC Code No. 3104 on sheet 2)	Unit will only be needed for brief periods of time. No problem is envisioned in sharing unit provided for experiments.
				2. Use vacuum unit provided for experiments	X					—		
				3. Use GFE unit	X					—		
Integ. Carrier Integrated Systems Test (Functional) at SATF Integ. Carrier IST (Environmental) at SSL Integ. Carrier Subsystem Functional Test at MSOB A & T Area Carrier - CSM CST and Mission Simulation at MSOB Alt. Ch.	Provide thermal simulators for check-out of Thermal Control System when actual loads on cold plates are not available (i.e., late experiments)	There are several cold plates in the TCS. It is anticipated that the equipment that mounts on some of these cold plates will not be available at the time subsystem tests are run. The heat load generated by each piece of unavailable equipment must be simulated. Heat loads are as follows: (Item TBD) (TBD) KW " " KW " " KW " " KW " " KW " " KW	MSE Cl.I	Provide insulated boxes that will be installed on the cold plates in such a way that the heat produced inside them is transmitted to the cold plates. Heat will be produced by a suitable method such as electrical resistors. These items will be provided as GSE or as test tools.					X		Provide a set of simulators, each one of which is heated electrically. The set will include an electrical harness to permit flexible installation and suitable controls to regulate the heat production of each simulator.	A management decision has made this equipment test tooling.

GROUND SUPPORT FUNCTION/EQUIPMENT MATRIX

BY ______ DATE ______ SUBJECT SERVICING GSE SHEET NO. 5 OF 6
CHKD. BY ______ DATE ______ JOB NO. ______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
Experiment Compl. Testing at SATF TCS Post-Inst. C/O at SATF Integ. Carrier IST at SATF Integ. Carrier IST at SSL Integ. Carrier S/S Functional Test at MSOB A & T Area Integ. Carrier Servicing at LC-34	Provide inter-connections between GSE and Carrier and between GSE and experiments	1. Provide flexible vacuum line to connect Vacuum Service Unit (Code 3104) to TCS accumulators. Line must be 1/2" diameter and 25' long. 2. Provide flexible freon line to connect Freon Distribution System (Code 3111) to TCS Freon Boiler. Line must be 1/2" diameter and 25' long. 3. Provide suitable adapters to connect above vacuum line to those experiments requiring vacuum service. Detailed requirements will be determined later. 4. Provide interconnections for other services not presently defined. An example of this is a set of connectors for status monitoring of the thermal control system.	MSE Cl.I	1. Provide required items as part of GSE that they are used with 2. Provide required items in kit form.					X X		Provide umbilicals, connectors, and adapters as a kit.	
Spacecraft Transport from MSOB to LC-34	Provide conditioned environment for experiments when the integrated Carrier is not in an air conditioned room. This is required when the Spacecraft is in transit between the MSOB and LC-34.	Volume to be conditioned (Interior of SLA) = 3500 ft^3 Temperature Limits - 40-85°F Relative Humidity Limits - 20-50% Air changes - 20/HR using 100% outside air Cleanliness - Class 100,000 clean room environment Air handled = 1200 CFM Pressure in SLA = ¼" H_2O Location - On transport trailer for Spacecraft Power supply - Use gasoline powered engine provided with unit.	MSE Cl.I	1. Modify design of Titan III Van Air Conditioner 80801N57500 2. Provide new commercially available unit			 X	X		50 K (est.) 10 K (est.)	Provide new commercial-type unit of standard design	Van Air Conditioner is a very expensive unit which is more sophisticated than is required for this application.

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GROUND SUPPORT FUNCTION/EQUIPMENT MATRIX

BY ______ DATE ______ SUBJECT SERVICING GSE SHEET NO. 6 OF 6
CHKD. BY ______ DATE ______ JOB NO. ______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
Carrier-Subsystems Checkout at SATF Carrier-CSM CST and Mission Simulation at MSOB Alt. Chamber Carrier-CSM Docking Test at MSOB EAC	Leak Check Carrier pressurized compartment and leak check carrier-CSM when docked.	Leakage from the pressurized compartment of the Carrier cannot exceed (TBD) when the compartment is pressurized with gaseous (TBD) to (TBD)+(TBD) psig Leakage from the Carrier-CSM while docked cannot exceed (TBD) when the combined volume is pressurized with gaseous (TBD) to (TBD) + (TBD) psig	MSE CL.I	1. Pressurize volume and monitor pressure decay using one of following: a. Leak Check Unit MMC Code No. 3110 b. Module Leak Test Unit NAA Model No. S14-079 2. Isolate leakage points using Mass spectrometer leak tester NAA Model No. S14-003, MMC Code No. 3103			X			See Remarks 18K See Remarks	Use Leak Check Unit MMC Code No. 3110, and Mass Spectrometer MMC Code No. 3103. (This is same equipment as is used for leak checking the Thermal Control System. See Sheet 1.)	Because of the different volumes involved in the Carrier and the TCS it may not be practical to use one set of equipment to do both jobs; however, until the actual requirements are established, the baseline approach will be to use the same equipment for both applications.

