~~G.M ANDERSON~~

VOLUME 6
SUPPORTING STUDIES

EARLY LUNAR SHELTER DESIGN AND COMPARISON STUDY

BOOK 1 STRUCTURAL DESIGN AND LM/T INTEGRATION

BOOK 2 REVIEW OF SCIENTIFIC MISSION REQUIREMENTS

BOOK 3 HASSLE ANALYSIS OF PROPOSED SCHEDULE

FINAL REPORT

CONTRACT NUMBER
NAS 8-20261

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

GARRETT
AIRESEARCH
MANUFACTURING DIVISION
LOS ANGELES 9, CALIFORNIA

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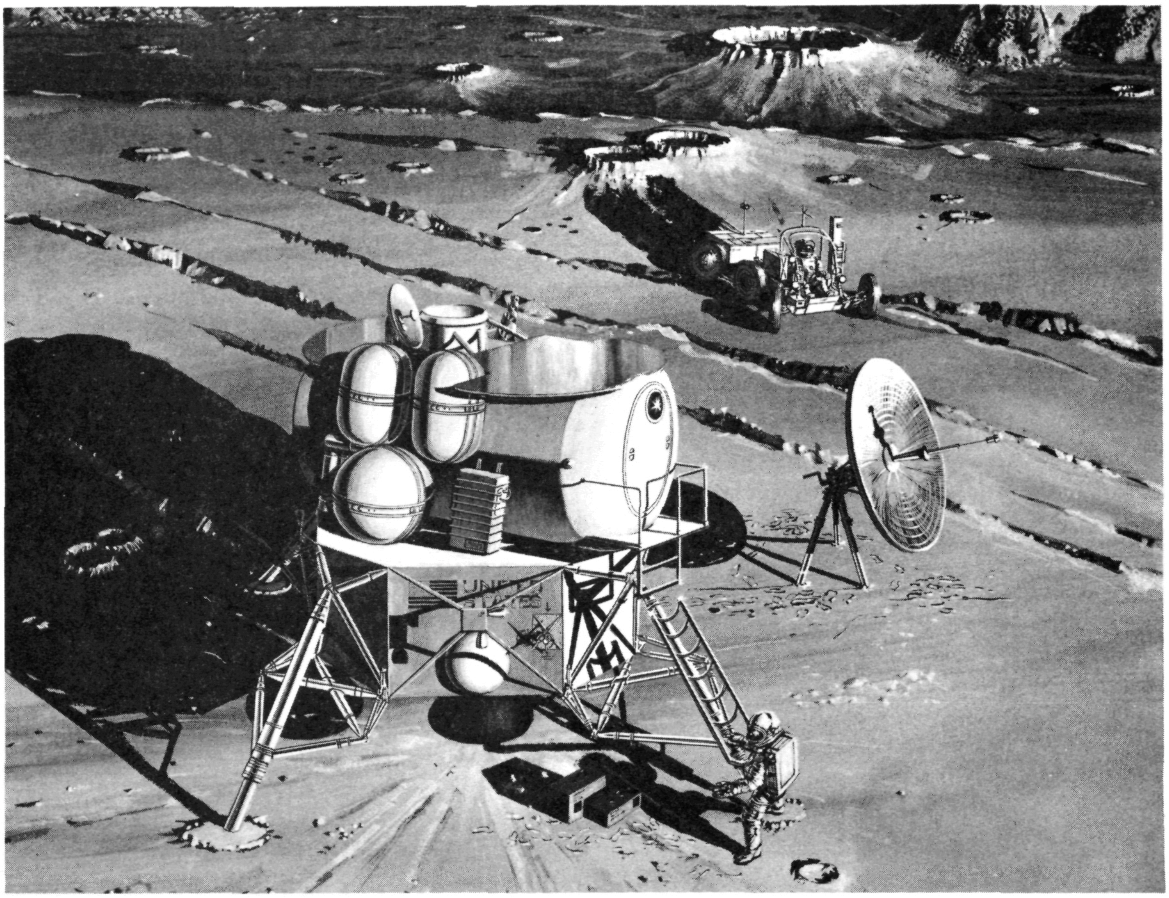

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FOREWORD

This report was prepared by personnel of the AiResearch Manufacturing Company, Los Angeles, California, under Contract NAS8-20261, "Early Lunar Shelter Design and Comparison Study." The program was monitored by W. D. Powers of the NASA George C. Marshall Space Flight Center, Huntsville, Alabama. W. L. Burriss, N. E. Wood, and M. L. Hamilton were principal authors of this report at AiResearch. This final report consists of the following volumes:

Volume 1 - Summary

Volume 2 - Mission Timelines and Requirements

Volume 3 - Subsystem Studies

Volume 4 - System Integration and Configuration Design

Volume 5 - Resource Plans

Volume 6 - Supporting Studies

Honeywell, Incorporated, and Grumman Aircraft Engineering Corporation were subcontractors in the study. Grumman was responsible for structural design and LM/T integration. Honeywell assisted in the analysis of crew tasks and performance. The subcontractor studies are contained in Volume 6.

PREFACE TO VOLUME 6

The supporting studies contained in Volume 6 are divided into three books, as follows:

Book 1	Structural Design and LM/T Integration
Book 2	Review of Scientific Mission Requirements
Book 3	HASSLE Analysis of Proposed Schedule

Book 1 contains a portion of the work performed by the Grumman Aircraft Engineering Company under this contract. Other parts of the Grumman work are integrated into other volumes of the report. In addition to the work appearing here, Grumman furnished detailed performance and cost data concerning the Apollo Lunar Module (LM) subsystems and components applicable to the ELS. These data were used by AiResearch in the subsystem and resources planning studies. M. G. Grubelich was Grumman Principal Investigator for this study.

Books 2 and 3 were prepared by Honeywell, Incorporated under this program. Honeywell personnel participating in these studies include L. P. Schrenk, R. D. Kinkead, J. E. Haaland, O. H. Lindquist, and D. S. Hanson.

BOOK 1
STRUCTURAL DESIGN AND LM/T INTEGRATION

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SECTION I

INTRODUCTION

This is the final report of Grumman's participation in the Early Lunar Shelter Design and Comparison Study, NAS 8-20261. The work was performed under a 10-month subcontract to the AiResearch Manufacturing Company, Purchase Order No. 218-70525-6. The objective of the study was to develop, define, and evaluate conceptual designs of lunar shelters, for application in the early 1970's, which can, after 6 months of unattended storage, sustain a 2-man crew for at least 14 days. The shelter and required support equipment must be deliverable to the lunar surface by an unmanned Lunar Module/Truck (LM/Truck) using the Saturn V-Apollo system.

Grumman's primary responsibilities were the evolution of shelter payload configurations, preliminary structural sizing, micrometeoroid and radiation protection analyses, and integration of the shelter payload with the LM-Truck.

Additional responsibilities included providing design and operating characteristics and procurement costs pertinent to the electrical power, environmental control, and astrionics (communications, mission programmer, and instrumentation) subsystems of the Lunar Module (LM) to AiResearch.

The basis for Grumman's work is specified in the following:

a. Garrett Corporation, AiResearch Manufacturing Company Document 66-0232, Rev. 2, May 9, 1966 - Statement of Work for Grumman Aircraft Engineering Corporation

b. NASA Study Guidelines-Design Criteria and Reference Data Handbook for Lunar Exploration Systems

    Volume I: General Criteria
    Volume II: LM/Truck Shelter Payloads

c. NASA Document - Statement of Work, Early Lunar Shelter Design and Comparison Study, P-163, July 1965

SECTION 2

SUMMARY

The shelter payload configuration studies by Grumman are documented in the body of this report. The supporting tasks performed by Grumman, such as LM subsystem data/descriptions and review of study guidelines are given in the Appendixes to this report.

A series of shelter concepts and the corresponding outboard and inboard profiles of overall shelter payloads were generated to ascertain the upper range of shelter volumes attainable consistent with the weights, volumes, and form factors of scientific equipment, reactant tankage, subsystem equipment, etc., for a 2- to 3-man multiweek staytime mission.

Preliminary results showed that about 550 to 600 cu ft was attainable for shelters having simple geometric pressure shell forms: right circular cylinders and spherical sectors.

Further iterations of the conceptual designs were performed to accommodate changes in equipment and expendable volumes and to satisfy a shelter volume goal of about 700 cu ft.

The resulting final series of shelter configurations were compared, and two candidate configurations were selected: a vertical cylinder and a horizontal cylinder.

In addition to further development of the outboard profiles used in selecting the candidate shelter configurations, inboard profiles, and structural arrangements of the overall shelter payload for each candidate configuration were developed to allow a more comprehensive comparison between vertical and horizontal cylinder shelters.

The horizontal cylinder shelter was selected as the recommended configuration because it more readily satisfies the functional form factors associated with required crew activities and equipment placement, provides greater shelter volume at less weight, and is simpler to fabricate.

As illustrated in Figure 2-1, it consists of an 8.1-ft-dia horizontal cylinder with 7-ft radius spherical sector end domes; it has an overall length of 16 ft and a gross internal volume of approximately 750 cu ft. It would be fabricated primarily from 2219 - T87 aluminum alloy and would have a structural weight of approximately 750 lb.

The shelter has a 2-man air lock, internal arrangements for a 3-man crew, and satisfies the requirements of a mission duration of 6 months quiescent storage and 50-day staytime.

Concomitant with the conceptual design of the shelter, radiation and micrometeoroid protection analyses were performed, and the required protection

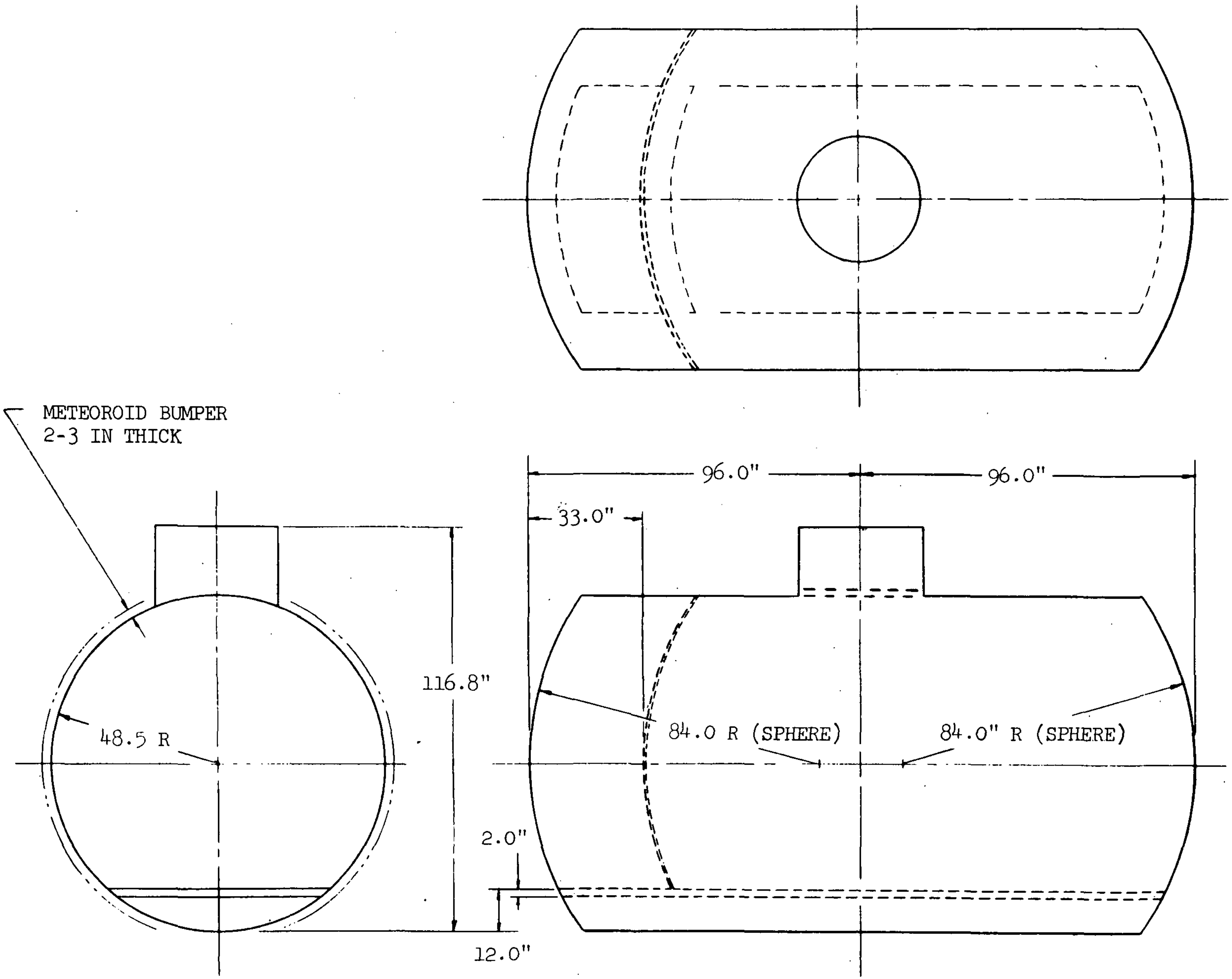

Figure 2-1. Early Lunar Shelter (ELS) Recommended Configuration

provisions were integrated into the shelter payload configuration. The radiation protection is afforded by internally stored equipment and supplies supplemented by polyethylene water blankets. Micrometeoroid protection is achieved by a bumper and backup sheet with a layer of foam in the spacing between them.

Deployment techniques and devices to bring the shelter payload from an "as landed" condition to operational status were also studied.

The preferred approach is to leave the shelter payload on the LM/Truck, level the LM/Truck, employ two devices for equipment unloading (jib boom and cable arrangement for scientific equipment packages, pivoting A-frame and cable arrangement for the Local Scientific Survey Module (LSSM)), and use a separate ladder and platform at the air lock door for routine access between the shelter and lunar surface.

This approach results in minimum overall weight penalty, minimum complexity of deployment devices, and minimum surface activities to attain shelter payload operational status.

The total weight of the shelter (including structural supports for all internal and external equipment, deployment devices, thermal insulation, radiation and micrometeoroid protection) is approximately 1600 lb.

SECTION 3

SHELTER CONSTRAINTS AND REQUIREMENTS

The NASA study guidelines (Reference 1) and statement of work (Reference 2) provided the initial definition of constraints and requirements. The generation of initial shelter concepts and the preliminary results of subsystem studies led to concurrence/direction by AiResearch to utilize the following ground rules for continued evolution of shelter configurations:

- LM/Truck payload volume and center of gravity (cg) envelope as shown in Figure 3-1
- 6-month quiescent storage mode
- 14- to 50-day staytime
- Consumable weights and volumes for a two-man, 50-day staytime as given in Table 3-1
- Habitable volume, equipment, and nonconsumable provisions for a 3-man crew
- 2-man air lock having 80 cu ft free volume
- 0.997-percent probability of no meteoroid puncture
- 0.99-percent probability of not exceeding 500 rad to the skin or 200 rad to the blood-forming organs (BFO)
- 15 deg horizontal attitude correction capability from an "as landed" maximum of 18 deg
- LM/Truck flight and landing loads as discussed in Section 4 under the heading STRUCTURAL CRITERIA AND LOADS
- Scientific equipment, as shown in Table 3-2, to be carried as part of the shelter payload

The LM/Truck is a Lunar Module (LM) descent stage modified by the addition of the reaction control, communications, guidance, and navigation equipment (normally carried in the LM ascent stage) to allow an unmanned landing of the Truck. It will be delivered to lunar orbit by a manned Apollo Command Module and Service Module (CSM). The CSM will transpose and dock to the LM/Truck after translunar injection in the same manner as for the LM. This will require a docking ring and drogue, on the top of the LM/Truck payload, identical to those located on top of the LM ascent stage. Following separation from the CSM, the Truck payload descends automatically to the surface along a flight profile similar to that followed by an LM.

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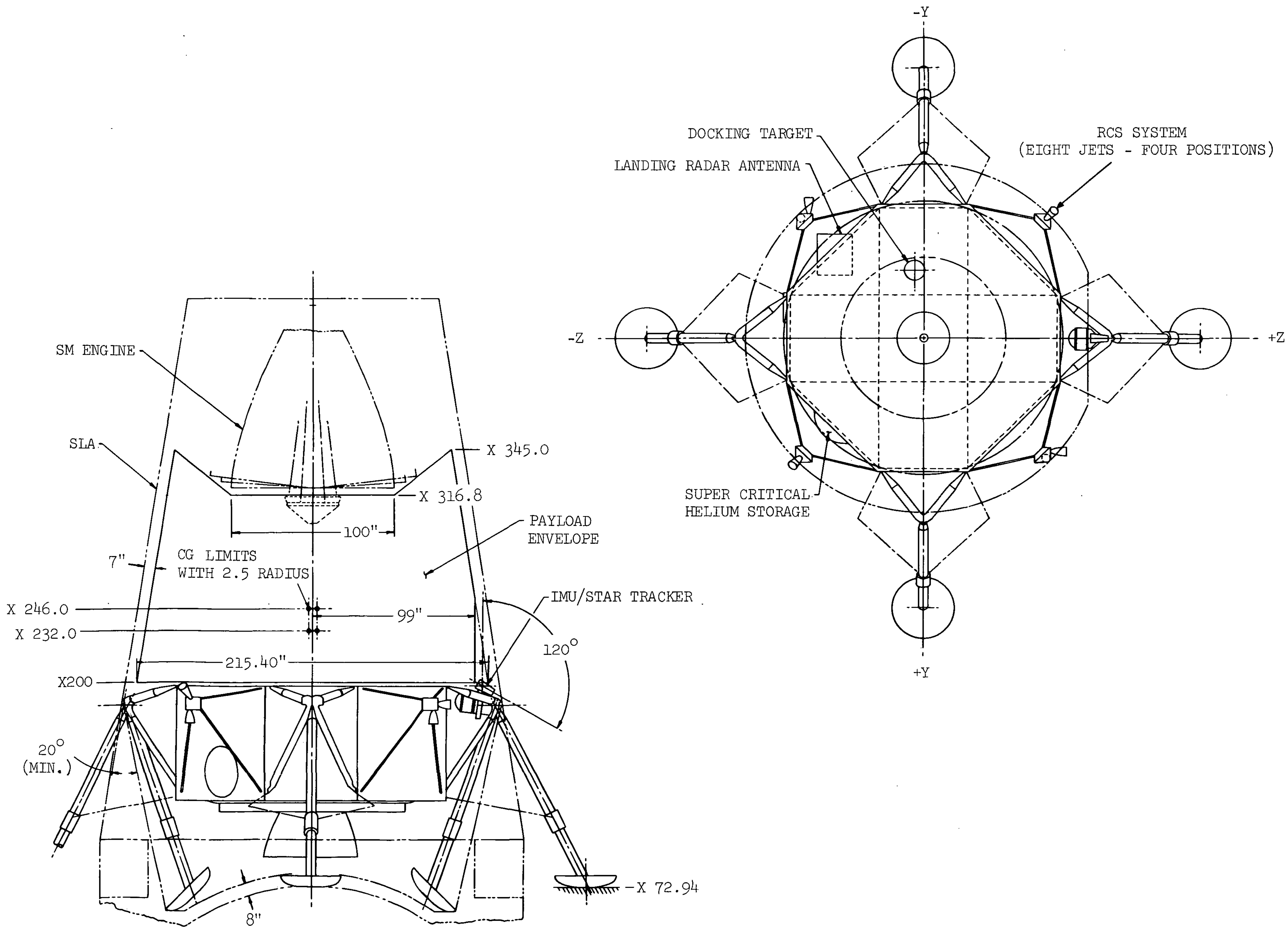

Figure 3-1. LM Truck Volume and CG Envelope

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TABLE 3-1

CONSUMABLES (FOR 2-MAN - 50 DAY STAY TIME)

EQUIPMENT	DIMENSIONS CM		(IN)	VOLUME CM^3	(FT^3)	MASS KG		(LBM)	COMMENTS
150 LiOH Cartridges	15.2 DIA x 30.5	*	(6x12)	834,000	(29.4)	272		(600)	Nominal dimensions per cartridge
Food		*		226,500	(8)	75.4		(166)	No individual packages dimensions given
H_2	109x140	*	(43x55)	1,940,000	(68.2)	209		(460)	Dimensions per H_2 tank, 2 tanks required, dimensions exclusive of 5 cm high x 7.6 cm wide (2x3) girth rings. Mass of H_2 per tank = 31.8 kg (70)
O_2	132 DIA SPHERE		(52)	1,205,000	(42.6)	715		(1575)	Dimensions exclusive of 5 cm high x 7.6 cm wide (2x3) girth rings. Mass of O_2 = 636 kg (1400)
H_2O		*		*			*		Potable H_2O initial fill 27.3 kg (60) at beginning of stay time 72.6 kg (160) available. (Maximum waste tankage capacity 236 kg (520))
Crew Hygenic Supplies, Disposable Garments, etc.		*		133,000 *	(4.7)	21.3	*	(47)	As shown in Table 4-2 Internal Equipment

TABLE 3-2

SCIENTIFIC EQUIPMENT

EQUIPMENT	DIMENSIONS CM	(IN)	VOLUME CM^3	(FT^3)	MASS KG	LBM
Theodolite and Ranging Laser	2 -30x13x45 2 -30x30x25	(11.8x5.2x17.8) (11.8x11.8x9.9)	35,100 45,000	1.24 1.59	45.4	100
Surveying Markers	12.5x10x180 30x38.5x60	(5x4x71) (11.8x15.2x23.6)	22,500 69,300	.795 2.45	9.1	20
Sketch Board & Maps	45x45x5	(17.8x17.8x2)	10,125	.358	2.3	5
Multiboard Photography & Radiometry	78x38x51	(30.8x15x20.1)	151,000	.534	39	86
Gravimeter	11x22x15	(4.4x8.7x5.9)	3,630	.128	5.9	13
Magnetometer	15 DIA SPHERE 10x10x20	(5.9) (4x4x7.9)	1,760 2,000	.062 .071	4	9
Nuclear Measurements Package	5DIA x 85 25x20x20	(2x33.5) (9.9x7.9x7.9)	1,670 10,000	.059 .353	15.6	34
Sample Containers & Hand Tools	22x30x60.5	(8.7x11.8x23.8)	40,000	1.415	12.5	27
Surveying Staff & Extra Battery	10x15x140 10x12.5x18	(4x8.7x55.1) (4x5x7.1)	21,000 2,250	.742 .079	13 5.9	29 13
Data Handling & Interface	22x30x60.5	(8.7x11.8x23.8)	40,000	1.415	30	66
Shelter Geology	30x15x20	(11.8x5.9x7.9)	9,000	.318	8	18
Astronomy Experiments	22x30x45	(8.7x11.8x17.8)	29,700	1.05	22.1	48.5
Seismic Deep Defractor	60x60x84	(23.6x23.6x33.1)	302,400	10.68	204	450
Gas Analyzer	12x10x76	(4.8x4x30)	9,120	.322	4.5	10
Penetrometer	26x15x18	(10.3x5.9x7.1)	7,560	.268	2.7	6
Surface Electrical Package	5 DIA x 25	(2x9.9)	810	.003	1.5	3.3
Radiometry Package	10.2x12.7x25.4	(4x5x10)	3,290	.116	4	9
10 Foot Drill	10.2x10.2x330	(4x4x130)	34,300	1.215	13.6	30
Sonic Velocity Logging	5 DIA x 91 10 DIA x 6.6 18x6x6.6	(2x35.9) (4x2.6) (7.1x2.4x2.6)	1,790 518 712	.063 .018 .025	4.9	10.8
Electrical Induction Logging	2.3 DIA x 20 20x20x12.5	(.9x7.9) (7.9x7.9x5)	83 5,000	.003 .177	2.3	5
100 Foot Drill	15.25 DIA x 30.5 30.5x91.5x106.6 22.8x76.1x366*	(6x12) (12x36x42) (9x30x144)	5,560 298,000 635,000	.197 10.51 22.45	12.25 5.45 68.0	27 12 150
Telluric Current	3- 1 DIA x 100 36x36x36	(.4x39.4) (14.2x14.2x14.2)	236 46,600	.008 1.646	14	31
Erosion Samples	36x30x15	(14.2x11.8x5.9)	13,500	.476	4.5	10
Environment Exposure Panel	35x35x1.5	(13.8x13.8x.6)	1,837	.065	1	2.2
Meteoroid Ejecta	4x4x1	(1.6x1.6x.4)	16	0	.5	1.1
Tissue Equivalent Ion Chamber	5x5x20	(2x2x7.9)	500	.018	2.3	5
Emplaced Scientific Station	45x60x120 60x60x60 60 DIA x 60	(17.8x23.6x47.3) (23.6x23.6x23.6) (23.6x23.6)	322,000 216,000 170,000	11.380 7.625 6.00	63 100 25	139 220 55
Satellite ESS	3-23.1x34.6x46.2	(9.1x13.7x18.2)	111,000	3.92	102.3	225

*Dimensions of drill rod extensions specified by AiResearch; may be changed to a minimum of 72" with commensurate width and/or depth changes or multiple packages.

The payload volume envelope shown in Figure 3-1 differs in several details and contains additional constraining dimensions as compared to that shown in the study guidelines; the envelope is the same as that defined for the Apollo Extension System studies (precursor to AAP). The 5-in. clearance between the spacecraft LM adapter (SLA) and the payload envelope was increased to 7 in., and the upper surface of the volume contoured to accommodate a 7 deg gimbaling excursion of the Service Module engine nozzle during on-pad checkout.

The resulting primary envelope is a truncated cone of approximately 2050 cu ft with a base dia of 18 ft, upper dia of 15 ft and a height of 9.7 ft. To accommodate the solid angle requirement of the inertial measuring unit (IMU) and automatic star tracker mounted on the top of the +Z landing gear truss, the conical surface of the payload envelope at this location is interrupted to form a flat plane surface. The volume of the triangular cross section annulus above the truncated cone is approximately 150 cu ft, but its configuration severely limits the usefulness of this volume to accommodation of small antennas or local protuberances of equipment from the primary envelope. In the vicinity of the S IV B adapter section of the SLA a 20 deg extraction angle, relative to the SLA, defines the clearance constraint for any equipment mounted on the LM/Truck faces. Also, and 8-in. clearance above the S IV B dome was used as the limit for equipment mounted below the Truck main structure.

Use of the volumes below station X-200 is limited due to the small, odd-shaped envelopes, close priximity to the reaction control system (RCS) units, and the desirability of minimizing the number of structural interfaces with the Truck.

The maximum payload capability is 10,300 lbm, and its cg must be within the envelope defined by a 2.5-in. radius about the vehicle's vertical (X) axis and stations X232 to 246.

The primary structure of the LM/Truck consists of two sets of parallel main beams (the two beams of each set are on 54-in. centerlines, and each is approximately 64 in. deep) arranged as a cruciform and interconnected by diagonal members. A tubular truss structure at each end of the cruciform transfers the Truck loads to the SLA. These cruciform beams are used to support the shelter payload.

The 6-month maximum unattended storage is a design specification of the study statement of work (Reference 2) for meteoroid shielding, cryogenic boiloff and other time-related factors.

Results of initial subsystem studies defining weights, volumes, and consumable rates were the basis for considering staytimes of 14 to 50 days.

The tabulation of consumable weights and volumes shown in Table 3-1 is the final iteration in support of a 2-man crew, 50-day staytime. However, to facilitate subsequent considerations of growth potential or operational flexibility (without major reconfiguration of the shelters), shelter volumes, internal arrangements, and accoutrements were based on a 3-man crew.

The crew safety considerations implicit with having an air lock which could accommodate the ingress/egress operations of 2 men simultaneously far outweighed the minor reduction in work/living volume in the shelter as a result of the 2-man air lock.

The 0.997-percent probability of no meteoroid puncture of the shelter during the storage and operational phases was assigned to satisfy the overall probability requirement of 0.99. The protection analysis was based on the AAP meteoroid criteria.

The 0.99-percent probability of not exceeding 500 rad-skin or 200 rad-BFO as specified by the study statement of work was considered as an upper bound, the requirements for lesser exposures and higher probabilities were also examined. The protection analysis was based on the solar flare data provided in NASA TN D-2746 (Reference 3).

The 18 deg maximum slope of the Truck horizontal plane relative to the local horizontal is specified by the study guidelines, the 15 deg correction capability was specified by AiResearch.

The LM/Truck flight and landing loads discussed in Section 4, STRUCTURAL CRITERIA AND LOADS are revised versions of those shown in the study guidelines to include the loads used in the AAP study program.

The scientific equipment summary shown in Table 3-2 is the final iteration derived from NASA-approved revisions to the equipment volumes and weights given in the study guidelines. The influence of various equipment envelopes on the shelter configuration development is discussed later in this report.

The storage mode configuration, weight, and pertinent data for integrating the LSSM into the shelter payload are shown in Figure 3-2. Although the study guidelines also specified that a lunar flight vehicle (LFV) would be used on some missions, at NASA direction, this requirement was later dropped. The LSSM was considered in the development of the shelter outboard profiles since it occupies about 4 times the volume of the LFV and has a more difficult form factor to accommodate in the payload envelope. Consequently, if desired, the LFV could be substituted for the LSSM at a later date.

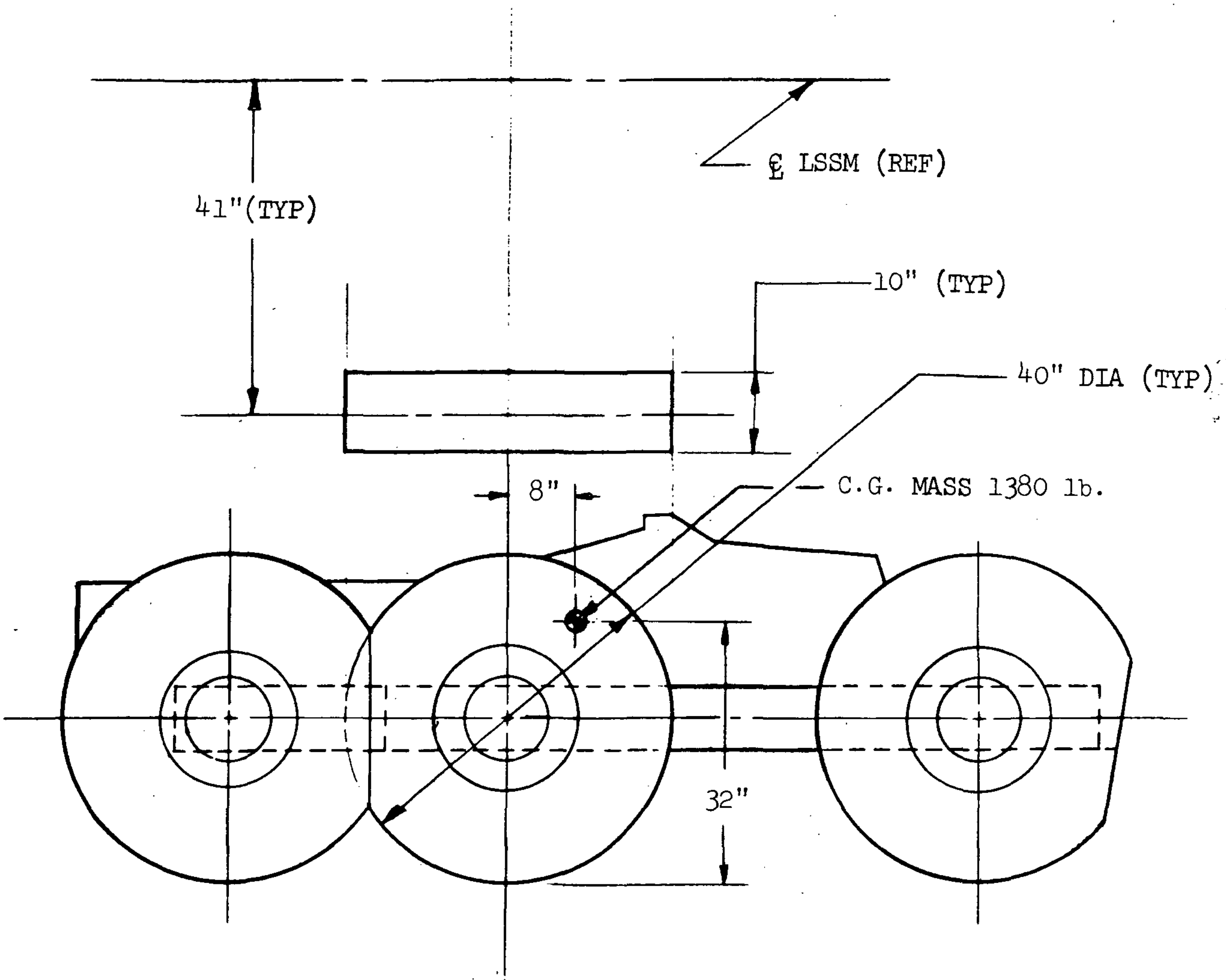


Figure 3-2. LSSM Storage Mode Configuration

SECTION 4

SHELTER CONCEPTUAL DESIGN

GENERAL

The conceptual design of the shelter and overall payload arrangement was an iterative process guided by the volume - weight interactions of the following overall mission/system constraints and requirements:

- LM/Truck payload envelope
- Scientific equipment and the LSSM
- Multi-man crew habitability for staytimes greater than 14 days
- Expendables and equipment to sustain the shelter operation and mission activities

The conceptual design was initiated by determining the volume available for the shelter after accommodating other components of the payload within the 2050 cu ft primary envelope. The volumes and dimensions for all externally located equipment as specified in the initial phase of this study are shown in Table 4-1. Considering the form factors of the equipment and that the necessity for maintaining a cg position precluded locating them as a single group, approximately 750 cu ft is required for integrating this equipment into the payload. Structure to carry the equipment loads to the LM/Truck cruciform beams and the docking ring with its supporting structure, to perform the same function as on LM, required a volume allocation of about 100 to 200 cu ft. The total volume required for the equipment, the docking ring and support structures amounted to 850 to 950 cu ft, leaving approximately 1100 to 1200 cu ft for the shelter.

Initial configurations resulting from the use of combination of simple geometric pressure shell shapes (circular arc and spherical sectors) had form factors which caused a further reduction in attainable shelter internal volumes to a range of about 600 to 800 cu ft; a volume of 70 to 100 cu ft was allocated to provide for micrometeoroid shielding based on using a bumper-backup sheet spacing of 2 to 3 in. over a surface area of 400 cu ft.

The utilization of volume within the shelter was also examined at this point. The volumes and dimensions of internally located equipment (ECS unit, hard suits, bunks, food, etc.) as specified in the initial phase of this study are shown in Table 4-2 and account for about 250 ct ft. The resulting ratio of free volume to total shelter volume is about 0.6 to 0.7 which compares quite well with the results of previous studies.

Although the volumes and form factors of these initial configurations appeared adequate for satisfying the crew habitability and mission requirements, a primary consideration during the initial phase of the study was to provide overall shelter payload arrangements which were amenable to variations in mission requirements or constraints as defined by:

TABLE 4-1

EXTERNAL EQUIPMENT (INITIAL PHASE OF STUDY)

EQUIPMENT	DIMENSIONS CM	(IN)	VOLUME CM^3	(FT^3)	MASS KG	(LBM)	*COMMENTS
H_2 Tank	167 DIA SPHERE*	(59)	1,762,000	(62.2)	222	(490)	Tank configurations, volumes and masses changed for later phases of study as described in sections 4.2.1.1, 4.2.1.2 and 4.7.1.1
O_2 Tank	142 DIA SPHERE*	(56)	1,505,000	(53.1)	750	(1650)	
Fuel Cell Assembly FCA Collector Tank	30.5 DIA x 96.5 30.5 DIA x 46	(12x38) (12x18)	289,500 * 25,500	(10.2) (.9)	149 * .9	(328) (2)	Volume allocation for 3 FCAs, but mass allocation for only two as specified by AiResearch
FCA Radiator	*		127,400	(4.5)	24.5	(54)	Area of 27 ft^2 and 2" nominal thickness specified**
ECS Radiator	*		340,000	(12)	63.5	(140)	Area of 72 ft^2 and 2" nominal thickness specified**
Power Conversion	30.5x61x76.5	(12x24x30)	141,800	(5)	90.8 *	(200)	Mass reduced to 25.2 kg (100) for later phases of study
Electronic Conversion	61x91.5x91.5	(24x36x36)	510,000	(18)	100	(450)	Dimensions and mass reduced to 30.5x38.1x61 (12x15x24) and 45.4 kg (100) for later phases of study
LSSM	(See figure 3-2)		(See figure 3-2)		445 *	(980)	Configuration remained unchanged but mass increased to 626 kg (1380) for later phases of study
H_2O Waste Tank	76.4 DIA SPHERE	(30.1)	235,000	(8.3)	6.8 *	(15)	Empty tank weight } For later phases of study, integrated into bunks, floor tanks and ECS internal unit
ECS Condensate Tank	47.7 DIA SPHERE	(18.8)	56,600	(2)	1.4 *	(3)	Empty tank weight
ECS Potable H_2O Tank	70.6 DIA SPHERE	(27.8)	184,000	(6.5)	4.5 *	(10)	Empty tank weight
Theodolite and Ranging Laser	*		*		*		As listed in Table 3-2, only set stored externally
Surveying Marker	*		*		*		As listed in Table 3-2
Sketch Board & Maps	*		*		*		As listed in Table 3-2
Multiband Photography & Radiometry	*		*		*		As listed in Table 3-2
Gravimeter	*		*		*		As listed in Table 3-2
Magnetometer	*		*		*		As listed in Table 3-2
Nuclear Measurements Package	*		*		*		As listed in Table 3-2
Sample Containers & Hand Tools	*		*		*		As listed in Table 3-2
Surveying Staff & Extra Battery	*		*		*		As listed in Table 3-2
Astronomy Experiments	*		*		*		As listed in Table 3-2
Seismic Deep Refractors	*		*		90 *	(198)	Mass increased to 204 kg (450) for later phases of study dimensions and volume same as in Table 3-2
Penetrometer	*		*		*		As listed in Table 3-2
Surface Electrical Package	*		*		*		As listed in Table 3-2
Radiometry Package	*		*		*		As listed in Table 3-2
10 Foot Drill	*		*		*		As listed in Table 3-2
Sonic Velocity Logging	*		*		*		As listed in Table 3-2
Electrical Induction Logging	*		*		*		As listed in Table 3-2
100 Foot Drill	66x46x366 66 DIA x 335 107x30x91 76x46x25	(26x18x144) (26x132) (42x12x36) (30x18x10)	1,110,000 1,148,000 292,000 87,500	(39.2) (40.6) (10.3) (3.1)	91	(200)	For later phases of study 66 dia x 335 package eliminated and dimensions and volumes changed as shown in Table 3-2
Telluric Current	*		*		*		As listed in Table 3-2
Erosion Samples	*		*		*		As listed in Table 3-2
Environment Exposure Band	*		*		*		As listed in Table 3-2
Meteoroid Ejecta	*		*		*		As listed in Table 3-2
Tissue Equivalent Ion Chamber	*		*		*		As listed in Table 3-2
Emplaced Scientific Station	91.5 DIA x 76 51 DIA x 63.5	(36x30) (20.1x25)	499,000 129,500	(17.6) (4.7)	136	(300)	For later phases of study changed to 3 packages with increased total volume and mass, 708,000 cm^3 (25 ft^3) and 188 kg (404 lb) as listed in Table 3-2
Satellite ESS	Not Determined		Not Determined		65.6	(145)	For later phases of study 3 Satellite ESSs required, 34.1 kg (75 lbm) each and dimensions as listed in Table 3-2

**Areas changed and radiators integrated into one unit for later phases of study

TABLE 4-2

INTERNAL EQUIPMENT

EQUIPMENT	DIMENSIONS CM	(IN)	VOLUME CM³	(FT³)	MASS KG	(LBM)	QUANTITY	TOTAL VOLUME CM³	(FT³)	TOTAL MASS KG	(LBM)
Hard Suit	116.8x38.2x60.9	(46x15x24)	271,040	9.58	38.6	85.0	3	813,000	28.74	115.8	255.0
Soft Suit	22.8x68.6x178	(9x27x70)	279,000	9.85	29.5	65.0	3	835,000	29.50	88.5	195.0
Liquid Cooled Garment (LCG)	15.25x30.48x30.48	(6x12x12)	14,150	.5	1.95	4.3	3	42,500	1.5	5.85	12.9
Constant Wear Garments (CWG)	4.82x25.4x25.4	(1.95x10x10)	3,200	.113	.363	.8	48	153,000	5.4	17.42	38.4
Anti-Meteoroid/Thermal Garment	20.3x30.5x45.7	(8.0x12x18)	28,300	1.0	3.94	8.7	3	84,900	3.0	11.4	25.1
EVA Boots	16.5x30.5x35.6	(6.5x12x14)	18,900	.67	.566	1.25	3 Pairs	56,600	2.0	1.7	3.75
EVA Gloves	12.7 DIA x 27.9	(5 DIA x 11)	3,510	.124	.58	1.75	3 Pairs	10,530	.372	2.38	5.25
Intravehicle Slippers	7.6x15.3x30.5	(3x6x12)	3,520	.125	.09	.2	3 Pairs	10,560	.375	.273	.6
Suit Spare Parts & Repair Kits	12.7 DIA x 27.9	(5 DIA x 11)	3,600	.174	.453	1.0	3	14,800	.522	1.36	3.0
Tool Kits	24.1x36.8x36.8	(9.5x14.5x14.5)	32,800	1.16	17.2	38.0	1	32,800	1.16	17.2	38.0
Helmet	30.5x30.5x30.5	(12x12x12)	28,300	1.0	1.36	3.0	3	84,900	3.0	4.8	9.0
ECS Package	45.7x71x191	(18x28x75)	390,000	13.8	181.5	400.0	1	390,000	13.8	181.5	400.0
PLSS	26.7x45.7x68.5	(10.5x18x27)	84,700	3.0	29.5	65.0	6	510,000	18.0	177.0	390.0
LiOH	14 DIA x 27.9	(5.5 DIA x 11)	4,360	.151	1.8	4.0	150	642,000	22.65	270.0	600.0
PLSS Battery Charger	8.9x15.24x16.5	(3.5x6x6.5)	2,240	.079	1.8	4.0	1	2,240	.079	1.8	4.0
PLSS Batteries	8.6x12.7x14.2	(3.4x5x5.6)	1,550	.055	2.27	5.0	12	18,700	.66	27.2	60.0
PLSS Calibration Unit	2.54 DIA x 1.27	(1 DIA x .5)	14	.0005	.0286	.063	3	42	.0015	.0857	.189
Emergency Oxygen System	15.24 DIA x 7.6	(6 DIA x 3)	1,390	.049	1.5	3.3	3	4,160	.147	4.5	9.9
Umbilicals	6.35 DIA x 274.3	(2.5 DIA x 108)	8,500	.307	2.04	4.5	3	26,100	.921	6.12	13.5
o Medical Emergency Supplies	30.5x30.5x42.6	(12x12x16.8)	39,600	1.4	5.45	12.0	1	39,600	1.4	5.45	12.0
o Housekeeping Provision Package	20.3x20.3x15.8	(8x8x6.25)	11,300	.4	2.27	5.0	1	11,300	.4	2.27	5.0
o Personal Hygiene Facilities	22.8x22.8x26.7	(9x9x10.5)	14,150	.5	2.72	6.0	1	14,150	.5	2.72	6.0
o Personal Storage	22.8x22.8x26.7	(9x9x10.5)	14,150	.5	2.49	5.5	1	14,150	.5	2.49	5.5
o Laundry	32.5x45.7x45.7	(12.8x18x18)	68,000	2.4	10.9	24.0	1	68,000	2.4	10.9	24.0
Recreation Equipment	25.4x27.9x27.9	(10x11x11)	19,800	.7	3.68	8.0	1	19,800	.7	3.68	8.0
Exercising Equipment	10.2x10.2x12.7	(4x4x5)	1,300	.046	.9	2.0	1	1,300	.046	.9	2.0
Waste Management System	37.8x45.7x50	(14.9x18x20)	87,700	3.1	23.6	52.7	1	87,700	3.1	23.6	52.7
TV Camera	10.2x15.3x25.4	(4x6x10)	3,940	.139	3.4	7.5	1	3,940	.139	3.4	7.5
Movie Camera	7.6x12.7x12.3	(3x5x6)	1,470	.052	1.13	2.5	1	1,470	.052	1.13	2.5
Still Camera	21.6x21.6x25.4	(8.5x8.5x10)	11,300	.42	4.75	10.5	1	11,300	.42	4.75	10.5
Extra Film & Tape	15.3x17.8x20.3	(6x7x8)	5,510	.195	11.3	25.0	1	5,510	.195	11.3	25.0
Data Handling Interference Equipment	22x30x60.5	(8.7x11.8x23.8)	40,000	1.415	30.0	66.0	1	40,000	1.415	30.0	66.0
Theodolite and	30x13x45	(11.8x5.2x17.8)	35,100	1.24	22.7	50.0	1	35,100	1.24	22.7	50.0
Ranging Laser	30x30x25	(11.8x11.8x9.9)	45,000	1.59	22.7	50.0	1	45,000	1.59	22.7	50.0
Shelter Geology Equipment	30x15x20	(11.8x5.9x7.9)	9,000	.318	8.0	18.0	1	9,000	.318	8.0	18.0
Gas Analyzer	12x10x76	(4.8x4x30)	9,120	.322	4.5	10.0	1	9,120	.322	4.5	10.0
Radiation Dosimeter	2.54 DIA x 1.27	(1 DIA x .5)	14	.0005	.0286	.063	1	14	.0005	.0286	.063
Consoles: Equipment			835,000	29.4	65.57	145.00	1	835,000	29.4	65.57	145.0
Crew Provisions			564,000	19.9	47.6	105.0	1	564,000	19.9	47.6	105.0
Suit Checking Station	7.6x38x56	(3x15x22)	16,550	.585	2.72	6.0	1	16,550	.585	2.72	6.0
Tables: Work											
Eating & Recreation											
Seats	40.6 DIA x 15.3	(16 DIA x 6)	79,300	2.8	1.8	4.0	3	236,600	8.4	5.4	12.0
Bunk Beds	7.6x66x193	(3x26x76)	97,760	3.45	6.8	15.0	3	292,200	10.33	20.4	45.0
Lights: Portable	2.54x5x10.2	(1x2x4)	130	.0046	.9	.2	3	390	.0138	2.7	.6
Table	5 DIA x 1.9	(2 DIA x .75)	49	.00174	.9	.2	3	147	.00522	2.7	.6
Dome	7.6x2.54	(3 DIA x 1)	37	.0013	1.36	.3	3	110	.0039	4.08	.9
Food			226,200	8.00	75.2	166.0		226,200	8.00	75.2	166.0
Water Probe	1.6x7.6x10.2	(.625x3x4)	113	.004	.227	.5	1	113	.004	.227	.5
Hot Plate	25.4 DIA x 7.6	(10 DIA x 3)	3,850	.136	2.27	5.0	1	3,850	.136	2.27	5.0
Utensils	15.3x17.8x17.8	(6x7x7)	3,960	.14	2.27	5.0	1	3,960	.14	2.27	5.0
Dispenser	17.2x20.3x20.3	(6.8x8x8)	7,080	.25	2.27	5.0	1	7,080	.25	2.27	5.0

- A larger number of crewmen
- Increased staytime
- Changes in scientific payload complement
- Increased mobility

The capability of the ELS to accommodate larger crews is predominately based on the shelter volume available to satisfy the habitability and mission activities requirements of the crew. The most severe constraint on the attainable volume and resulting shelter form factors, for rigid structures, was the required integration of the LSSM or any other comparable size payload such as a lunar based astronomical observatory into the overall payload. Without this constraint, shelter volumes of approximately 1000 cu ft are possible in which the configuration is a vertical cylinder whose sides are tangent to the SLA, and which has a composite floor and supporting structure at least 30 in. deep similarly to that shown in Reference 4. The 1000 cu ft can provide the habitability needs of 4 to 6 men, the manned delivery compatability of two LM's. For this type configuration, the expendable tankage and associated equipment would be supported in the central part of the composite structure and the experiment packages supported in the annular volume about the equipment. The necessary compromise of limiting at least one dimension of the payload components, stored in this manner, to 30 in. was considered premature for early lunar shelters in which one logistics carrier provides both habitability and scientific mission equipment. However, it would be compatible with more ambitious activities using a separate logistic landing to supply the experiment payload as with the twin LM/Truck delivery system or a new large logistic vehicle (LLV).