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3.2.4 Recommended Approach/Equipment - This column presents the recommended approach and/or equipment which will best satisfy the requirements. The equipment shown in this column forms the servicing GSE baseline for this program.

3.3 GSE Baseline Definition

3.3.1 Summary List - The equipment end items are listed in Table III. The Code Numbers have been arbitrarily assigned from a block of numbers allocated for Servicing GSE in the IA Work Breakdown Structure. This block is 293100-293199. The first number used is 293101; 293100 has been reserved as a top number.

TABLE III SERVICING GSE LIST

CODE NO.	NAME
293101	Coolant Service Unit
293102	Liquid Nitrogen Service Unit
293103	Mass Spectrometer Leak Tester
293104	Vacuum Service Unit
293105	Freon Supply Unit
293106	SLA Air Conditioner
293107	Carrier Umbilical Set
293109	Experiment Black-Body Calibration Unit
293110	Leak Check Unit
293111	Freon Distribution System

3.3.2 Requirements Data Sheet - Table IV summarizes all the pertinent data pertaining to each end item. Of particular interest are quantities, probable sources, and descriptions.

TABLE IV GSE DATA
SUMMARY SHEET

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATIONS	CRITICALITY CATEGORY	DESCRIPTION	MODIFICATION DEFINITION	LEAD TIME (MONTHS)	PROBABLE SOURCE
293101	TCS Coolant Service Unit	1 →	(1)	Provide coolant storage, flushing, evacuating, filling, and draining capabilities for the coolant loop in the airborne thermal control system.	Denver (SATF, SSL) KSC (MSOB, LP)	Mission Support, Class I	Caster-mounted cabinet enclosed unit containing storage tank, vacuum pump, pressure regulator, flow meter, flow rate indicator and flow totalizer, valves, piping, and flex hoses. This unit will be very similar to the Titan III Propellant Servicing Unit 80801010900.		8	MMC New Design New Build
293102	Liquid Nitrogen Service Unit	1 →	(1)	Provide a source of liquid nitrogen for ground checkout of certain experiments and to service airborne dewars associated with some experiments.	Denver (SATF, SSL) KSC (MSOB, LP)	Mission Support, Class I	Small four-wheeled trailer, towable by hand or vehicle, and containing a 100-gallon liquid nitrogen dewar, a heat exchanger for self-pressurizing the dewar, a flow valve, and a 1/2" flex hose 25' long.		8	Outside Vendor
293103	Mass Spectrometer Leak Tester	1 →	(1)	Detect and measure leakage in fluid portion of the TCS when it is pressurized with helium gas. Also check leakage in carrier structure and carrier-CSM interface.	Denver (SATF), KSC (MSOB, LP)	Mission Support, Class II	Caster-mounted unit containing mechanical pump, diffusion pump, sampling probe and hose, control panel, leak rate indicator, calibration standard, and other associated components. North American Model #S14-003, Part No. G14-848001.		6	Outside Vendor (Possibly NAA)
293104	Vacuum Service Unit	1 →	(1)	Evacuate the spring side of the thermal control system accumulators prior to activation of the TCS for checkout, acceptance, and pre-launch operations. Also provide service as required to certain experiments which have vacuum requirements.	Denver (SATF, SSL) KSC (MSOB, LP)	Mission Support, Class II	Skid-mounted unit containing a motor, a vacuum pump, and control panel. Vacuum capability is 0.1 mm Hq; flow capacity is 4.5 cfm. North American Model S14-113, Part No. 90652-1.		6	Outside Vendor (Possibly NAA)
293105	Freon Supply Unit	1 →	(1)	Supply freon to airborne Freon Boiler in the Thermal Control System to handle heat load from TCS during ground operations (subsystem tests, acceptance tests, pre-launch operations)	Denver (SATF, SSL) KSC (MSOB, LP)	Mission Support, Class I	Skid-mounted unit containing a storage tank, a pump or pressure source for fluid transfer, a flow control device, a filter, valves, and interconnecting piping. Grumman (GAEC) Part # 430-54600.		6	Outside Vendor (Possibly GAEC)