Extensible and inflatable shelter structures were also considered for providing larger volumes to accommodate larger crews within the constraints of a single LM/Truck delivery.

The extensible shelter consists of concentric structurally rigid sections in which, for delivery to the lunar surface, the inner section is in a telescoped or retracted position within the main or outer section. _In situ_ extension of the inner section provides the additional volume for the larger crews. This concept is most suited to horizontal cylindrical shelter configurations and is discussed further in Section 6.

The investigation of using inflatables led to other considerations. The volumes, form factors, and preferred peripheral locations of shelter internal equipment require the retracted volume and, therefore, the exposed surface area of the inflatable to be a large fraction of its erected volume and surface. Therefore, from the viewpoint of reduced surface area exposed to the micrometeoroid environment during the quiescent period, one of the potential benefits of using inflatables is achieved only to a minor degree. The possibility of mitigating the above consideration by prearranging the equipment into a compact grouping or storing it externally to the contracted shelter was eliminated because the amount of _in situ_ crew activity to bring the shelter into operational status was considered too severe for an early lunar shelter. Docking ring and outboard equipment supporting structures necessary with an inflatable structure would impose larger weight and volume penalties than ones which are integrated into a shelter structure capable of taking concentrated loads. The primary advantages of inflatables are exhibited when the ratio of expanded volume to available storage volume is high, e.g., 5/1, and when wall weight is only a function of self supporting strength and internal pressure can be used to maintain the expanded configuration. Neither of these conditions exist in this study. Considering that the requirements for as many as 6 crewmen can be satisfied with a 1000 cu ft shelter, the ratio of available to expanded volume would be only about 1.5. Also the wall weight to satisfy micrometeoroid protection requirements exceeds the requirements to make it self supporting without relying on internal pressurization.

Based on the preceding considerations and the fact that volumes attainable with rigid shelters appeared suitable for 3-man crews, or up to 6-man crews with a rigid extensible section, the investigation of inflatables for the shelter was discontinued.

The applicability of inflatable or deployable air locks in conjunction with a rigid shelter structure was similarly reviewed and, based on the minimal volume gains (internal and external) compared to the attendant decrease in reliability and increase in operational complexity, they were eliminated for use in an early lunar shelter.

However, the use of inflatables to satisfy emergency or temporary habitability requirements in conjunction with the shelter payload does appear attractive as illustrated by the following description of the physical characteristics of an inflatable studied by Goodyear Aerospace Corporation in connection with increasing the habitability of the LM vehicle (Reference 5).

The inflated configuration consists of a 400 cu ft cylindrical section approximately 7 ft dia by 13 ft long and a 100 cu ft air lock section approximately 7 ft dia by 4 ft long; the two sections are connected by the inboard air lock door frame edge member. The weights of the cylindrical and air lock sections are 220 lb and 100 lb respectively. The corresponding unit structural weight is approximately 0.7 lb/sq ft for the pressure structure, internal pressure bladder, 2 in. compressible foam micrometeoroid barrier and an outer cover for the thermal coating. A full scale functional model was packaged into a 5 by 2 by 6 ft envelope; this size package could be stored in the space occupied by the LSSM or with minor repackaging could be stored in the shelter and removed upon shelter activation.

Increased staytime is primarily equatable to increased expendable requirements. An exoskeletal structural support approach for the expendable tankage and LSSM makes the substitution of tankage for the LSSM a comparatively minor modification with little influence on the shelter configuration or its primary structural arrangement. This structural approach also allows considerable flexibility to accommodate changes in sizes and shapes of the scientific equipment payload complement with minor influence on the shelter.

For continuous or intermittent occupancy of the ELS for periods as long as one year by sequenced crews, expendables could be supplied by a transfer operation from a separate logistics payload with the aid of a mobility system. This concept is currently under study for the AAP in which the Augmented LM is supplied by a logistic unmanned version of LM, called the Lunar Payload Module, carrying expendables and scientific payload.

If the shelter remains fixed at its landed site, the area of examination is limited by the range of the LSSM. A shelter which is transportable on the lunar surface would allow a series of sites to be examined or reduce the LSSM-Shelter travel time for a particular site of interest which did not coincide with the landed site.

To satisfy this mode of surface operation the shelter can be made as a powered trailer using the LSSM to guide it to particular sites. This concept is discussed further in Section 6.

During the development of the shelter configurations and the subsequent conceptual design, several previous studies of fixed and mobile shelters for extended durations were reviewed (References 4 through 7) to ascertain the applicability of their results to this study. It was found that the requirements and constraints of these preceding studies were sufficiently different from those of the current study to preclude any gross applicability of their results as solutions to the problems of this study. However, discrete aspects such as those pertaining to crew habitability, micrometeoroid protection, and payload deployment did provide points of departure or comparison for the approaches considered in this study.

SELECTION OF CANDIDATE CONFIGURATIONS

Approximately 10 preliminary concepts of shelter configurations were generated and reviewed. A comparison of these concepts led to the selection of two baseline configurations which satisfied the initial shelter volume goal of exceeding 500 cu ft. The were Configuration 3-Horizontal Cylinder (567 cu ft) as shown in Figure 4-1 and Configuration 4-Vertical Cylinder as shown in Figure 4-2; the corresponding outboard profiles are shown in Figures 4-3 and 4-4 respectively. It is to be noted that in both profiles, the 18 by 26 by 144 in. size envelope of one of the 100-ft drill packages, as specified at this phase of the study, and the LSSM were most influential in the arrangement of the overall shelter payload and the attainable shelter volume.

As a result of an increase in the volume goal to 700 cu ft and subsequent changes and allowable variations in the sizes of the 100-ft drill packages, four additional configurations based on the horizontal and vertical cylinder concepts were generated. These four configurations and the two baseline configurations are referred to as the Final Series of Shelter Configurations and are illustrated in Figure 4-5.

Configuration 3B was selected over the other horizontal cylinder shelters since its right circular pressure shell is structurally simpler and its volume is greater than the 700 cu ft goal.

AIRESEARCH MANUFACTURING DIVISION
Los Angeles, California

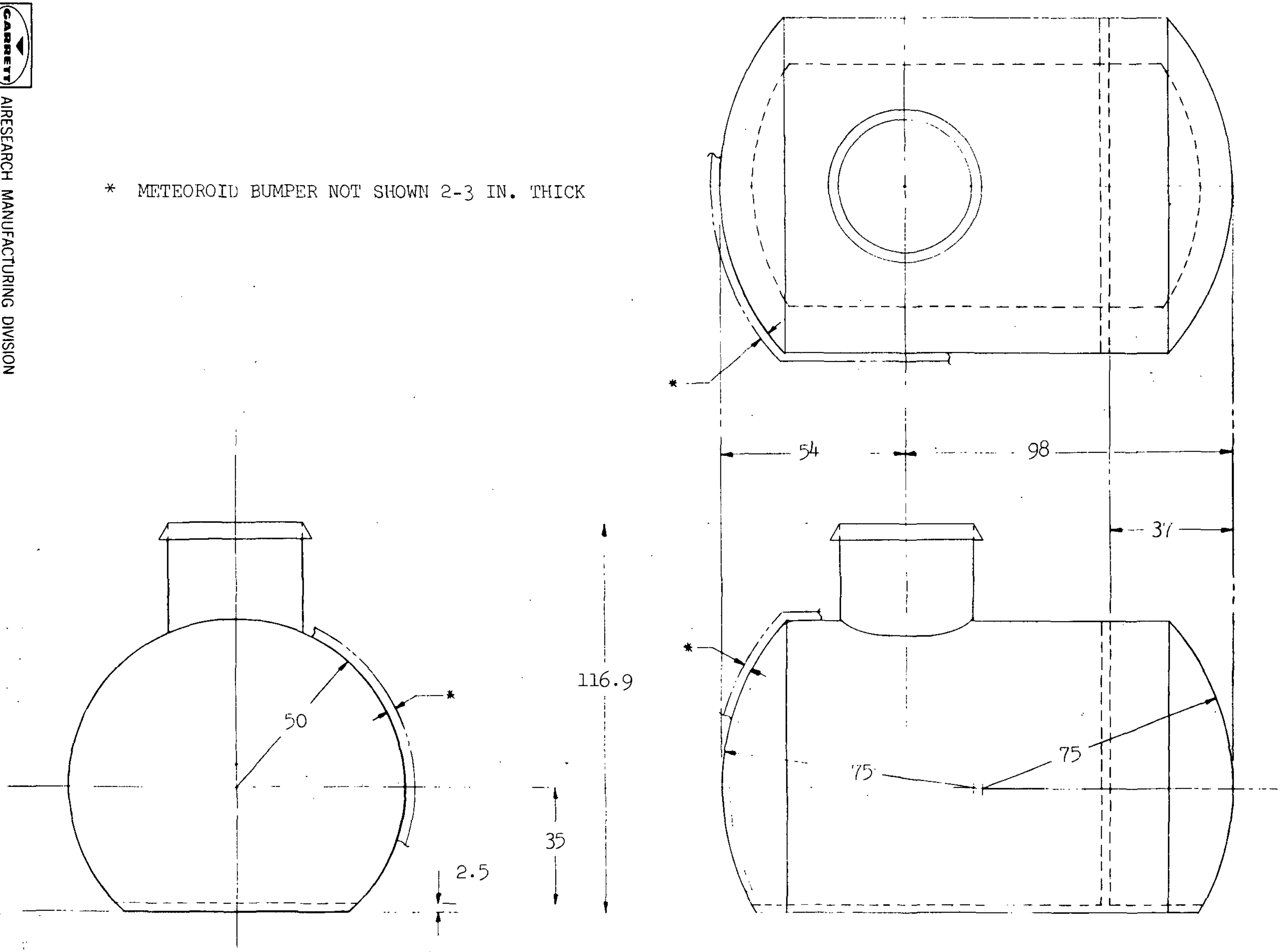


Figure 4-1. Baseline Configuration 3 Horizontal Cylinder

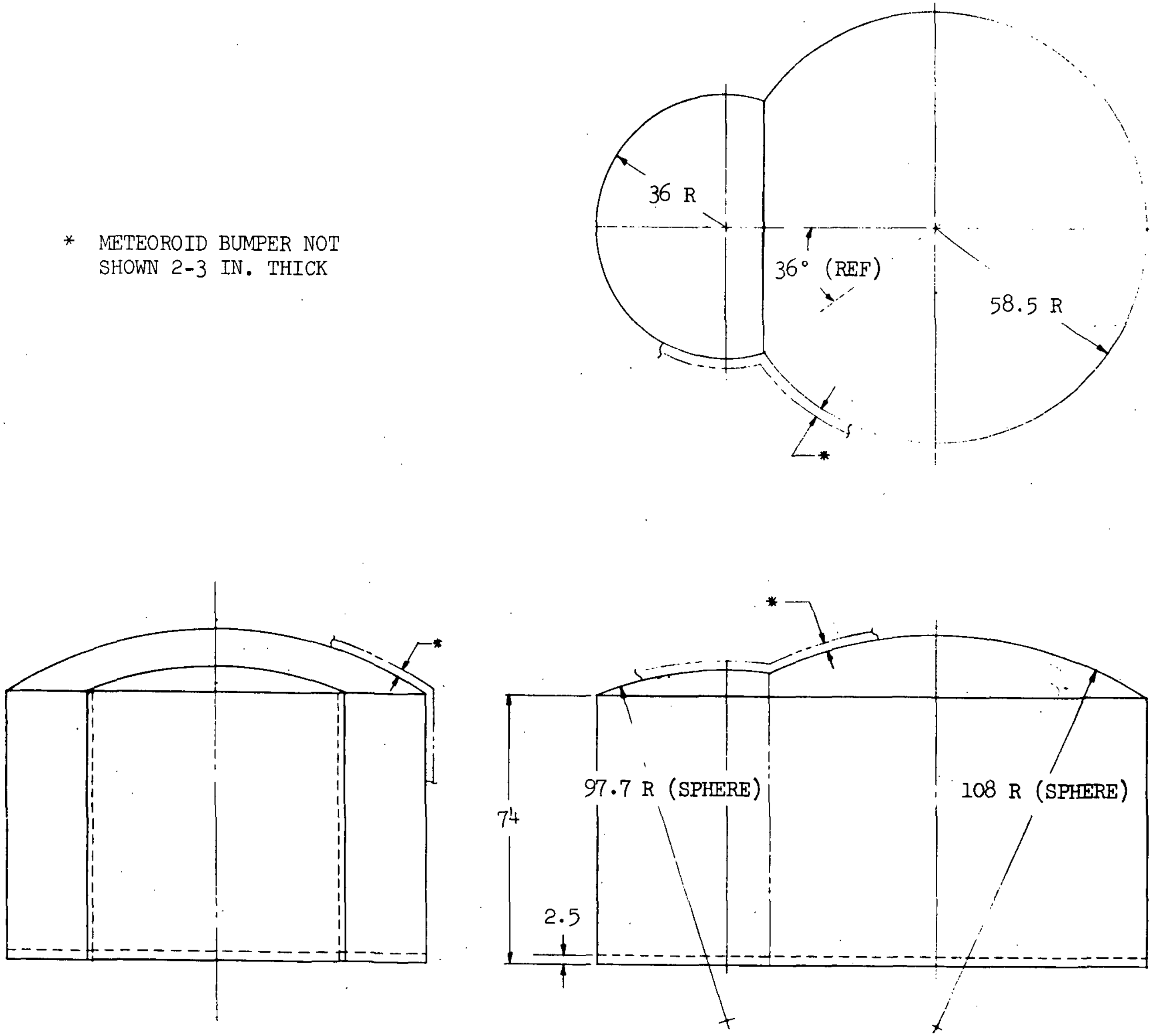
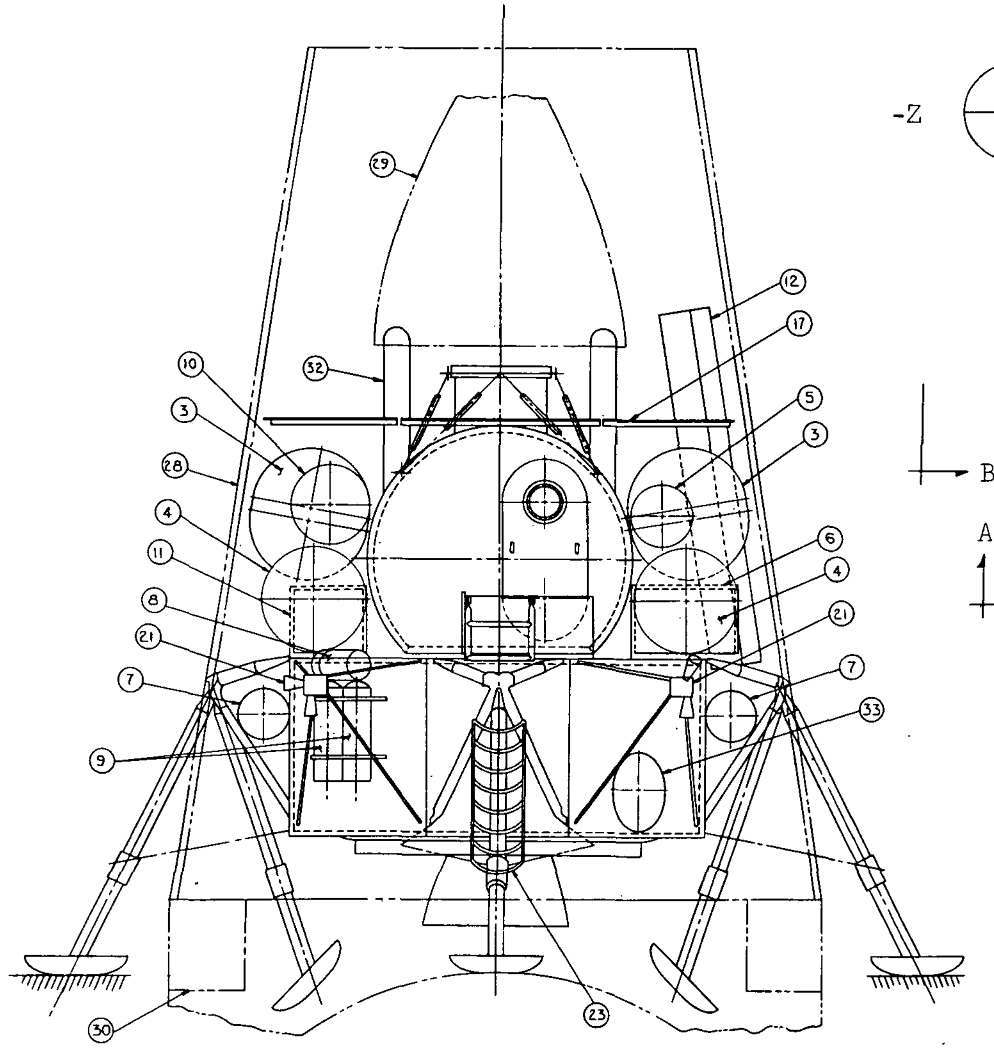
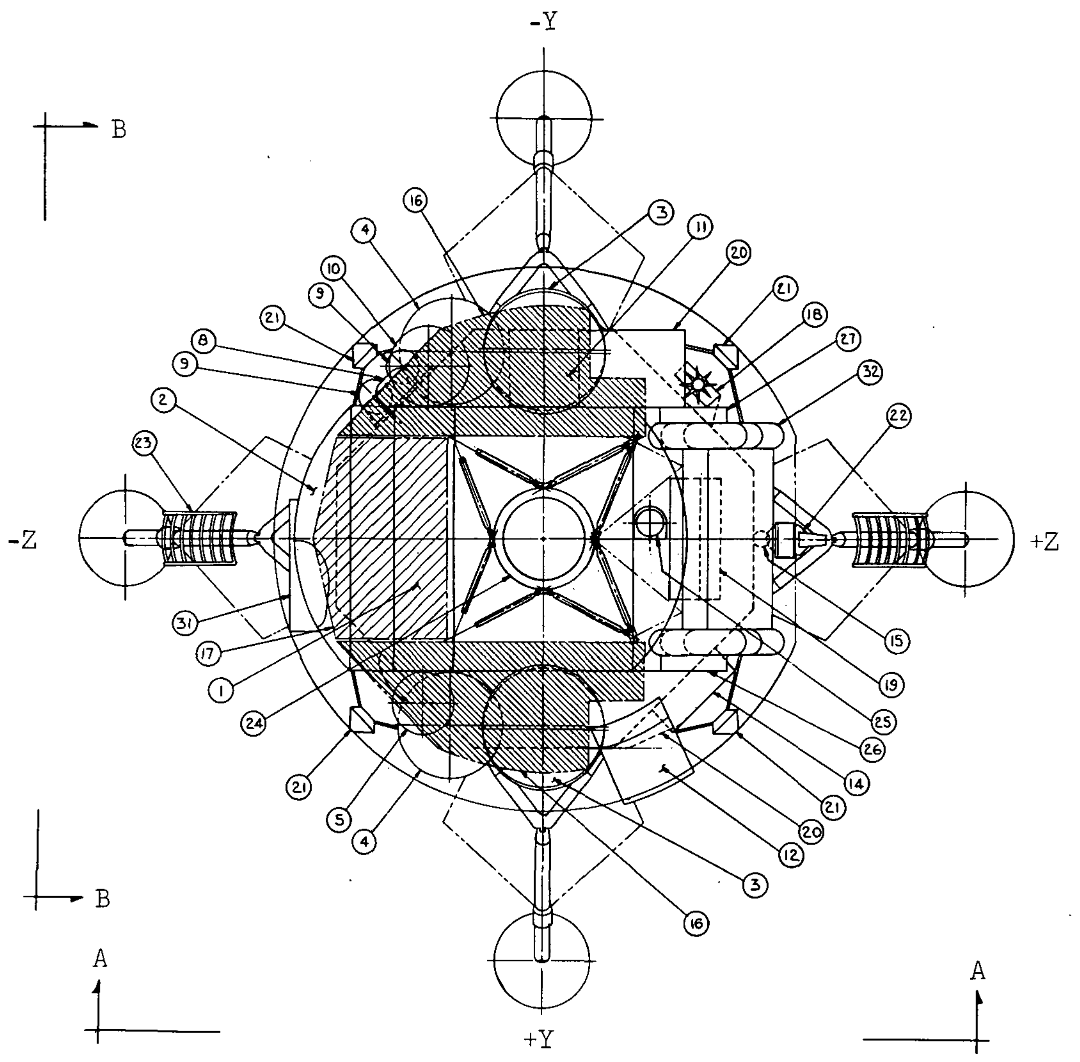
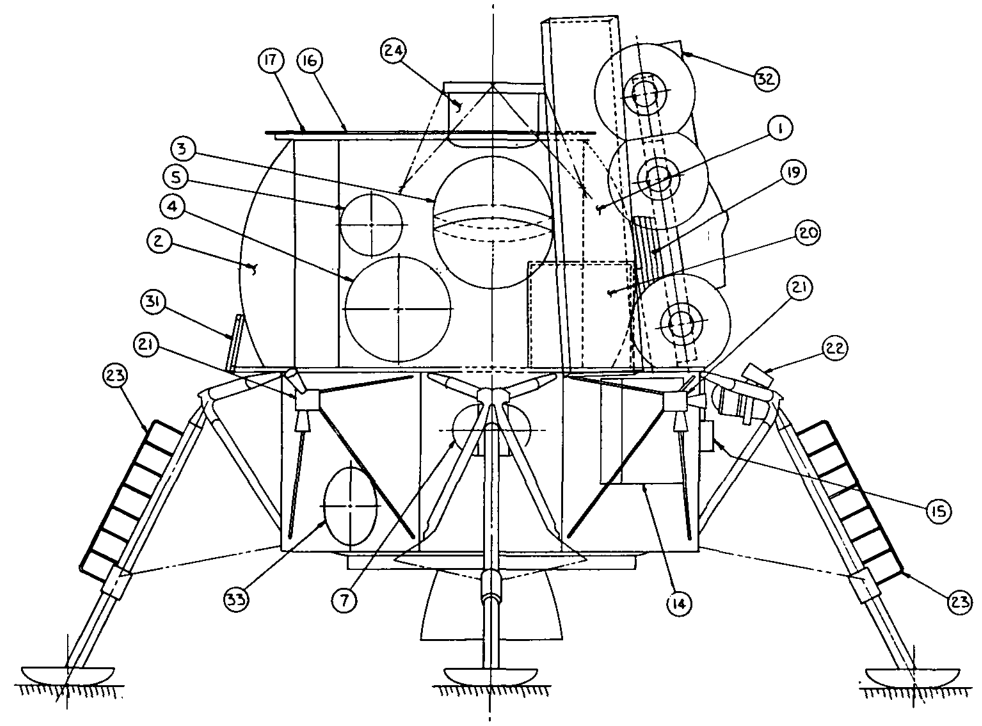


Figure 4-2. Baseline Configuration 4 Vertical Cylinder


VIEW B-B
(ROTATED 90° CCW)



PLAN VIEW


VIEW A-A

1. SHELTER
2. SHELTER AIRLOCK
3. H_2 TANK (2)
4. O_2 TANK (2)
5. ECS CONDENSATE TANK
6. ELECTRONIC EQUIP. STORAGE
7. WASTE STORAGE TANK (2)
8. FCA COLLECTOR TANK (H_2O)
9. FCA UNIT (2)
10. H_2O TANK
11. POWER CONVERSION EQUIP. STORAGE
12. 100 FT. DRILL PACKAGE (12')
14. 100 FT. DRILL PACKAGE (3.5')
15. 100 FT. DRILL PACKAGE (2.5')
16. ECS RADIATOR
17. FCA RADIATOR
18. RTG UNIT
19. WORK PLATFORM STORAGE
20. ESS MISSION EQUIP. STORAGE (2)
21. RCS JETS
22. STAR TRACKER
23. LEG LADDER (2)
24. DOCKING PORT
25. DOCKING TARGET
26. CREW/SHELTER EGRESS MECH. STORAGE
27. EQUIP. UNLOADING MECH. STORAGE
28. SLA
29. SM ENGINE
30. S-IV B
31. EGRESS PLATFORM
32. LSSM
33. He TANK (TRUCK)

CHANGE:

A - 42.5 FT^3 TOTAL L H_2 STORAGE VOLUME WAS 33 FT^3

B - 100 FT DRILL PACKAGES 144" X 30" x 9", 36 X 42 X 12, 6 DIA X 12 WERE 144 X 26 X 18, 26 DIA X 132, 36 X 42 X 12, 30 X 18 X 10

Figure 4-3. Baseline Configuration 3
Horizontal Cylinder Outboard Profile

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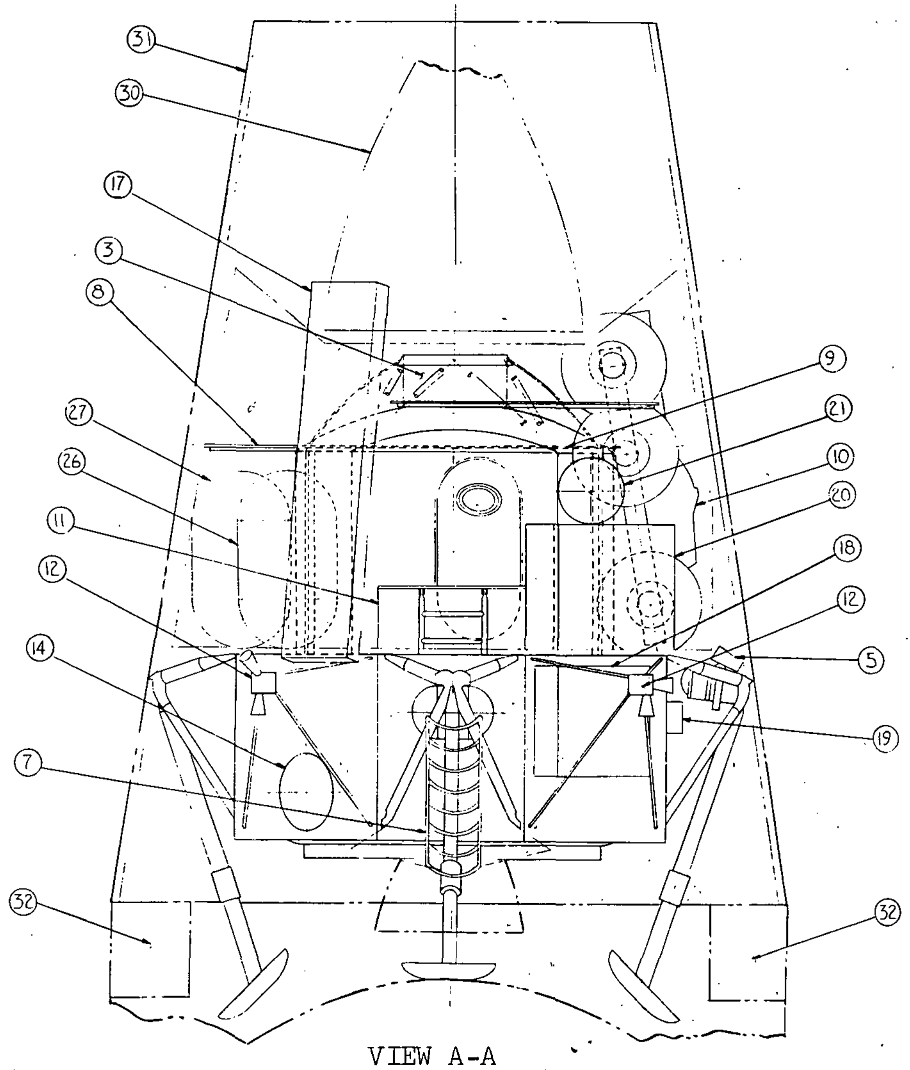
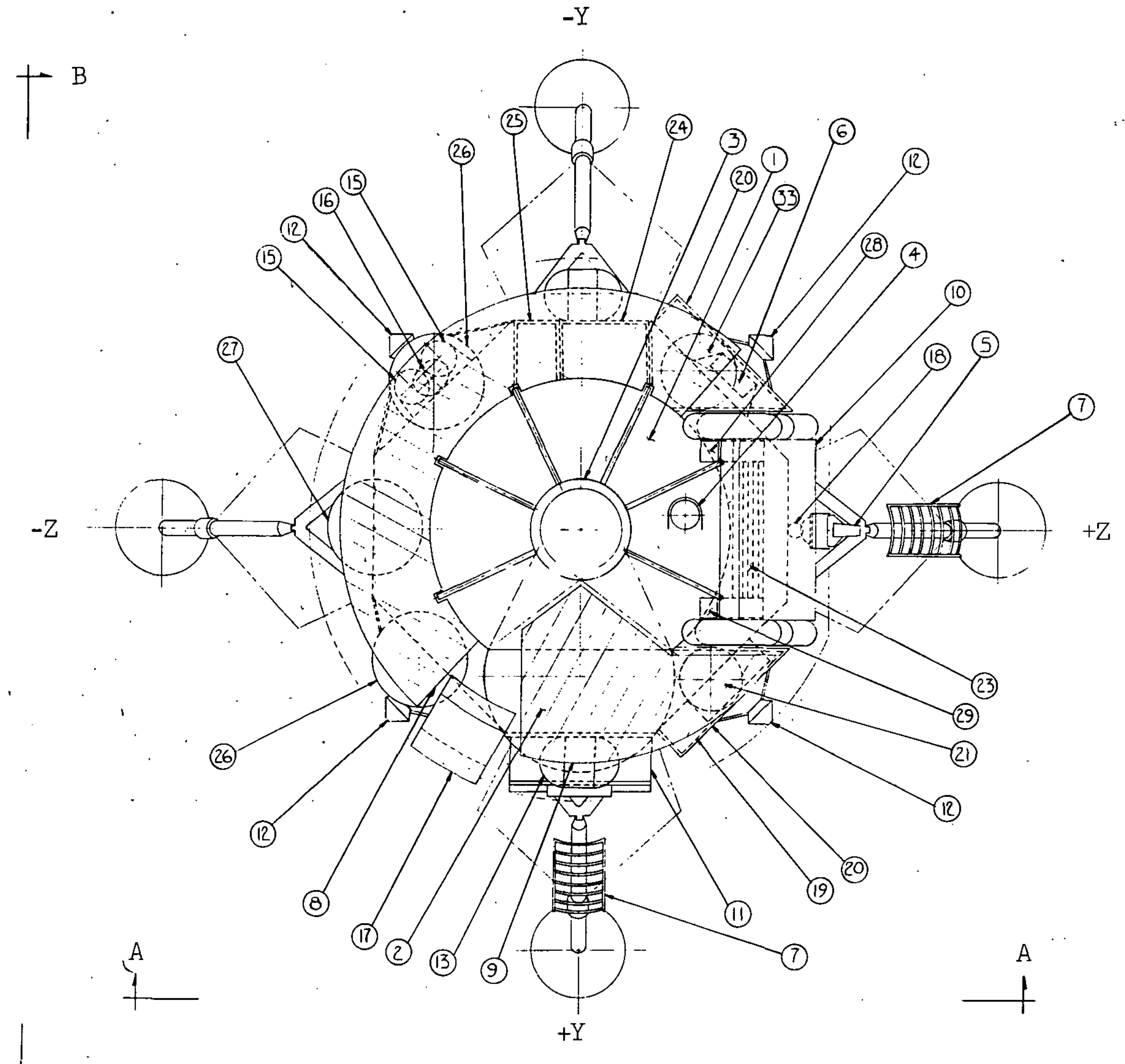
1. SHELTER
2. SHELTER AIRLOCK
3. DOCKING PORT
4. DOCKING TARGET
5. STAR TRACKER
6. RTG UNIT
7. LEG LADDER (2)
8. ECS RADIATOR
9. FCA RADIATOR
10. LSSM
11. EGRESS PLATFORM
12. RCS JETS
13. H_2O WASTE STORAGE TANK
14. H_e TANK (TRUCK)
15. FCA UNIT
16. FCA COLLECTOR TANK
17. 100 FOOT DRILL PACKAGE 12'
18. 100 FOOT DRILL PACKAGE 2.5'
19. 100 FOOT DRILL PACKAGE 3.5'
20. ESS EQUIPMENT
21. ECS CONDENSATE TANK
22.
23. WORK PLATFORM
24. ELECTRONIC EQUIPMENT STORAGE
25. POWER CONVERSION EQUIPMENT
26. H_2 TANK
27. O_2 TANK
28. EQUIP. UNLOADING MECH. STORAGE
29. CREW/SHELTER EGRESS MECH. STORAGE
30. SM ENGINE
31. SLA
32. S-IV B
33. H_2O TANK


VIEW A-A



PLAN VIEW

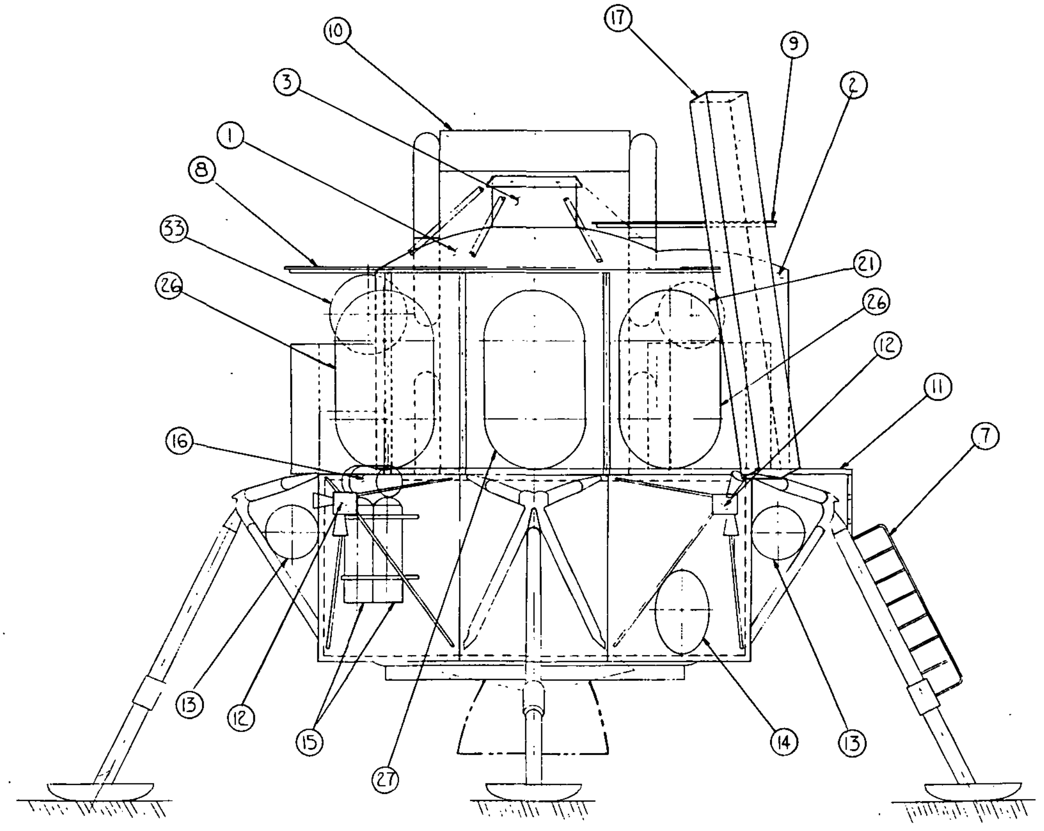

VIEW B-B

Figure 4-4. Baseline Configuration 4
Vertical Cylinder Outboard Profile

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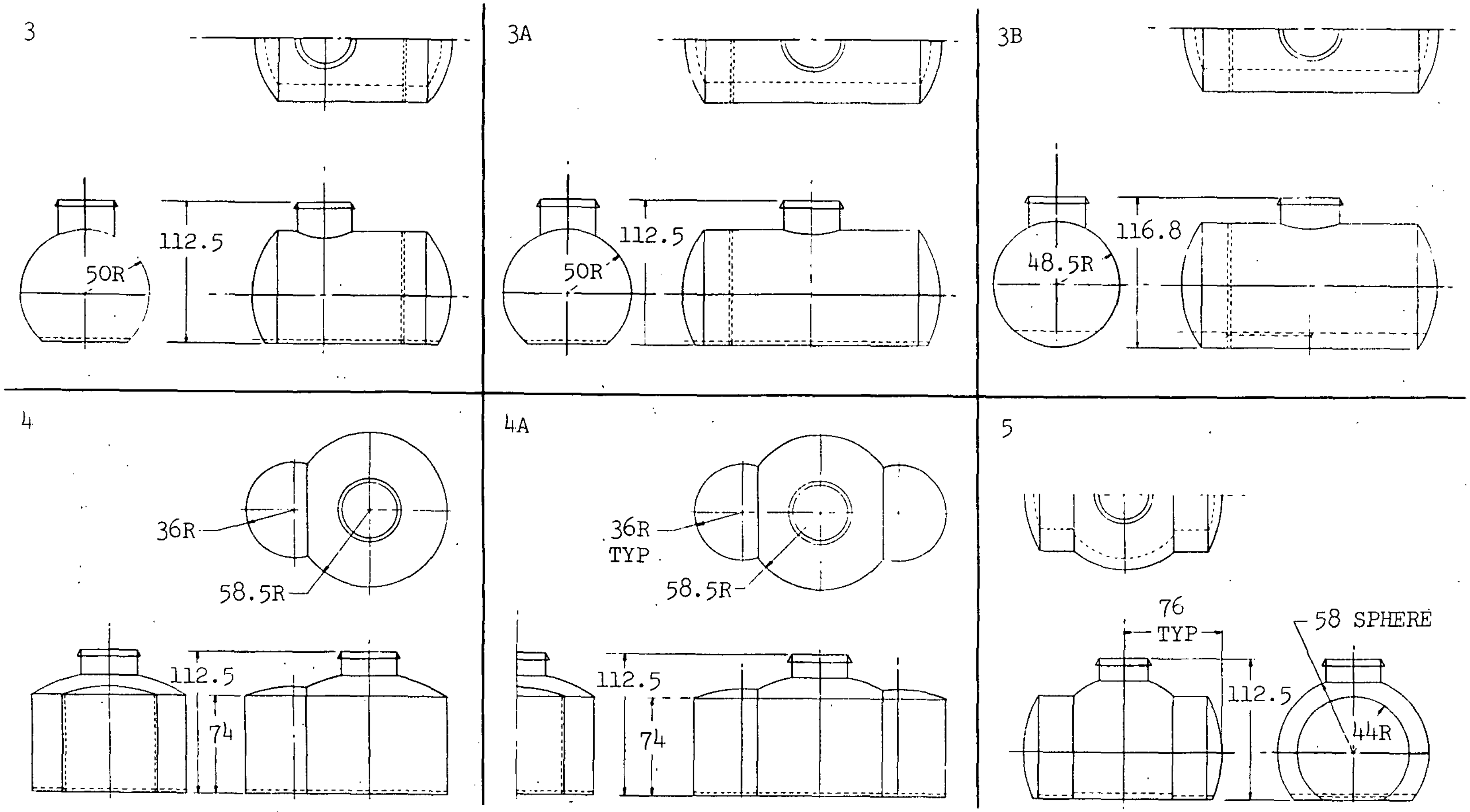

CONFIGURATION	TOTAL VOL. FT^3	FLOOR AREA FT^2
3 HORIZONTAL CYLINDER	567	61
3A HORIZONTAL CYLINDER	715	72
3B HORIZONTAL CYLINDER	758	68
4 VERTICAL CYLINDER	618	91
4A VERTICAL CYLINDER	740	106
5 SPHERE - CYLINDER	700	76

Figure 4-5. Final Series of Shelter Configurations

The comparison of the vertical cylinder shelters resulted in the selection of Configuration 4 even though the volume of 4A exceeds the volume goal of 700 sq ft and 4 does not. This seeming contradiction to objectives was based on the following considerations. For Configuration 4A, a greater amount of equipment preferably stowed externally had to be placed inside the shelter, and the form factor of the volume available in the second lobe limits its utilization to a small fraction of the geometric volume.

Although the volume goal was 700 cu ft, the over 600 cu ft of Configuration 4 could satisfy the requirements of a 3-man crew; therefore, both Configurations 3B and 4 were studied further to allow a more quantitative comparison between vertical and horizontal cylinder configurations.

SELECTION OF RECOMMENDED CONFIGURATION

To provide a basis for a comparative evaluation of the two candidate shelter configurations and the subsequent selection of a recommended configuration, the following were developed for the two candidate shelter payload configurations:

- Outboard profiles
- Inboard profiles
- Structural arrangements
- Mass summaries

The shelter payload can be considered to consist of four groupings:

a. The shelter and all internal equipment and furnishings

b. Externally located equipment and consumables which are directly related to shelter operation and are connected to the shelter by electrical and fluid lines

c. Externally located equipment which are related to extra-shelter activities (ESA) such as scientific equipment packages and the LSSM

d. Support or handling provisions which are not required for initial occupancy of the shelter such as temporary access platforms and unloading devices and small equipment such as, sample containers, and surveying markers

Outboard Profiles

In addition to satisfying the requirements, constraints and goals noted in Section 3 and previously in Section 4, the following ground rules were applied in the development of outboard profiles for Configuration 3B-Horizontal Cylinder, and Configuration 4-Vertical Cylinder.

Items of group (b) such as cryogenic tankage and fuel cell assemblies should be positionally fixed to the shelter whether or not the shelter is to be moved relative to the LM/Truck and functionally grouped to minimize electrical and fluid line lengths.

Items of group (c) should be arranged to localize unloading requirements and the provisions for unloading should also be independent of the "as landed" attitude of the LM/Truck or the final position of the shelter payload relative to the LM/Truck.

Items of group (d) may be stored in the shelter.

Initial access to the airlock outboard door, entry, and pressurized occupancy of the shelter should not require relocation of stored equipment.

Minimum use of LM/Truck sides should be made for mounting stored equipment or supplies.

Equipment of all groupings should be located to help maintain overall cg location limitations.

I. Configuration 3B Outboard Profile

The outboard profile for Configuration 3B is shown in Figure 4-6. The pressurized shelter is an 8.1-ft dia cylinder with 7-ft radius spherical sector end domes. Its overall length is 16 ft, and it is located symmetrically with respect to the Y and Z axes of the LM/Truck with the airlock (shelter forward end) facing in the -Z direction. A docking ring and tunnel for accepting the Apollo Command Module is symmetrically located at the top center of the cylinder. The shelter end domes are tangent to the payload envelope, and therefore in the primary payload envelope only the space adjacent to the sides of the shelter is available for equipment storage.