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ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATIONS	CRITICALITY CATEGORY	DESCRIPTION	MODIFICATION DEFINITION	LEAD TIME (MONTHS)	PROBABLE SOURCE
293106	SLA Air Conditioner		1	Provide conditioned air to the SLA interior in order to maintain experiments within their survival temperature and humidity limits during transport between the MSOB and the launch complex.	KSC (between MSOB & LP)	Mission Support Class I	Skid-mounted cabinet-enclosed unit containing an air-cooled refrigeration unit, supply fan, absolute filters, and controls. It will have its own power supply. It will supply 1200 cfm of air at 60°F and 55% RH when the outside temperature is 125°F. A 25' long 12" diameter flexible duct will be included with the unit.		8	Outside Vendor
293107	Carrier Umbilical Set	1 →	(1)	Provide interconnections between GSE and Carrier and between GSE and Experiments (Note: some GSE end items include flex lines that attach directly to the Carrier; these flex lines are not included in this umbilical set).	Denver (SATF,SSL) KSC (MSOB, LP)	Mission Support Class I	Suitcase type container with one 25' 1/2" flexible vacuum line with AN fitting on end, one 25' 1/2" freon line with 1/4" ground half connector to mate with existing A/B connector, and one or two adapters to adapt vacuum umbilical hose to fittings on experiments.		7	MMC New Design New Build
293109	Experiment Black Body Calibration Unit	1 →	(1)	Provide standards for ground calibration of airborne experiment sensors.	KSC (LP)	Mission Support Class II	Kit containing a "black-body" calibrator, a liquid nitrogen system to maintain the black body at liquid nitrogen temperature, and a vacuum system (bell jar) to prevent frosting of the black body.		8	MMC New Design New Build
293110	Leak Check Unit	1 →	(1)	Supply helium gas to fluid portion of the TCS under pressure up to 75 psig, and monitor pressure decay. Also supply helium to Carrier structure and monitor pressure decay.	Denver (SATF) KSC (MSOB, LP)	Mission Support Class I	Portable unit containing adjustable pressure regulators, shut off valves, pressure gages, manometer, and flex lines and connectors for connection to helium source and system to be leak checked.		6	MMC New Design New Build
293111	Freon Distribution System	1	1	This equipment connects the Freon Supply Unit to the spacecraft umbilical either directly or through a facility line. It also provides a means for filtering and sampling the freon just before it enters the airborne system to supply the Freon Boiler. A main shut-off valve is also provided.	Denver (SATF,SSL) KSC (MSOB, LP)	Mission Support Class I	Consists of the following unpackaged equipment: 1" flex line 15' long; sample port and shut-off valve; filter; and line shut-off valve. This equipment will be used between the Freon Supply Unit and the freon umbilical.			MMC New Design New Build

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3.3.3 Schematics - Figure 2 is a basic schematic drawing of the servicing equipment required by the Experiments. Figure 3 shows schematically the equipment required by the Thermal Control Subsystem. The leak check equipment for Carrier and Carrier-CSM leak checks is not shown but is the same equipment that is used on the Thermal Control Subsystem.

3.3.4 GSE Provisioning - A full complement of servicing GSE has been previously provided for the mainline Apollo program. Several of these items could be utilized without change on the Flight IA program if they were available when needed. Since at this time it cannot be determined whether or not the equipment will be available, the approach has been to furnish all new servicing GSE. As the program progresses it may be found that certain items will be available, at which time such items will be identified as Government Furnished Equipment (GFE) rather than Contractor Furnished Equipment (CFE), resulting in a decrease in program cost.

Since only one flight is scheduled on this program, it is planned to provide only one set of servicing GSE to be used first at Denver and then shipped to KSC for use there. The single exception is the Freon Distribution System which will have a different configuration at Denver than at KSC; therefore, two systems are required.

No major provisioning problem areas have been uncovered during this study. Lead times are estimated to vary between six and eight months. Items with lead times in excess of six months are considered long-lead items and will require design effort prior to Phase D (hardware phase) go-ahead.

At this point it is reasonable to assume that experiment requirements will change and that airborne subsystem requirements will change. Some possibilities of changes are as follows:

a. It may be established that all experiment calibrators are provided with the experiments. In this event the Experiment Black Body Calibration Unit will be deleted as an end item.