The cryogenics are stored in two separate tanks, the H_2 tank above and slightly inboard of the O_2 tank, located symmetrically with respect to the Y axis on the -Y side of the shelter. The tanks have an overall wall thickness of approximately 4 in. The O_2 tank is spherical and has an outside dia of 52 in. The H_2 tank is nearly spherical with a $L/D = 1.1$ and an outside dia of 55 in. The combined mass of the cryogenic fluids and tankage is about 2100 lb.

The fuel cell assemblies (FCA), power conversion and electronic equipments are grouped together aft of the cryogenic tanks on the -Y side of the shelter. Their combined mass is approximately 480 lb based on using two FCA's; the third FCA is shown to satisfy the requirement that space, but not mass, is allocated for 3 FCA's.

The LSSM, in a contracted configuration, is located symmetrically relative to the Y axis on the +Y side of the shelter. It is positioned with the driving station facing radially outward and downward such that its longitudinal axis is at an angle of 5 deg with respect to the LM/Truck XZ plane. It was assumed

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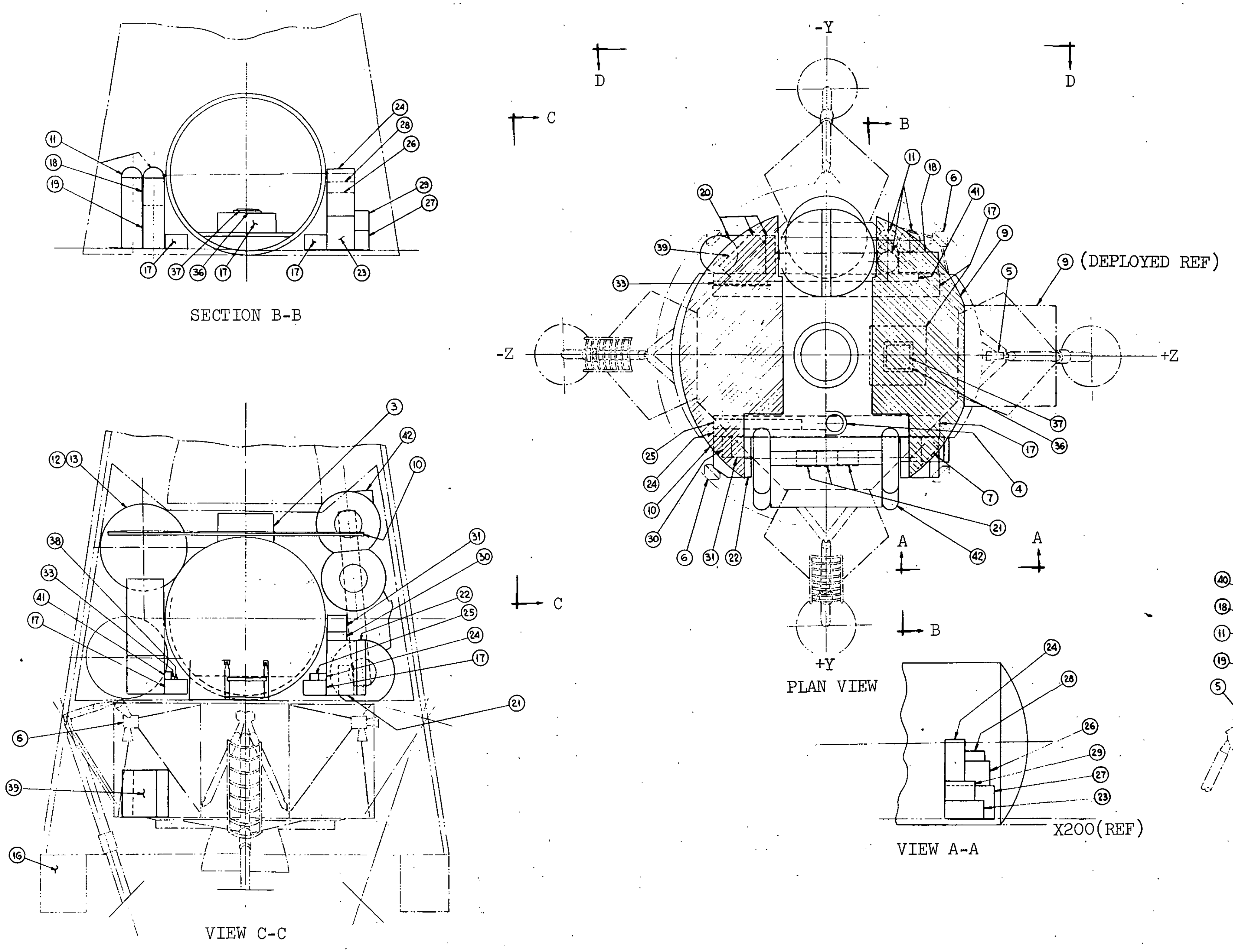

1. SHELTER
2. SHELTER AIRLOCK
3. DOCKING PORT
4. DOCKING TARGET
5. STAR TRACKER
6. RCS JETS
7. RTG UNIT
8. LEG LADDER
9. ECS RADIATOR
10. FCA RADIATOR
11. FCA
12. H_2 TANK
13. O_2 TANK
14. SM ENGINE
15. SLA
16. SIV-B
17. 100 FOOT DRILL PACKAGE
18. POWER CONVERSION EQUIPMENT
19. ELECTRONIC EQUIPMENT
20. ESS EQUIP'T. 3 PACKAGES: 24 DIA x 24 RTG
    24 x 24 x 24
    18 x 24 x 48
21. SATELLITE ESS EQUIP'T. 3 PACKAGES: 9 x 13.3 x 18
22. SEISMIC REFRACTOR
23. MULTIBAND PHOTOGRAPHY & RADIOMETRY EQUIP'T.
24. SURVEYING MARKERS (2)
25. SURVEYING STAFF
26. TELLURIC CURRENT (A & B)
27. SAMPLE CONTAINERS & HAND TOOLS
28. EROSION SAMPLES
29. ASTRONOMY EXPERIMENTS
30. THEODOLITE
31. RANGING LASER
32. DATA HANDLING EQUIPMENT
33. NUCLEAR MEASUREMENTS
34. SHELTER GEOLOGY EQUIPMENT
35. GAS ANALYSER
36. SKETCH BOARD & MAPS
37. ENVIRONMENTAL EXPOSURE PANEL
38. SONIC VELOCITY LOGGING
39. STORAGE COMPARTMENT INCLUDES FOLLOWING SCIENTIFIC EQUIPMENT:
    - GRAVIMETER
    - PENETROMETER
    - RADIOMETRY
    - SURFACE ELECTRICAL PACKAGE
    - BATTERY (SURVEY STAFF)
    - MAGNETOMETER
    - ELECTRICAL INDUCTION LOGGING
    - METEROID EJECTA DETECTOR
    - TISSUE EQUIVALENT ION CHAMBER
    - COMPONENTS OF { 100 FOOT DRILL, SONIC VELOCITY LOGGING, NUCLEAR MEASUREMENTS }
40. FCA COLLECTOR TANK
41. 10 FOOT DRILL
42. LSSM

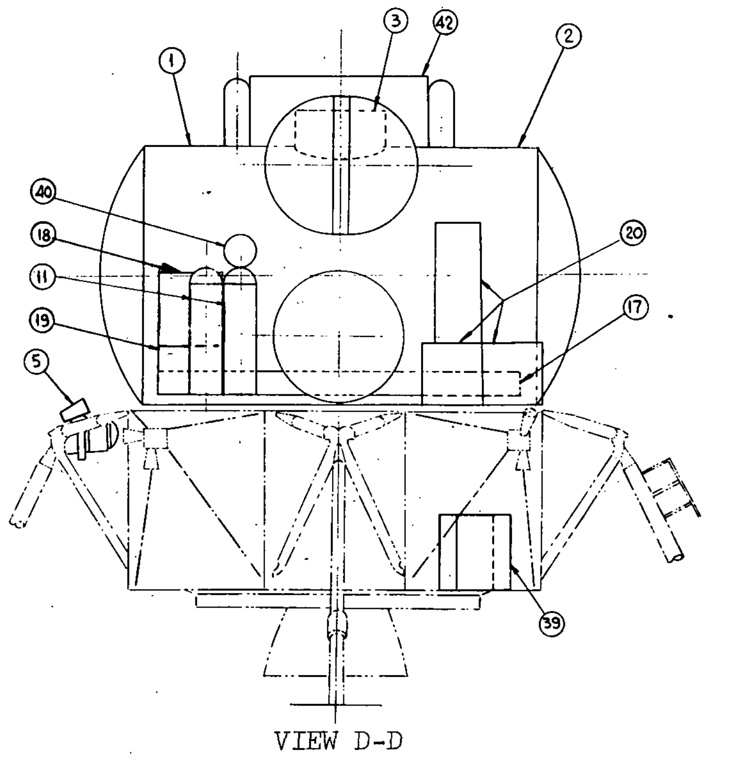

Figure 4-6. Configuration 3B Outboard Profile

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that in the contracted configuration its suspension system is locked out and the entire vehicle can be considered a rigid body; its mass in this storage mode is 1380 lb.

The environmental control and fuel cell radiators are located in a horizontal plane approximately tangent to the top of the cylinder on the -Z and +Z sides of the docking tunnel. The protrusions of the LH_2 tank and the LSSM above the primary space envelope and the docking ring structure occupied sufficient area to require a folding section in the aft radiator which is deployed after the shelter is occupied. The radiators have a combined surface area of 117 sq ft and a total mass of 235 lb.

The majority of the scientific equipment (Table 3-2) to be stored external to the shelter is located in several clusters within the primary payload envelope. Since all the equipment packages are identified in Figure 4-6 only the major packages, from volumetric or mass viewpoints, will be mentioned in the following. The Emplaced Scientific Station packages, having a mass of approximately 414 lb, are located forward of the cryogenic tanks adjacent to the -Y side of the airlock end of the shelter.

The Seismic Deep Refraction package and one of the Theodolite and Ranging Laser packages, with a combined mass of approximately 500 lb, are located on the +Y side of the airlock end of the shelter forward of the LSSM. The three Satellite ESS packages, with a mass of approximately 225 lb, are located behind the LSSM and directly over the LM/Truck beam. The Multiband Photography and Radiometry package and five smaller mass packages are located aft of the LSSM and adjacent to the shelter. This cluster of equipment has a combined mass of about 210 lb.

As previously stated, there were several changes in the sizes, weights, and total number of packages comprising the 100 ft drill assembly, some of which were initiated to allow increased flexibility of storage location in the primary payload envelope. The more significant changes were the elimination of the 26-in.-dia by 132-in.-long package and the reduction of the 18- by 26- by 144-in. package to 9 by 30 by 144 in. with a mass of 150 lb.

Since this latter package contained the drill rod extensions, it could be reconfigured into two or three packages provided the aggregate cross-sectional area remained in the same, the 144-in. length being retained to minimize the number of rod joints. For this configuration the drill rod extensions are contained in two 9- by 15- by 144-in, 75-lb packages. They are located longitudinally along both sides of the shelter over the Y axis LM/Truck beams, their lengths positioned symmetrically with respect to the Y axis.

The remaining large (12- by 36- by 42-in.) package of the 100-ft drill assembly is located inside the shelter.

Other scientific equipment packages which have small cross-sectional areas and relatively long lengths such as the 10-ft drill and surveying staff are located above the 100-ft drill rod extensions.

The numerous equipment packages which are relatively small in size (0.02 to 0.6 cu ft) and mass (1 to 34 lb) can be located adjacent to some of the large equipment packages to allow storing all the scientific equipment in the primary envelope. Alternatives are to store them in cabinets in the shelter or to group them in an equipment box which is mounted in the shelter or on an LM/Truck -Y -Z face, as shown in Figure 4-6. The combined volumes and masses of the packages in the box are approximately 2 cu ft and 125 lb.

Auxiliary equipment, such as for unloading the scientific equipment, may be stored above the 100-ft drill rod extension packages or inside the shelter.

2. <u>Configuration 4 Outboard Profile</u>

The outboard profile for Configuration 4 is shown in Figure 4-7. The pressurized shelter consists of two parallel, intersecting circular cylinders 74 in. high with spherical radii roof domes and a common flat floor. The main cylinder is 117 in. in dia and has a 108-in. spherical radius roof dome. It is intersected by the airlock cylinder, or lobe, which has a dia of 72 in. and a 97.6 in. spherical radius roof dome. The plane of intersection is located 47.3 in. from the center of the main cylinder.

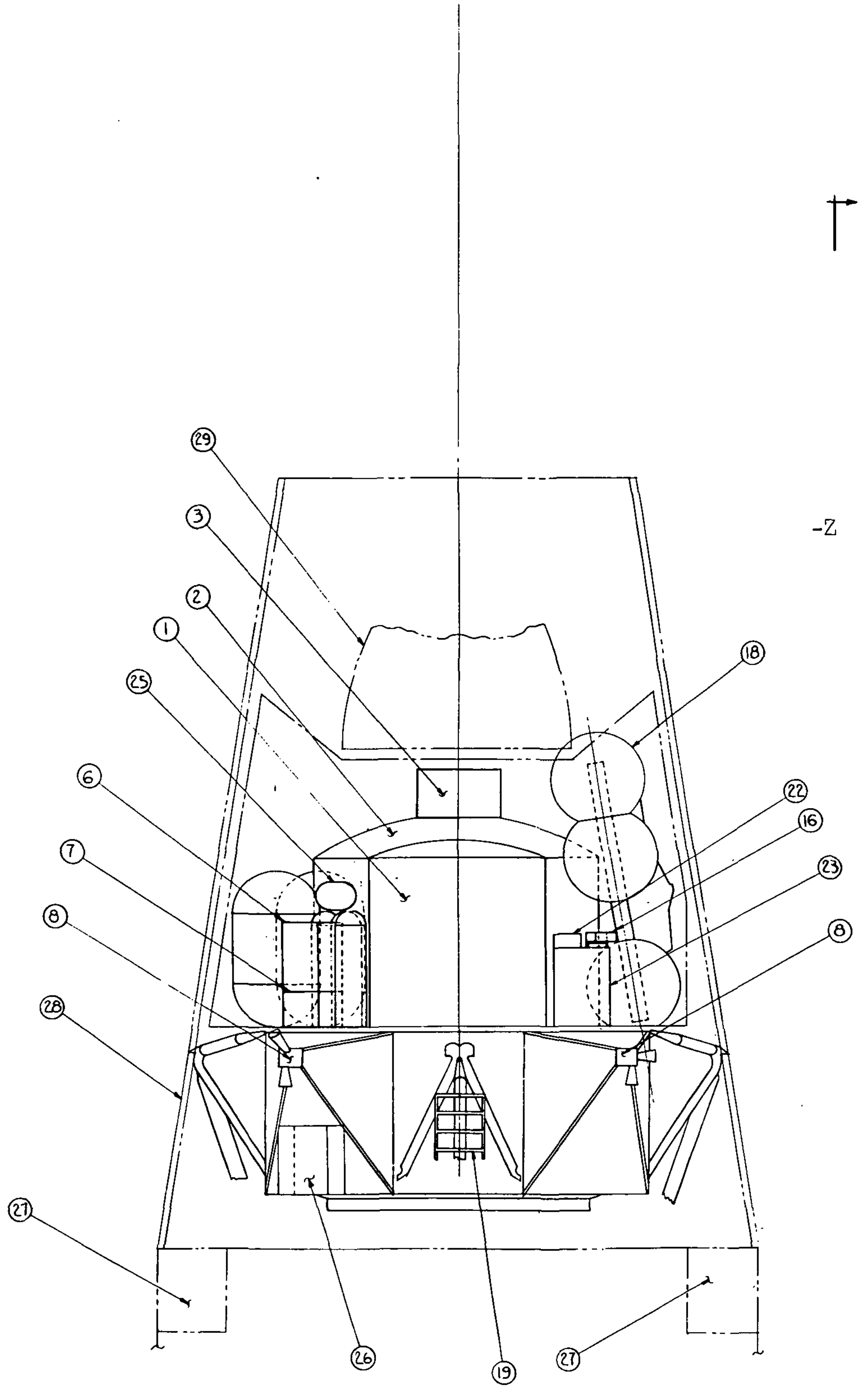
The shelter main cylinder is symmetrically located relative to the LM/Truck Y and Z axes with the common diametral axes of the cylinders aligned along the Y axis, the airlock cylinder facing in the -Z direction.

A docking ring and tunnel for accepting the Apollo Command Module is located at the top center of the main cylinder. Only the airlock end of the shelter is approximately tangent to the payload envelope, and therefore an annular volume extending approximately 290 deg about the main cylinder is available for equipment storage.

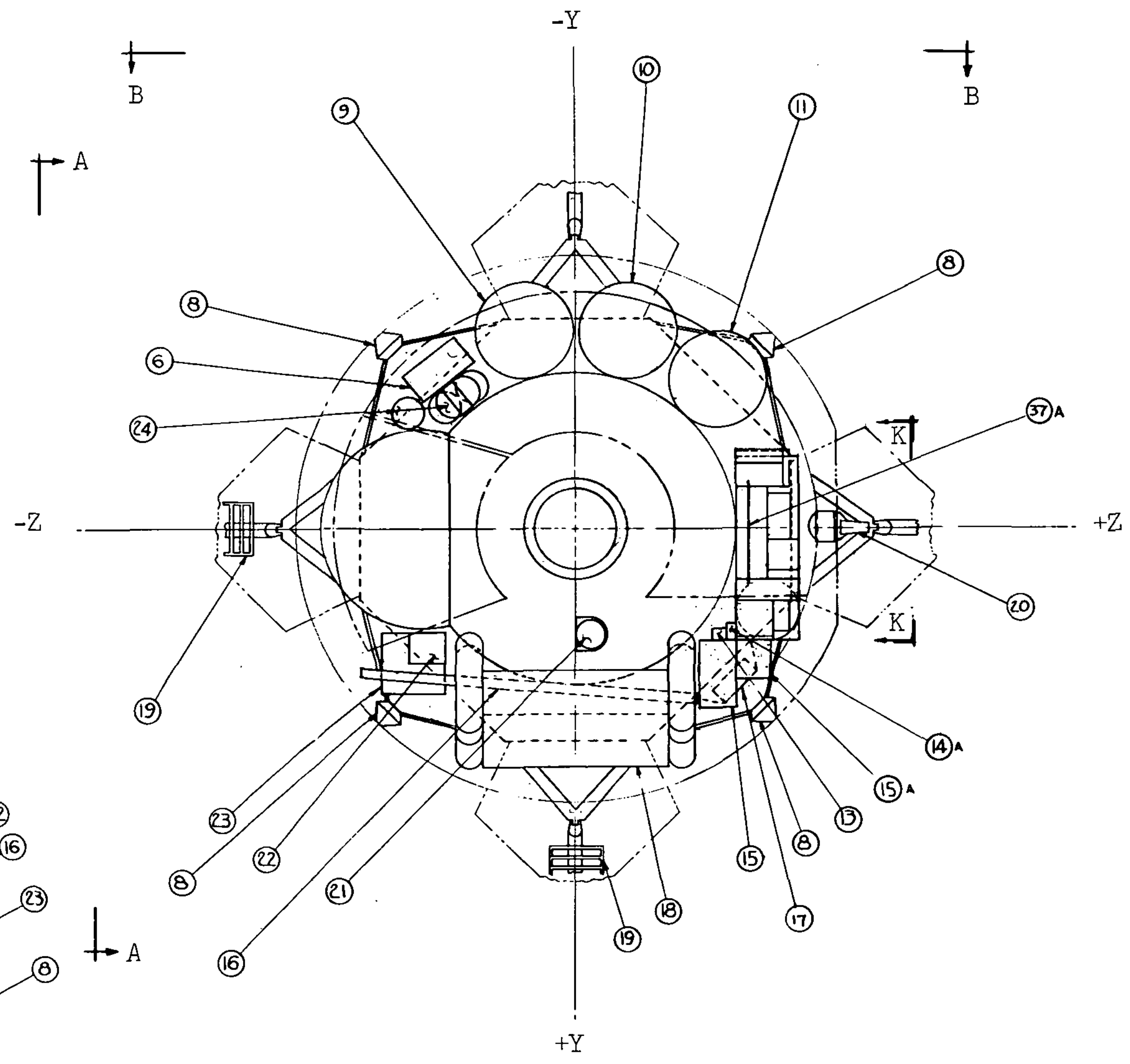
The cryogenics are stored in three tanks aligned side by side along the +Y periphery of the shelter, the O_2 tank centered between the two H_2 tanks. All the tanks are cylindrical with hemispherical domes, have a L/D of approximately 2, an outside dia of 38 in., and a nominal wall thickness of about 4 in. The combined mass of the fluids and tankage is about 2200 lb.

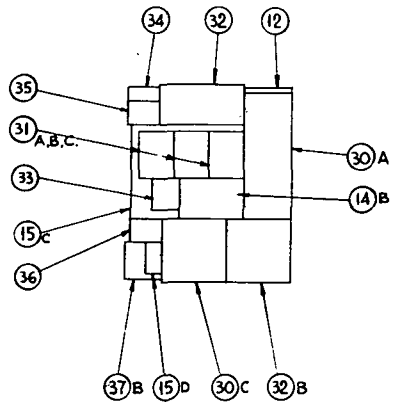
Examination of asymmetrically located shelters, with respect to the Truck Y and Z axes, to allow the use of spherical cryogenic tanks or at least ones with significantly more favorable length to diameter ratios showed that this could only be accomplished with significantly smaller useful volume vertical cylinder shelters.

The fuel cell assemblies (FCA), power conversion and electronic equipments are grouped together approximately midway between the +Z and +Y axis near the intersection of the airlock lobe and main cylinder. As in Configuration 3B, their combined mass is approximately 480 lb based on using two FCA's; the third FCA is shown to satisfy the requirement that space, but not mass, is allocated for 3 FCA's.