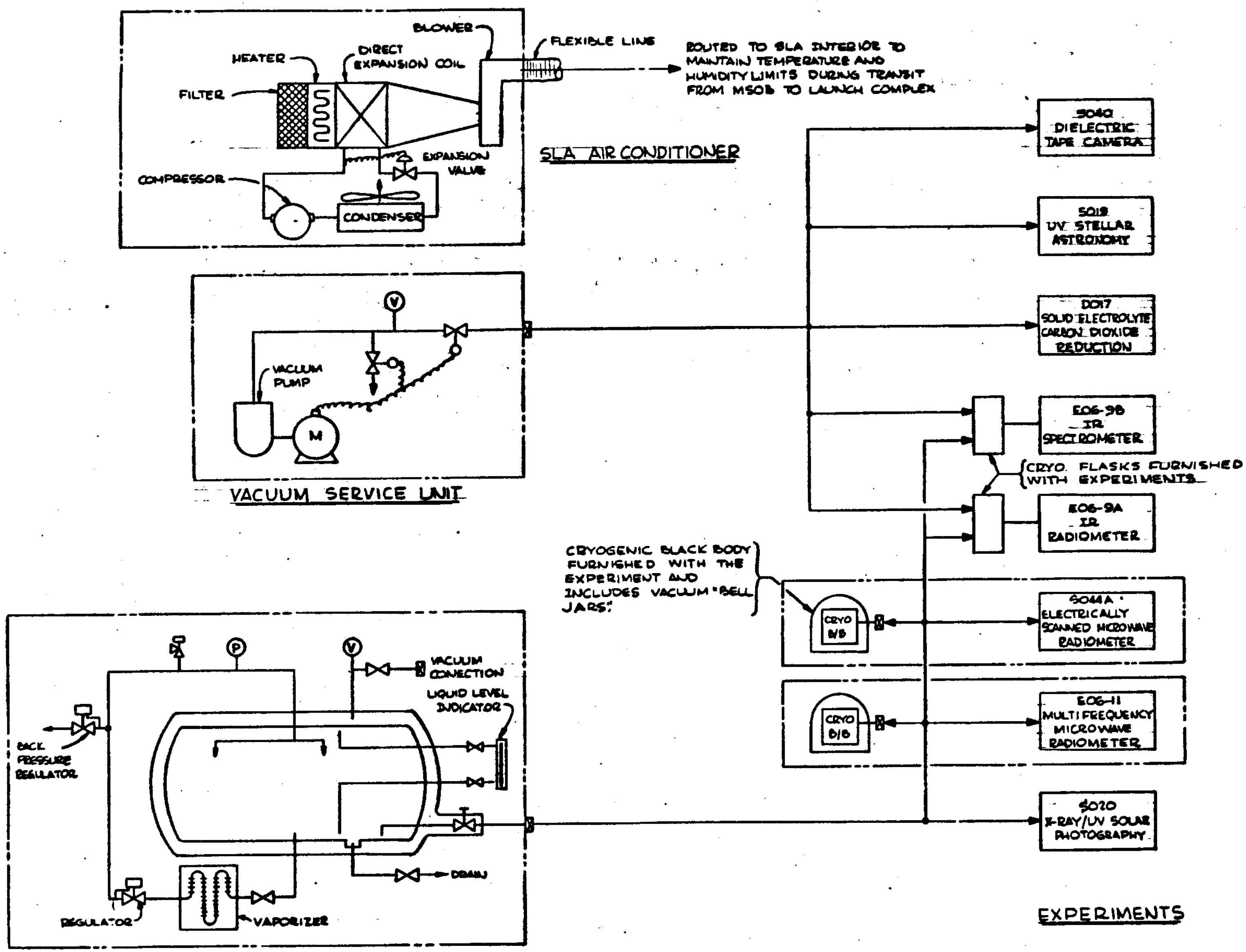

FIGURE 2 - FLUID SERVICING FOR EXPERIMENTS

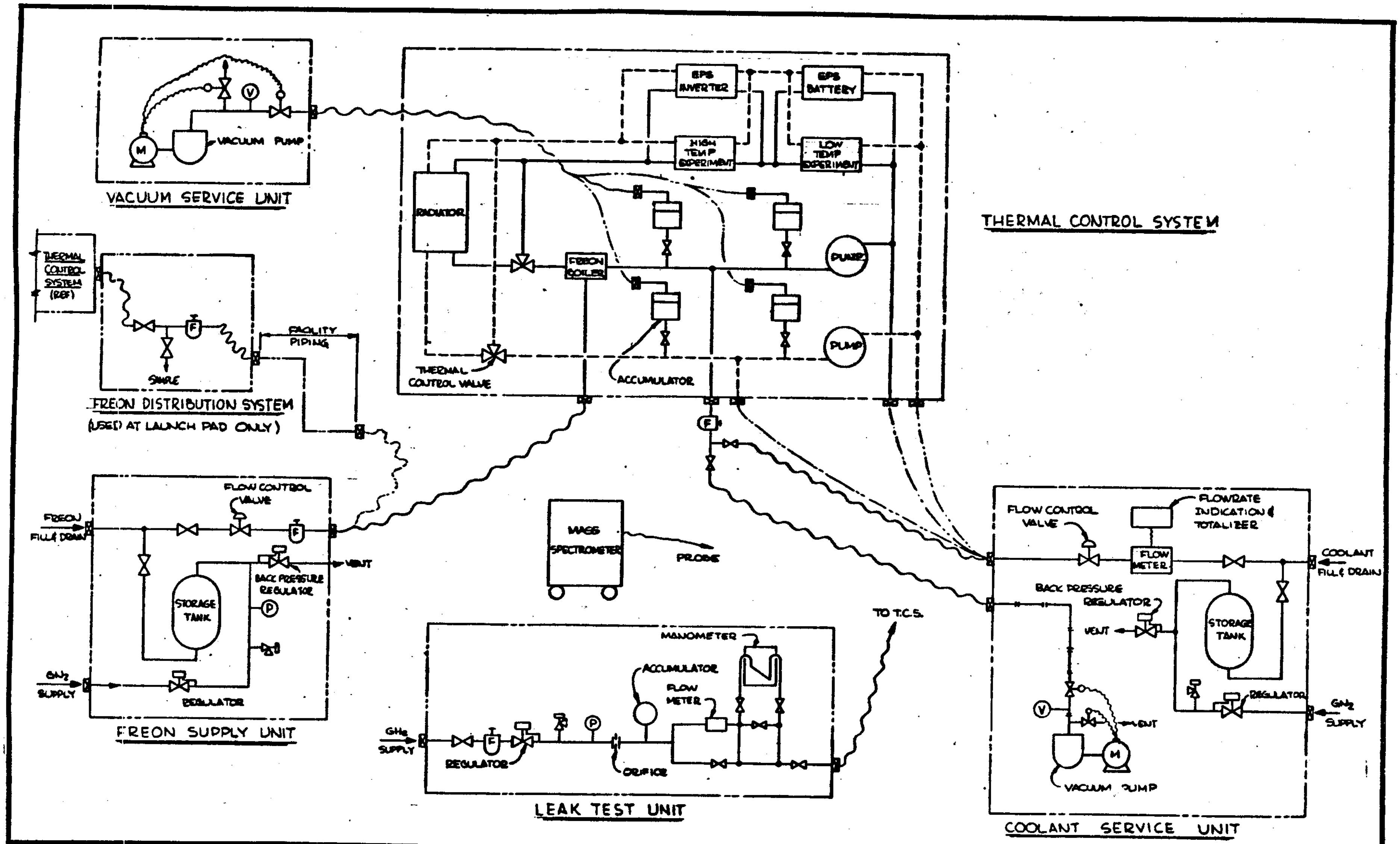

FIGURE 3 - FLUID SERVICING FOR THERMAL CONTROL SYSTEM

3.3.4 GSE Provisioning - (Continued)

b. There is a possibility that the Carrier will require an independent pressurization system. This would necessitate oxygen servicing equipment. A servicing unit would be supplied to regulate and distribute gaseous oxygen from the existing KSC oxygen system. No problem would be expected here.

c. There is a possibility of adding a heat exchanger to the TCS that would require chilled water from a ground source. Both Martin-Marietta and North American Aviation have designed water chillers and trim control units; therefore, this kind of equipment, if not available as GFE, could be readily designed and fabricated.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 There are no insurmountable engineering or development problems in providing servicing GSE in accord with the proposed program schedule.

4.1.2 All servicing equipment required at Denver can also be used later at KSC.

4.1.3 It is expected that experiment and airborne subsystem servicing requirements will change as the program progresses. Changes that can be presently envisioned can be readily accommodated.

4.2 Recommendations

4.2.1 Investigate the availability of existing equipment for use on the 1A program. Some possibilities are:

a. Equipment presently on hand at Denver for other programs. An example is the 50-gallon liquid nitrogen mobile dewars used at the Cold Flow Laboratory. These could be available when needed.

4.2.1 (Continued)

b. Existing Apollo GSE at KSC that could be shared with other programs or that might not be required for programs concurrent with the IA program.

c. Existing Apollo GSE available at other locations such as the Downey warehouse of North American Aviation.