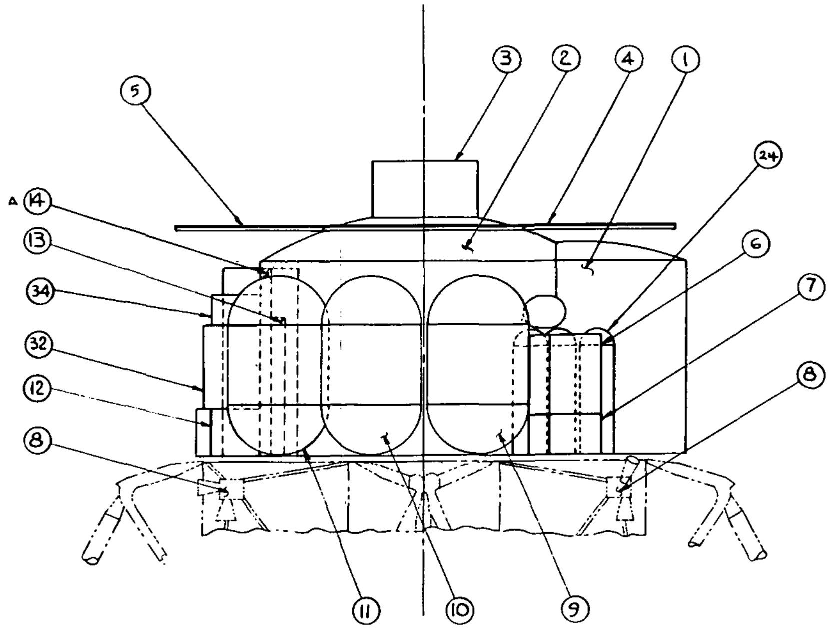
VIEW A-A (RADIATORS OMITTED FOR CLARITY)
ROTATED 90° CCW





VIEW K-K

1. SHELTER AIRLOCK
2. SHELTER
3. DOCKING PORT
4. FCA RADIATOR
5. ECS RADIATOR
6. ELECTRONIC EQUIPMENT
7. POWER CONVERSION EQUIPMENT
8. RCS JETS
9. LA_2 TANK
10. LO_2 TANK
11. LH_2 TANK
12. SKETCHBOARD & MAPS
13. SURVEYING STAFF
14. SURVEYING MARKERS {A, B}
15. 100 FOOT DRILL {A - 12x15x72; B - 14x26x72; C - 12x36x42; D - 6 DIA. x12}
16. 10 FOOT DRILL
17. RTG UNIT
18. LSSM
19. LEG LADDERS
20. STAR TRACKER
21. DOCKING TARGET
22. EROSION SAMPLES
23. SEISMIC DEEP REFRACTION
24. FCA
25. FCA COLLECTOR TANK
26. STORAGE COMP'T A, (SEE NOTE #1)
27. S-IVB
28. SLA
29. SM ENGINE
30. ESS {A - 12x18x24; B - 24x24x24; C - 24D.x24 (RTG)}
31. SATELLITE ESS {A - 9x13x18; B - 9x13x18; C - 9x13x18}
32. MULTIBAND PHOTOGRAPHY & RADIOMETRY EQUIP'T.
33. RANGING LASER
34. THEODOLITE
35. ASTRONOMY EXPERIMENTS
36. SAMPLE CONTAINERS & HAND TOOLS
37. TELLURIC CURRENTS {A, B}



VIEW B-B
ROTATED 180°

Figure 4-7. Configuration 4 Vertical Cylinder Outboard Profile

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The LSSM, in a contracted configuration, is located symmetrically relative to the Z axis on the +Y side of the shelter. It is positioned with the driving station facing radially outward and downward such that its longitudinal axis is at an angle of 10 deg with respect to the LM/Truck XZ plane. As in Configuration 3B, it was assumed that the suspension system was locked-out, and the entire vehicle was considered a rigid body; its storage mode mass is 1380 lb.

The environmental control and fuel cell radiators are located in a horizontal plane approximately tangent to the top of the main cylinder. Since the cryogenic tanks do not protrude above the radiator level, as the H_2 tank does in Configuration 3B, the folding section of the radiator was replaced by a permanent section of equivalent area located over the cryogenic tanks.

The radiators have approximately the same combined area and mass as for Configuration 3B, namely 117 sq ft and 235 lb.

The majority of the scientific equipment designated to be stored external to the shelter is located on both sides of the LSSM and in a large grouping adjacent to the rear of the shelter asymmetrically over the +Z axis LM/Truck beams.

The Seismic Deep Refraction package and the Erosion Sample package, with a combined mass of 460 lb, are located on the +Y side of the airlock lobe, forward of the LSSM.

To accommodate the external storage of the 100-ft drill rod extensions, in this configuration, their minimum allowable length was reduced to 72 in.; the required total cross-sectional area for storage commensurately increased to 540 sq in.

The packages containing the 100-ft drill extensions, surveying markers, and surveying staff are located aft of the LSSM. These packages have a total mass of 200 lb.

The 10-ft drill package, because of its 130-in. overall length is located in a horizontal attitude between the LSSM and the shelter. It is above the Seismic Deep Refraction package and at an angle to the Z axis to clear the 100-ft drill rod extensions package.

The equipment grouping aft of the shelter over the +Z LM/Truck cruciform beam has a volume of approximately 60 cu ft and contains approximately 900 lb of scientific equipment. The locations of this equipment to help maintain the overall cg envelope required the grouping to be offset six in. from the Z axis in the Y direction.

The remaining small equipment packages, 2 cu ft and 125 lb, are located in a box on the LM/Truck -Z, Y face as was done in Configuration 3B.

Auxiliary equipment, such as for unloading the scientific equipment, may be stored vertically adjacent to either side of the airlock lobe or inside the shelter.

Inboard Profiles

The interior of the shelter must satisfy the following general requirements:

- Ingress/egress via an airlock
- Three crewmen on the same work/rest cycle
- Duty stations for mission operations
- Stowage of equipment such as environmental control unit, food preparation, crew garments and space suits

In addition to the requirements and constraints noted in Section 3 and the above paragraph, the following ground rules were applied in the development of the inboard profile of Configurations 3B and 4:

- Accommodate 5 to 95 percentile men
- Minimum 2-man airlock volume of 80 cu ft exclusive of any installed equipment
- Minimum airlock head room of 75 in. and nominal floor area of approximately 10 sq ft
- Airlock door opening approximately 30 by 60 in. or equivalent for nonrectangular shape
- Sealing of airlock doors aided by internal pressure in the normal mode of operation
- Shelter free floor area with a minimum head room of 75 in. and aisle width of approximately 44 in. to accommodate pressure suit donning and access to the airlock
- Sleeping accommodations consisting of three bunks with minimum dimensions of 24 by 75 in. and 24 in. clear height above bunks to allow full length and 360 deg rotation sleeping

1. Configuration 3B Inboard Profile

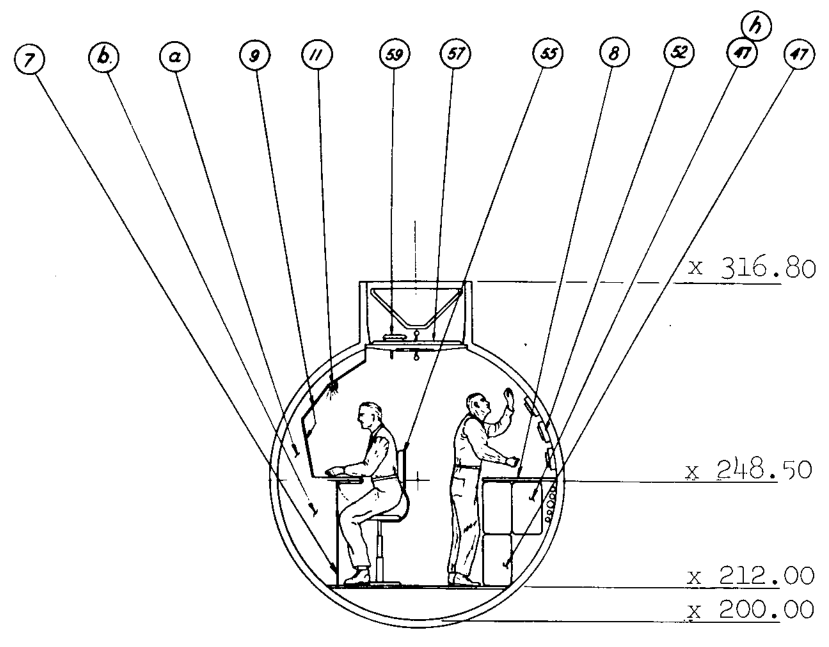
The inboard profile for Configuration 3B is shown in Figure 4-8.

The interior of the shelter is functionally divided along its length into three areas:

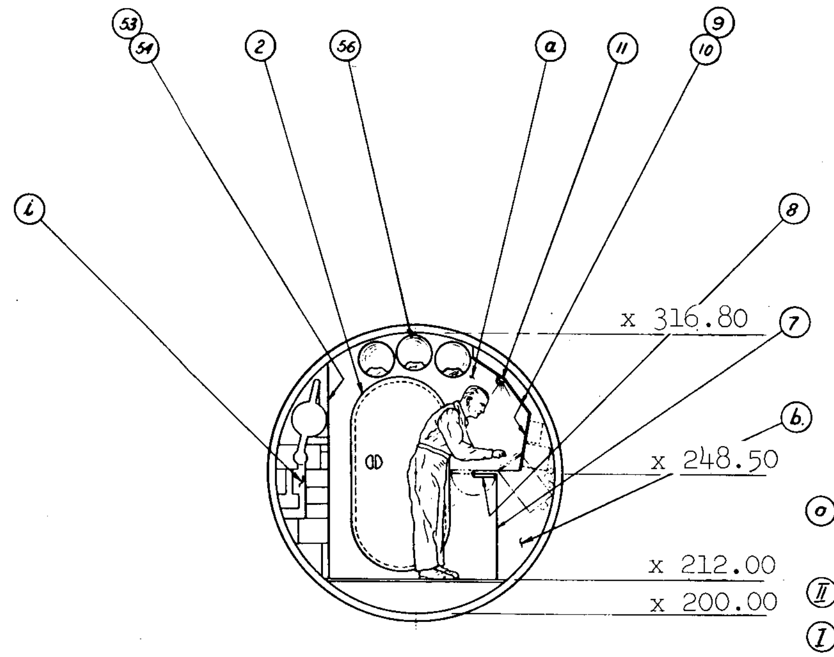
Airlock

Work/Living

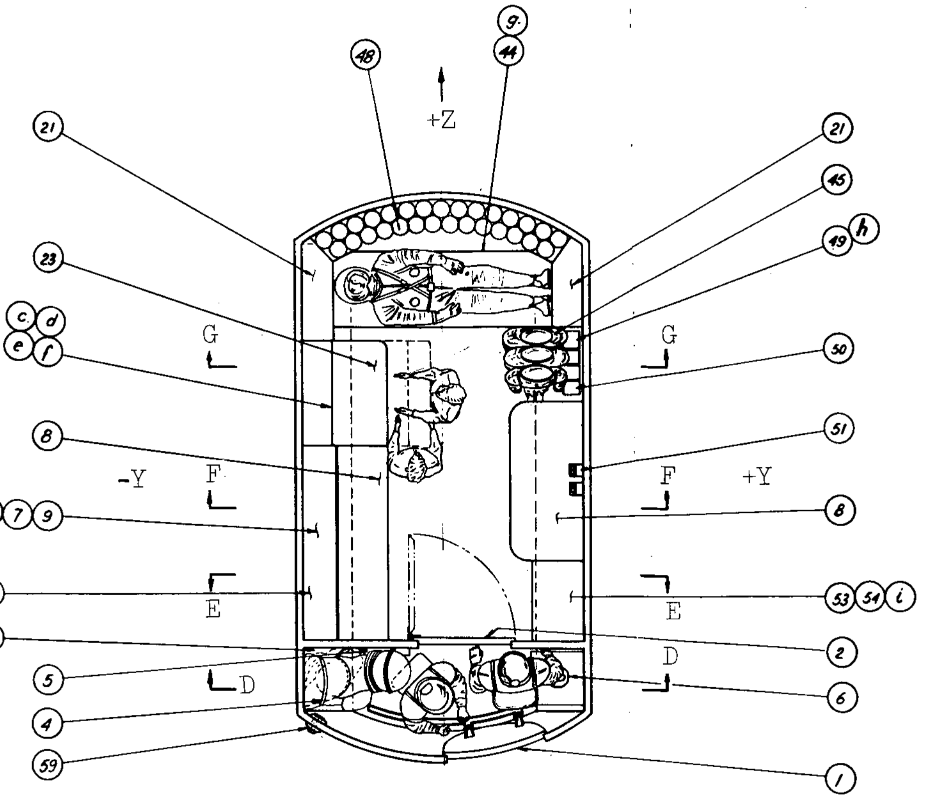
Sleep-Rest/Radiation Refuge



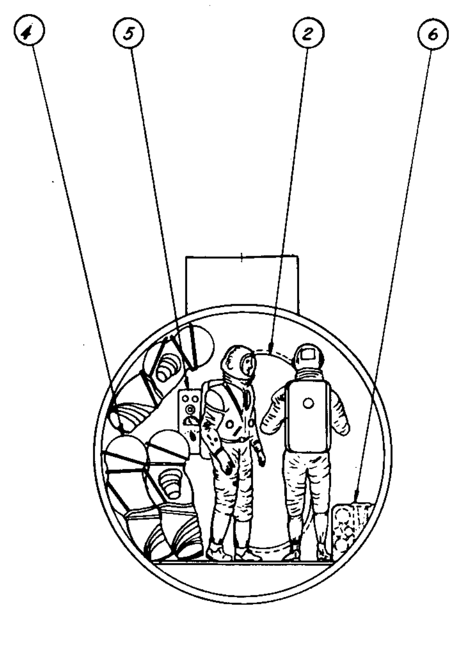
VIEW F-F



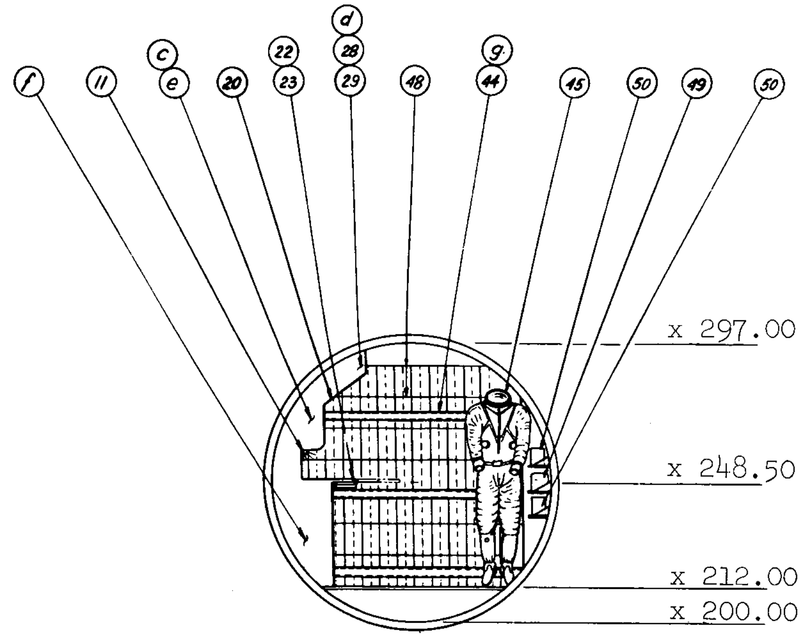
VIEW E-E
(CCW 180°)



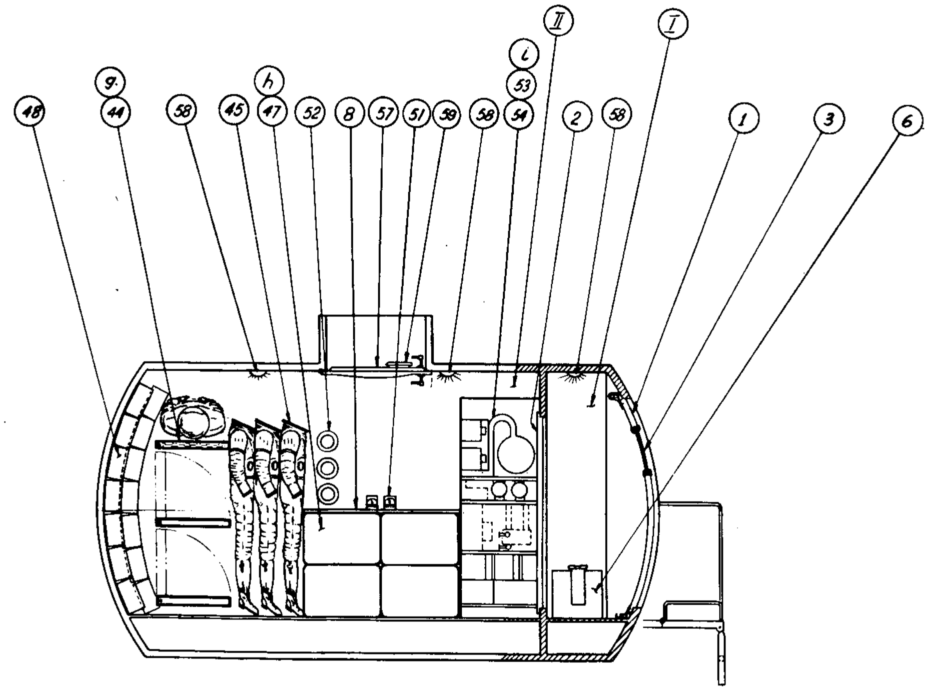
VIEW C-C
-Z



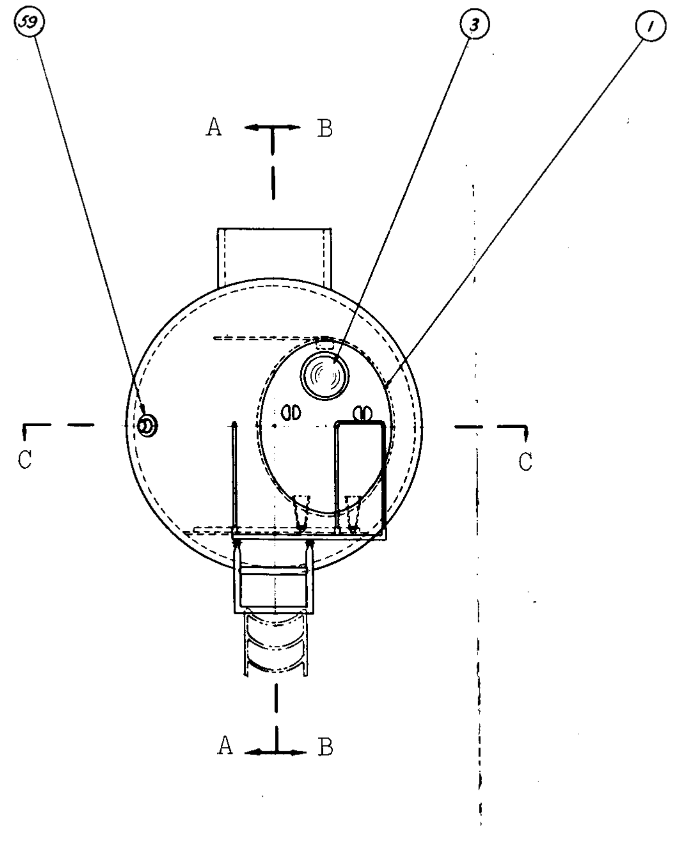
VIEW D-D

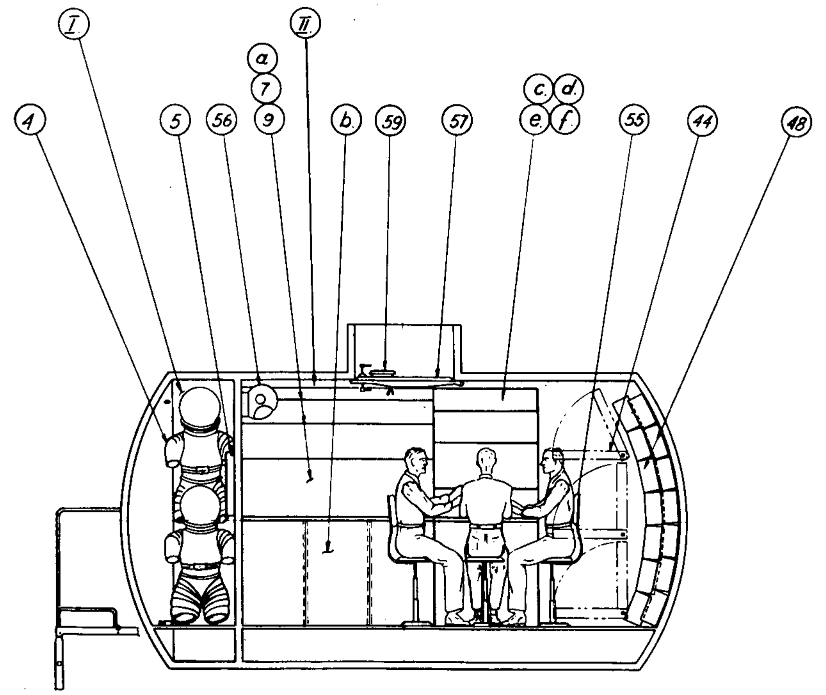


VIEW G-G



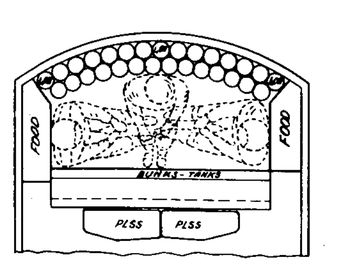
VIEW B-B
LOOKING OUTBD +Y SIDE

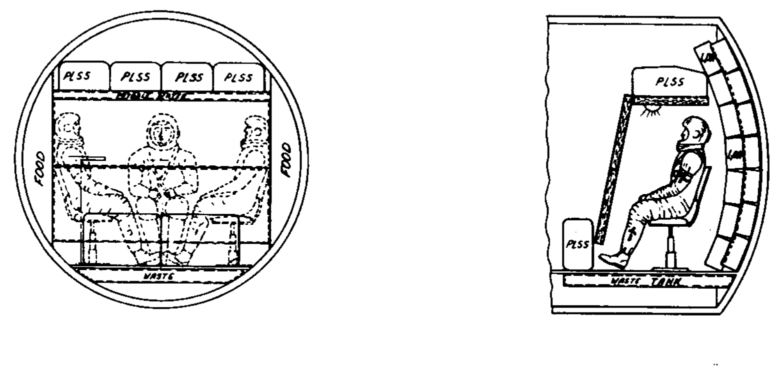




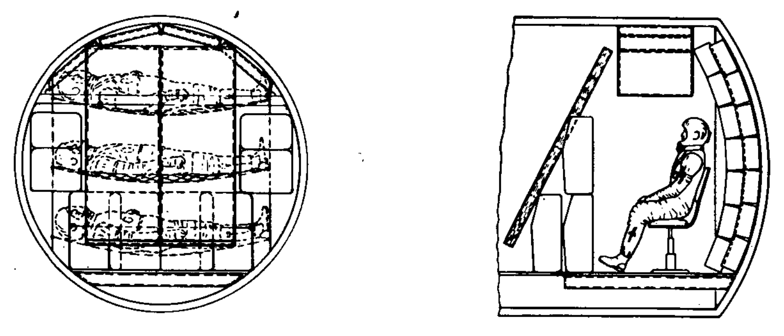
VIEW A-A
LOOKING OUTBD -Y SIDE

SOLAR FLARE CREW SHIELDING





RADIATION SHELTER ARRANGEMENT NO. 1



RADIATION SHELTER ARRANGEMENT NO. 2
PROVIDES FOR ONE MAN TO SLEEP IN
UPPER HAMMOCK WHILE TWO MEN SIT.

KEY

I. AIRLOCK

1. Door - External Sliding
2. Door - Internal
3. Window
4. Hard Suit (3)
5. Suit Checking Station
6. Waste Management System

II. SHELTER

a. WORK AREA (STATION)

7. Console - Equipment
8. Table - Work
9. Panels & Instruments
10. Radiation Dosimeter
11. Lights - Table (4)

b. SCIENTIFIC EQUIPMENT AREA

12. T.V. Camera
13. Movie Camera
14. Still Camera
15. Extra Film & Tape
16. Data Handling Interface Equipment
17. Theodolite & Ranging Laser
18. Shelter Geology Equipment
19. Gas Analyzer

c. EATING AREA

20. Console - Crew Provisions
21. Food Storage
22. Food Preparation
23. Table - Eating & Recreating
24. Water Probe
25. Hot Plate
26. Utensils
27. Dispenser

d. EXERCISE AREA

28. Hand Ergometer (Optional)
29. Bungee Cord (Optional)

e. RECREATION-STUDY AREA

30. Recreation Equipment

f. STORAGE AREA

31. Personal Storage
32. Personal Hygiene Facilities
33. Medical & Emergency Supplies (Station)
34. Housekeeping Provisions Package
35. Laundry
36. Anti-Meteoroid/Thermal Garments (3)
37. Liquid Cooled Garment (L.C.G.) (3)
38. Constant Wear Garment (C.W.G.) (48)
39. Eva Boots (3)
40. Eva Gloves (3)
41. Suit Spare Parts & Repair Kits
42. Intravehicle Slippers (3)
43. Tools

g. SLEEPING & REST AREA

44. Bunk Beds Removable (3)
45. Soft Suit (3)
46. Light-Portable (3)

h. PLSS CHARGING AREA

47. PLSS (6)
48. LiOH (150)
49. PLSS Battery Charger
50. PLSS Batteries (12)
51. PLSS Calibration Unit
52. Emergency Oxygen System (3)

i. ENVIRONMENT CONTROL AREA

53. ECS Package, Fan & Heat Exchanger
54. Umbilicals (3)

j. MISCELLANEOUS AREA

55. Seats - Foldable (3)
56. Helmets (3)
57. Hatch - Upper
58. Lights - Dome (3)
59. Pressure Dump Valve (2)

Figure 4-8. Configuration 3B Horizontal Cylinder Inboard Profile

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a. Airlock--The airlock has a volume of approximately 120 cu ft and is separated from the adjacent work/living area by a flat bulkhead located a centerline distance of 37 in. from the forward end-dome of the shelter. It can be used simultaneously by 2 suited men, accommodates the storage of 3 hard suits and contains the waste disposal system. It has approximately 11 sq ft of free floor area, 90 percent of which has a headroom of at least 75 in. Also, it can accommodate a hammock to provide a sleep-rest area isolated from the rest of the shelter.

It has a 30- by 64-in. inboard door, with semicircular ends, which is hinged to open into the work/living area and a 42- by 57-in. elliptical overboard door which slides laterally along the inner face of the forward end dome to allow maximum utilization of the airlock volume.

b. Work/Living--The work/living area is approximately 9-ft long. It contains the ECS unit, PLSS batteries, six PLSS backpacks and three soft suits stored along the +Y side; a table area is over the PLSS units. Internally stored scientific equipment storage shelves, crew equipment cabinets, status monitoring and communication consoles, and work tables are arranged along the -Y side. The arrangement shown provides a rectangular floor area of over 47 sq ft and about 35 sq ft of table surface, of which about 1/3 is foldable. Crew chairs or stools can be freely moved about the floor area, and crewmen seated at work stations do not inhibit passage of another man to the airlock or sleep-rest areas.

The floor has removable sections which allow access to storage space beneath the floor level and can have integral tanks for storage of potable water or waste liquids.

A 32-in.-dia, single-lever operated, quick-opening hatch for emergency use is located in the docking tunnel over the central aisle of the work/living area. This hatch also allows for in-flight manned access to the shelter for checkout.

c. Sleep-Rest/Radiation Refuge--The sleep-rest/radiation refuge area in its normal arrangement as a sleep area begins at a centerline distance of approximately 44 in. forward of the shelter aft end dome and occupies a volume of about 165 cu ft. It has three bunks which in normal use are tiered and occupy 80 cu ft. Almost all of this volume can be made available for use as additional work/living area by pivoting the bunks into a vertical plane or repositioning them vertically on end.

Two 6-cu-ft lockers, initially containing 166 lb of food and later used for waste storage, are located at the ends of the bunks.

During staytime the 150 LiOH cartridge, provided for CO_2 removal in the backpacks and shelter, are stored in cored polyethylene blankets behind the bunks on the inside face of the end dome. This arrangement occupies 50 cu ft and weighs 600 lb.

At launch, the cartridges are located on the shelter floor, as shown in Figure 4-9, to lower the payload cg and reduce the loading on the end dome during the high-g phases of launch through landing.

The normal sleep-rest arrangement of this area is readily convertible into a radiation refuge suitable for 3 suited crewmen as shown in Figure 4-8. The LiOH cartridges in polyethylene blankets and the food/waste lockers form three sides of the refuge. The bunks, which are constructed as compartmented flat tanks and filled with potable water or waste liquids, and the PLSS units are used to form the fourth side and roof of the refuge.

Polyethylene water blankets and strips are used where equipment and supplies do not provide sufficient shielding and to fill interstices between the equipment and supplies. The details of the protection afforded by this type of arrangement and the weight penalties associated with it are covered later in this section.

2. <u>Configuration 4 Inboard Profile</u>

The inboard profile for Configuration 4 is shown in Figure 4-10.

The interior of this shelter, as in Configuration 3B, also is functionally divided into three areas:

Airlock

Work/Living

Sleep-Rest/Radiation Refuge

a. <u>Airlock</u>--The airlock has a volume of approximately 120 cu ft and is separated from the adjacent work/living area by a flat bulkhead located a centerline distance of 45 in. from the forward end of the airlock. The airlock can be used simultaneously by 2 suited men, accommodates the storage of 3 hard suits, contains a waste disposal system, and has a suit checking station which is mounted on the bulkhead. It has a free floor area of 17 sq ft and headroom of at least 75 in. over 55 percent of the floor area.

The airlock has a 34- by 60-in. rectangular overboard door which slides circumferentially along the inner face of the airlock wall to minimize encroachment on the airlock volume, and a 42- by 56-in. elliptical inboard door hinged to open into the work/living area.

b. <u>Work/Living</u>--The work/living area is approximately 5 ft long. On the +Y side it contains the ECS unit mounted on the floor and occupying an approximately chordal volume which is 28 in. high, has a maximum chord depth of 18 in. and extends the length of the work/living area. A work table surface, with storage compartments under it, is located on top of the ECS unit. The ECS unit is located in the +Y side of the shelter to help maintain the required cg envelope. Internally stored scientific equipment shelves, crew equipment cabinets, status monitoring consoles, and work tables are arranged along the -Y side of the shelter. The three soft suits are suspended from the roof dome for drying and storage.

1. WASTE MANAGEMENT SYSTEM
2. ECS CONSOLE
3. PLSS BACKPACKS (6)
4. PORTABLE O_2 SYSTEM
5. CHAIRS
6. BUNKS
7. L_1OH PACKAGE (3) (SEE DETAIL D)
8. L_1OH PACKAGE (18) (SEE DETAIL E)
9. 100 FT. DRILL RADIATORS
10. HARD SUITS (3)

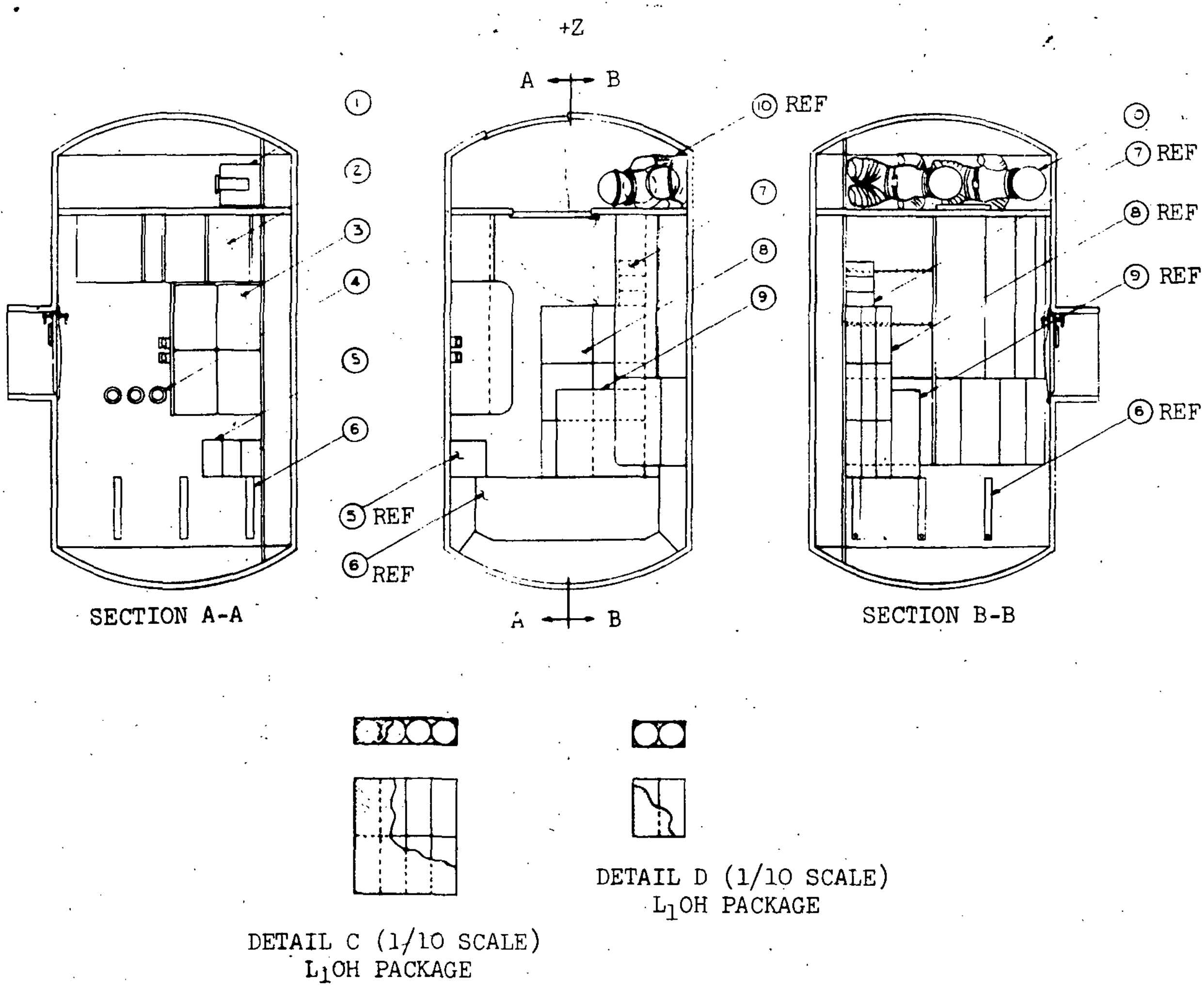

Figure 4-9. Configuration 3B Horizontal Cylinder Profile-Launch Arrangement

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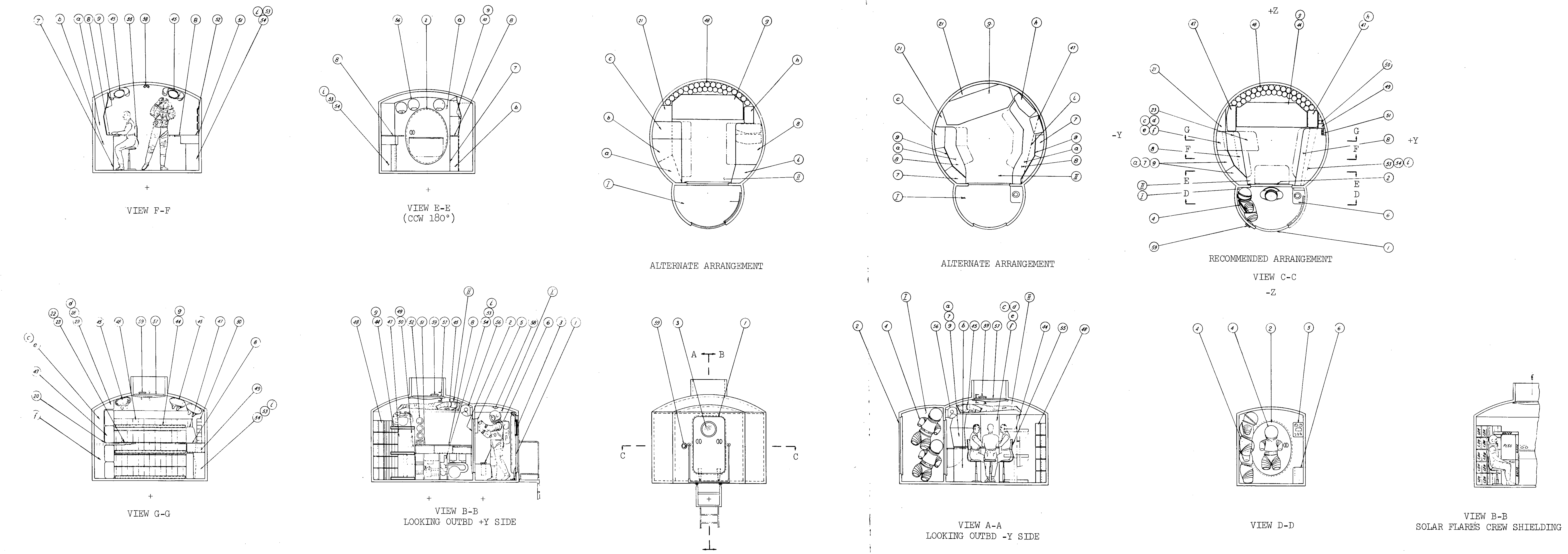

KEY

I. AIRLOCK

1. Door - External Sliding
2. Door - Internal
3. Window
4. Hard Suit (3)
5. Suit Checking Station
6. Waste Management System

II. SHELTER

a. WORK AREA (STATION)

7. Console - Equipment
8. Table - Work
9. Panels & Instruments
10. Radiation Dosimeter
11. Lights - Table (4)

b. SCIENTIFIC EQUIPMENT AREA

12. T.V. Camera
13. Movie Camera
14. Still Camera
15. Extra Film & Tape
16. Data Handling Interface Equipment
17. Theodolite & Ranging Laser
18. Shelter Geology Equipment
19. Gas Analyzer

c. EATING AREA

20. Console - Crew Provisions
21. Food Storage
22. Food Preparation
23. Table - Eating & Recreating
24. Water Probe
25. Hot Plate
26. Utensils
27. Dispenser

d. EXERCISE AREA

28. Hand Ergometer (Optional)
29. Bungee Cord (Optional)

e. RECREATION-STUDY AREA

30. Recreation Equipment

f. STORAGE AREA

31. Personal Storage
32. Personal Hygiene Facilities
33. Medical & Emergency Supplies (Station)
34. Housekeeping Provisions Package
35. Laundry
36. Anti-Meteoroid/Thermal Garments (3)
37. Liquid Cooled Garment (L.C.G.) (3)
38. Constant Wear Garment (C.W.G.) (48)
39. Eva Boots (3)
40. Eva Gloves (3)
41. Suit Spare Parts & Repair Kits
42. Intravehicle Slippers (3)
43. Tools

g. SLEEPING & REST AREA

44. Bunk Beds Removable (3)
45. Soft Suit (3)
46. Light-Portable (3)

h. PLSS CHARGING AREA

47. PLSS (6)
48. LiOH (150)
49. PLSS Battery Charger
50. PLSS Batteries (12)
51. PLSS Calibration Unit
52. Emergency Oxygen System (3)

i. ENVIRONMENT CONTROL AREA

53. ECS Package, Fan & Heat Exchanger
54. Umbilicals (3)

j. MISCELLANEOUS AREA

55. Seats - Foldable (3)
56. Helmets (3)
57. Hatch - Upper
58. Lights - Dome (3)
59. Pressure Dump Valve (2)

Figure 4-10. Configuration 4 Vertical Cylinder Inboard Profile

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The work/living area equipment arrangement shown provides an unobstructed approximately rectangular floor area of about 25 sq ft and about 23 sq ft of work table surface, of which about 40 percent is foldable. Crewmen seated at work stations do not inhibit passage of another man to the airlock or sleep-rest areas.

As in Configuration 3B, a 32-in.-/dia, single-lever operated, quick-opening hatch for emergency use is located in the docking tunnel in the center of the roof dome. This hatch also allows for in-flight manned access to the shelter for checkout purposes.

3. Sleep-Rest/Radiation Refuge

The sleep-rest/radiation refuge area occupies the aft section of the shelter in the form of a chordal volume occupying approximately 250 cu ft which extends from the floor to the roof dome, has a maximum chord depth of 44 in. and chord length of 114 in. It has three bunks which in normal use are tiered and aligned along a chord parallel to the Y axis. As in Configuration 3B, the bunks can be pivoted or repositioned vertically on end to make the 80 ct ft they normally occupy available for use as additional work/living space.

A locker, initially containing 166 lb of food and later used for waste storage, 6 PLSS units, and PLSS batteries are located at the ends of the bunks.

During stay time the 150 LiOH cartridges, provided for CO_2 removal in the backpacks and shelter, are stored in cored polyethylene blankets behind the bunks on the inside face of the shelter pressure wall. Although Figure 4-10 shows all the cartridges uniformally distributed in two layers for use as radiation protection, which is discussed later, the cartridges on both vertical ends of the blanket can be relocated to form 3 layers in the middle section of the blanket and thereby eliminate the contouring of the bunk corners.

At launch, the cartridges are located on the floor, similarly as shown for Configuration 3B, to lower the cg and reduce the loading on the shelter wall during the high-g phases of launch through landing.

The normal sleep-rest arrangement for this shelter configuration is also readily convertible into a radiation refuge in the same way as used for Configuration 3B. The LiOH cartridges in polyethylene blankets and the PLSS units form three sides of the refuge, and water filled compartmented bunks form the fourth side and a partial roof for the refuge. Polyethylene water blankets and strips are used to complete the roof, fill openings between equipment and supplement low density areas of the PLSS units and bunk interfaces.

The enclosed volume accommodates 3 suited crewmen as shown in Figure 4-10. The protection provided by this type of arrangement and the attendent weight penalties are similar to those of Configuration 3B which are covered later in this section.

Structural Arrangements

The structural criteria and loads which were used in the development of the structural arrangements of the shelters and outboard equipment supports are described in Section 4, "Structural Criteria and Loads."

To take advantage of the load carrying capabilities of the LM/Truck cruciform beams for supporting outboard equipment and also have the supporting structures of the outboard equipment amenable to shelter deployment (e.g., leveling of the shelter, orienting it azimuthally or unloading it to the lunar surface), the following ground rules were applied to the development of the structural arrangements:

- For equipment located directly over or in close proximity to the LM/Truck beams, the supporting structures to carry the flight and landing loads will be connected directly to the LM/Truck cruciform beams.
- The shelter structure may be used to react Y and Z axis flight and landing loads on equipment since it can provide this capability for only a small weight increment for the fittings.
- Under postlanding load conditions, the shelter structure will be capable of supporting all externally located equipment and consumables which are directly related to shelter operation and connected to it by electrical or fluid lines.
- The supporting structures for the above equipment will have elements to provide the connections to the shelter and provisions for disconnecting the structural ties to the Truck beams.

1. Configuration 3B Structural Arrangements

The shelter structural arrangement for Configuration 3B is shown in Figure 4-11.

The pressure shell consists of a stiffened thin skin cylindrical shell 97 in. in dia by 162 in. long with 7-ft radius spherical sector end domes; the resulting overall length is 16 ft.

A 35-in.-dia docking ring and tunnel are symmetrically located above the center of the cylindrical shell. The ring is structurally supported by four trusses which are connected to the stiffened shell at the intersections of two upper longerons and the two main frames.

Internally, the shelter has an aluminum honeycomb flat bulkhead located 37 in. from the forward end dome, separating the airlock from the work/living area. An aluminum honeycomb non-pressurized floor, located at a chord height of 12 in., extends throughout the shelter.

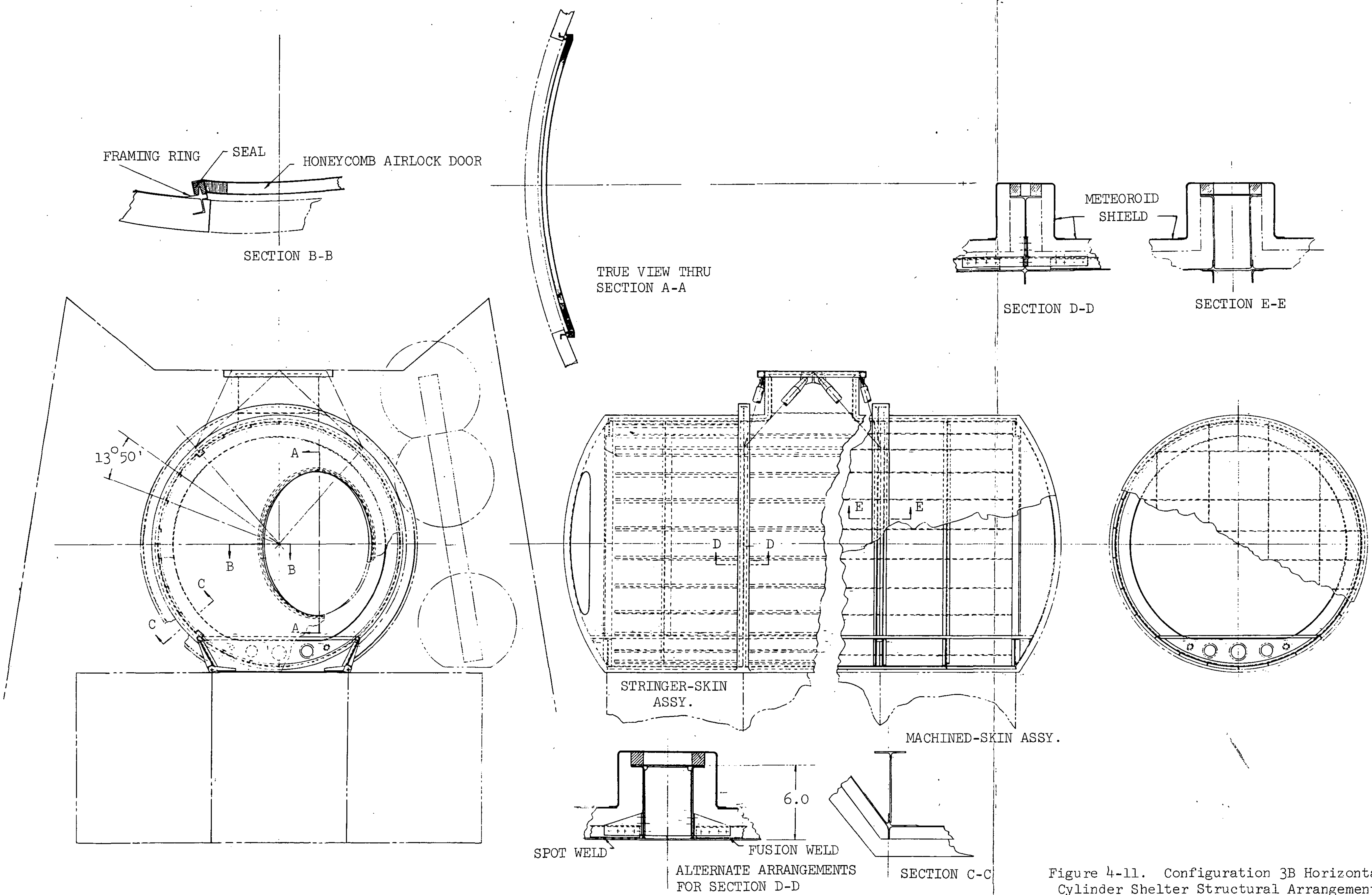

Figure 4-11. Configuration 3B Horizontal Cylinder Shelter Structural Arrangement

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The shelter structure is connected to the LM/Truck by four fittings tying the intersections of the two main frames and lower longerons to the upper caps of the four main beams at their intersection forming the cruciform.

a. Stiffened Cylindrical Shell--Two methods of providing the structural connection of frames and longerons to the cylindrical shell are illustrated in Figure 4-11, the stringer-skin and the machined-skin. The stringer-skin method utilizes circumferential and longitudinal stiffening elements which are welded or riveted to preformed thin sheet skins to produce the shear panels. The required built-up main frames and longerons are, in turn, welded or mechanically fastened to the elements which form the boundaries of the shear panels.

In the machined-skin method, the circumferential and longitudinal stiffening elements are integral with the skin as a result of milling-out the shear panels from a plate and therefore do not require penetrations of the thin sheet skins or cause changes in its properties. The machined peripheral stiffeners are nominally about 0.10 in. thick and 0.75 in. high to accommodate welding or mechanically fastening built-up longerons and frames.

The general arrangement of the stiffened cylindrical shell is the same for both of the above methods of providing structural connections to the shell; a discussion of the various stiffened skin approaches which were considered is given later in Section 4.

The nominal thickness of the skin is 0.030 in. for both of the above methods of providing structural connections to the skin. It is based on the backup sheet requirements for micrometeoroid protection and is more than sufficient for the hoop tension caused by the 11.6 psi burst pressure requirement. To accommodate local discontinuities where frames, bulkhead, and end domes are joined to the skin, its thickness is increased to about 0.065 in. to 0.090 in., as required by the joining member, for about 2 in. on each side of the discontinuity. In most cases this 'land', or thicker portion of the shell, also serves as the inner cap of the I or box beam cross-section of the structural frames.

The cylindrical shell acts as the prime shear carrying member for inertial loading. The shear panels are approximately 10 to 12 in. wide by 27 in. long. The circumferential and longitudinal stiffening elements extending radially outward around the shear panels also provide the locations for fastening the standoffs which are used for supporting the micrometeoroid bumper panels.

Eight main longerons are spaced at approximately 45 deg intervals about the periphery of the cylindrical shell. These longerons plus the effective skin in tension represent the beam bending strength of the stiffened shell for inertial loads. The nominal individual longeron area required is 0.114 sq in. which is increased to about 0.18 sq in. where major loads are reacted such as at the docking ring truss connections, cryogenic tank supports and where the shelter is connected to the cruciform beams.

The stiffened shell has two external main frames which, in conjunction with the longerons, carry the loads from the docking ring, external equipment such as the cryogenic tanks and LSSM, and the shelter to the LM/Truck. They are 54 in. apart and symmetrically located to match the vertical edge members of the LM/Truck cruciform beams. The two main frames are built up externally and may have either an I or box cross-section 6 in. deep with a section modulus of 3 cu in. as shown in Sections D-D or E-E of Figure 4-11.

Internally, there are three light convenience frames to carry the vertical and radial inertia loads on wall mounted internal equipment. Two of the convenience frames are coplanar and built off the main frames; the third is located 27 in. aft of the rear main frame is therefore midway between the main frame and the end dome compression ring. It may be welded or bonded to the skin.

Internally located longitudinal stiffeners, which are bonded to the skin, are used to carry the relatively minor longitudinal loads from equipments which are located too high above the floor for efficient attachment to it.

b. <u>End Domes and Airlock Bulkhead</u>--The micrometeoroid protection backup sheet thickness of 0.030 in. is sufficient for the tension loaded membrane skins of the end domes. A compression ring as shown in Section C-C of Figure 4-11 is used at the dome/cylinder intersection.

The forward end dome has a 42 by 57 in. elliptical opening for the airlock door. It is horizontally offset from the center of the bulkhead by 16 in. This large asymmetrically located opening has a framing ring to resist the membrane tension loads in hoop tension. A framing ring which also provides the surface for supporting the seal for the airlock door is shown in Section A-A of Figure 4-11.

External stiffeners, welded or bonded to the skins of both end domes, provide the locations for fastening the standoffs which are used for supporting the micrometeoroid bumper panels.

The inboard bulkhead, located 37 in. from the forward end-dome, has a 30 by 64 in. cutout with semicircular ends which is horizontally offset from the center of the bulkhead by 8 in. It is constructed of flat honeycomb aluminum approximately 6 in. deep with a 3 to 4 lb/cu ft core and tapered face sheets which have a maximum thickness of 0.040 in. The bulkhead is attached to the cylindrical skin by means of a peripheral edge angle welded or mechanically fastened to a land on the skin; in the latter case a sealant is used to provide pressure integrity.

c. <u>Shelter Floor</u>--The shelter floor, in addition to being a convenience floor for the crew, also reacts the loads from consoles and equipment located on the floor during flight and landing as well as during stay time. The floor consists of flat honeycomb aluminum panels approximately 2 in. deep with 2 lb/cu ft cores and face sheets 0.020 in. thick. The panels are approximately 5 ft wide and have lengths to match the spacings between the frames, bulkhead and end-dome compression rings. The panels are supported by and mechanically fastened to the frames, end-dome compression rings, airlock bulkhead, and to shear ties attached to the cylindrical shell. The floor panels have removable sections to allow rapid access to the space beneath the floor level; also, they can have integral tanks below the lower face for storage of potable water or waste liquids.

d. Docking Ring and Tunnel--To accommodate the docking tunnel and in-flight hatch a thickened skin, increasing from 0.030 in. to approximately 0.090 in. over a radial distance of about 5 in., is used in addition to an edge member which provides the sealing surface. The tunnel section may be welded or mechanically fastened to the cylindrical shell skin outboard of the hatch sealing surface edge member. If mechanically fastened, sealant would be used to provide the pressure integrity for the docked checkout phase of the flight.

The docking ring is supported by four trusses made from 3 in. dia by 0.063 in. wall thickness aluminum tubing. The trusses are connected to the docking ring at 4 equidistant places about its periphery and to the stiffened cylindrical shell at the intersections of the two main frames and two of the upper main longerons which are located approximately 45 deg on either side of the vertical centerline.

The outboard equipment structural arrangement for Configuration 3B is shown in Figure 4-12.

As previously considered, the outboard equipment consists of two groupings:

- Equipment and consumables which are directly related to shelter operation such as the cryogenic tankage and fuel cell assemblies

- Equipment related to extra-shelter activities, namely, the scientific equipment packages and the LSSM

e. Cryogenic Tanks--It was assumed that each cryogenic tank would have three thermally isolated points of support located at 90 deg intervals on a common circle; the two points 180 deg apart would have torque restraint provisions.

As shown in Figure 4-12, each tank is supported on diametrically opposite sides by tubular trusses and by a tubular link oriented at 90 deg to the approximately parallel planes of the trusses. A common member in each truss is used to carry the X direction flight and landing loads from both tanks to the LM/Truck cruciform beams at ±27 Z, - 75 Y. This member is 2 in. dia aluminum tube with an 0.065 in. wall thickness. The Y direction loads on each tank are carried separately by the truss members which are connected tangentially to the two main frames of the shelter structure.

The Z direction loads on each tank are carried from the center support point on the tank to the shelter structure by a horizontal tubular link which is parallel to the shelter longitudinal axis and differentially by the trusses to the cruciform beams.

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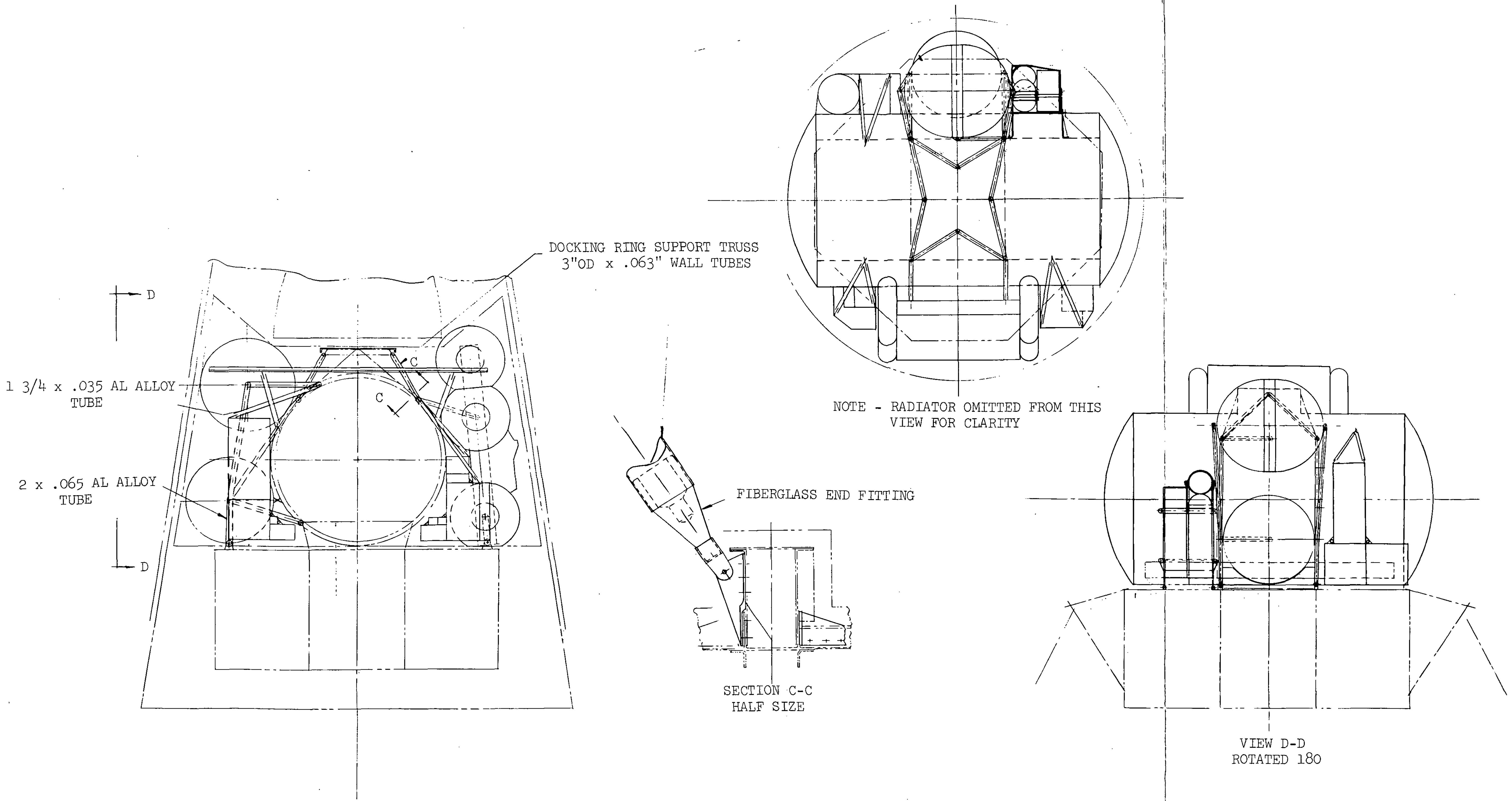

Figure 4-12. Configuration 3B Horizontal Cylinder Outboard Equipment Structural Arrangement

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For post landing support of X direction loads independently of the LM/Truck, a member of each truss carries the X direction loads on both tanks from the common truss connection at the O_2 tank trunnion to a tangential fitting on each main frame.

Except for the above cited dimensions of the truss member connected to the LM/Truck beam, all other truss members and the Z direction horizontal links are 1-3/4 in. dia aluminum tubes with an 0.035 in. wall thickness. All truss connections to the shelter have fiberglass interfaces for thermal isolation.

f. Fuel Cell Assemblies, Power Conversion and Electronic Equipments--Since in the outboard profile the consideration of a third fuel cell assembly was primarily to show that it could be accommodated, for the structural arrangement the power conversion and the electronic equipments were reoriented 90 deg in the Y Z plane to position the cg of the combined mass in closer proximity to the LM/Truck cruciform beam.

A common structural frame is used to contain the two fuel cell assemblies, FCA collector tank, power conversion and electronic equipments. The lower member of the frame face in close proximity to the cryogenic tanks is connected by fittings to the LM/Truck cruciform beams. The vertical corner members of the frame face adjacent to the shelter structure are connected to the middle longeron, the aft main frame and the aft convenience frame of the shelter structure. The prelanded X direction loads are carried by the cruciform beam and the convenience frame, the Y direction loads differentially by the cruciform beam, and the Z direction loads by the longeron and cruciform beam.

For post landing loads, without the connections to the truck, the two shelter frames and middle longeron react all the loads from the equipment container/frame.

g. Thermal Control Radiators--The inboard and outboard edges of each radiator are connected by fittings to the upper longeron where it intersects the two main frames and each of the end-dome compression rings. These four fittings carry the Y and Z direction loads and part of the X direction loads. The remainder of the X direction loads are carried by a series of aluminum struts, 0.75 in. in dia with a wall thickness of 0.028 in., from radiator hardpoints to connections at the main frames and end-dome compression rings.

h. Scientific Equipment--Considering the number of individual packages and the variety of sizes, shapes, and masses, it was assumed that the clusters of equipment as shown in the outboard profile, Figure 4-6, would be housed in structural container/frames, minimizing the number of individual connections to the shelter and LM/Truck and facilitating the application of dynamic mounts for the individual items.

The structural connection of the scientific equipment container/frames to the LM/Truck and shelter would be as previously described for the fuel cell assemblies, etc., with the probable exception of complete support by the shelter for post landing loads, which is necessary only to allow various forms of shelter deployment.

Equipment container/frames which are not located directly over or in close proximity to the LM/Truck beams, such as on both sides of the LSSM, utilize shear webs connected to the end dome compression rings and convenience frame, or airlock bulkhead edge member, to react all vertical loads.

i. LSSM--The storage configuration of the LSSM was considered as a rigid structural unit capable of carrying its own loads between tie down points and having a self-contained force system to deflect the wheels. It was assumed that fittings could be attached to the LSSM to provide two sets of tie-downs, the tie-downs of each set being 54 in. apart to match the spacing of the shelter main frames and the LM/Truck beams.

The LSSM is supported at the forward end of the chassis by two fittings mounted directly to the LM/Truck beams at ±27 Z, ±81 Y and at the aft end by two links from the main chassis, near the center wheel support, to the two main frames of the shelter structure. The two fitting connections to the LM/Truck beams carry all the LSSM loads in the X and Z directions. The Y direction loads are carried by the forward end fittings to the LM/Truck and the upper links, which are 1/2 in. dia aluminum tubing with an 0.035 in. wall thickness.

2. Configuration 4 Structural Arrangements

The shelter structural arrangement for Configuration 4 is shown in Figure 4-13. The pressure shell consists of two parallel, 74-in.-high, intersecting, stiffened thin skin cylindrical shells with spherical sector roof domes and an aluminum flat honeycomb floor. The main cylindrical shell has a 58.5-in. radius and its roof dome has a 108-in. radius. It intersects the airlock cylindrical shell, which has a 36-in. radius and a roof dome radius of 97.7 in., along a common chord 68 in. wide.

A 35 in. dia docking ring and tunnel are symmetrically located above the center of the main cylindrical shell; the ring is structurally supported by four trusses which are connected to the intersection of the four inverted-U shaped main frames used to carry docking and shelter loads to the LM/Truck.

Internally, the shelter has a aluminum honeycomb flat bulkhead located at the chord of intersection, which is 47 in. forward of the center of the main shell, separating the airlock from the work/living area.

The shelter structure is connected to the LM/Truck by eight fittings tying the lower ends of the four main frames to the four beams forming the cruciform.

a. Stiffened Cylindrical Shells--The methods of providing circumferential and longitudinal stiffening elements to produce shear panels are the same as for Configuration 3B.

Also the nominal 0.030 in. skin thickness, required for the micrometeoroid backup sheet, is more than sufficient for the 11.6 psi burst pressure requirement; and as for Configuration 3B, local discontinuities where structural members are joined to the skin are accommodated by increasing the skin thickness to about 0.065 to 0.090 in. for approximately 2 in. on each side of the discontinuity.

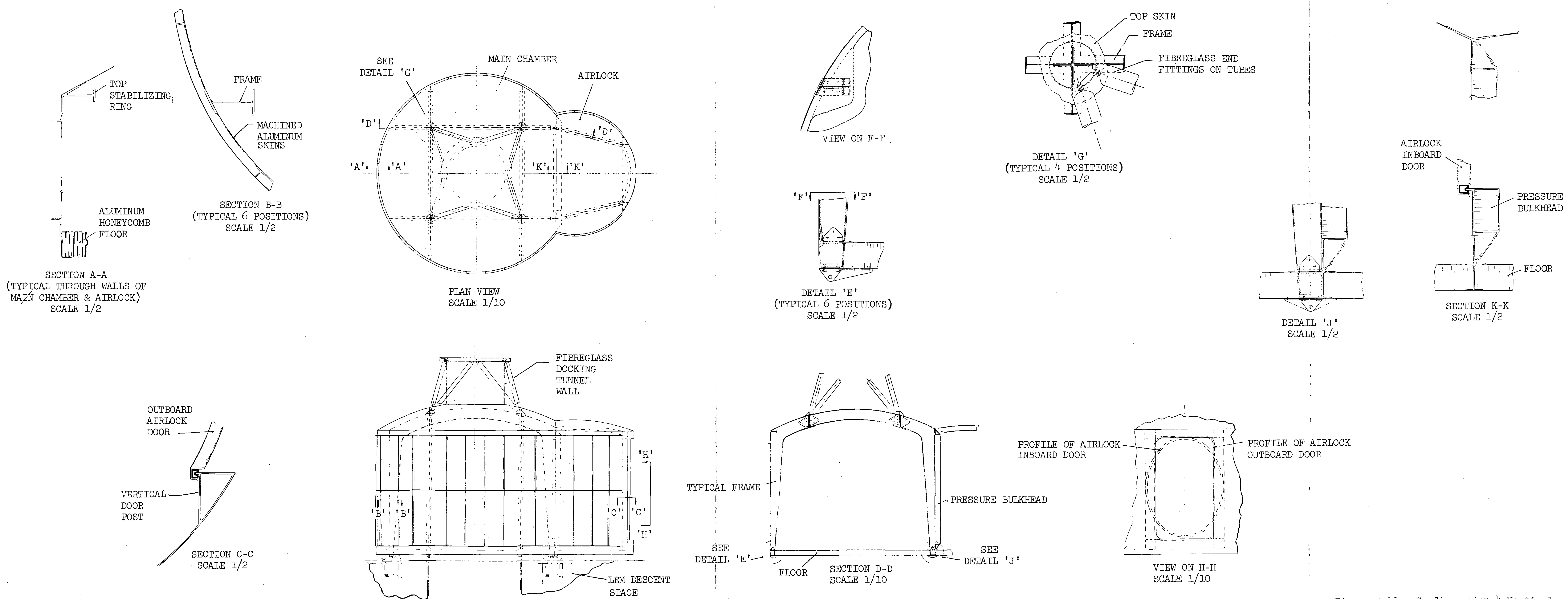

Figure 4-13. Configuration 4 Vertical Cylinder Shelter Structural Arrangement

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The shear panels for this configuration are approximately 12 in. wide by 32 in. high and, except at six locations where the main frames join the stiffened skin, have radially outward extending vertical and horizontal stiffening elements of approximately 0.1 sq in. cross-sectional area. These stiffeners also provide the locations for fastening the standoffs which are used for supporting the micrometeoroid bumper panels.

The main cylindrical shell has four inverted-U main frames, located internally, to carry the loads from the docking ring, external equipment, and shelter to the LM/Truck. They are symmetrically located with respect to the centerline of the main cylindrical shell and are arranged as orthogonal pairs of frames, the frames of each pair are 54 in. apart to match the LM cruciform beam edge-member spacing. The frames have an I cross-section with a maximum depth of 6 in. and 3-in.-wide flanges which are approximately 0.12 in. thick. The depth of the I section for the vertical legs of the frames tapers from the maximum of 6 in. at the top to approximately 3 in. at the fittings which attach the shelter to the truck beams. The outer flanges of the frames are locally thickened areas of the main cylindrical shell and roof dome; the use of the cylindrical shell skin as a flange is shown in Section B-B of Figure 4-13.

Eight longerons arranged coincident with the vertical legs of the four main frames would provide the beam strength to the stiffened main cylindrical shell for inertial loads. The nominal individual longeron area required is approximately 0.15 sq in. The section properties of the vertical legs of the frames as described above also satisfies these requirements.

The internal location of the eight legs of the four frames allows their direct use for carrying the vertical and radial inertial loads on wall mounted internal equipment and consoles. Internally located intercostal horizontal stiffeners attached to the skin are used to carry the relatively minor tangential loads from equipments which are too high above the floor for efficient attachment to it.

The airlock cylindrical shell has a 34- by 60-in. rectangular opening for the airlock door; it is symmetrically located with respect to the intersection with the main cylindrical shell. The reinforcing edge-members consist of two vertical posts, a lintel, and a coaming, supported directly from the honeycomb pressure floor. The vertical posts carry the bending and torsion loads from the pressurized door reactions and hoop tension in the cylindrical shell. As shown in Section C-C of Figure 4-13 they are triangular tubes with 0.12-in.-thick sidewalls which are approximately 4 in., 6 in., and 7 in. wide. The loads in the posts are reacted by the floor and two internal I-beams, having flanges integral with the roof dome skin, connected to two of the main cylinder frames. The lintel over the opening is a 6- by 3-in. boxbeam with 0.12 in. thick walls which acts as a balcony beam and transfers the roof dome membrane loads across the top of the opening to the vertical posts. The coaming is similar in size to the lintel but of lighter wall thickness.

b. <u>Roof Domes and Airlock Bulkhead</u>--The micrometeorid protection backup sheet thickness of 0.030 in. is sufficient for the tension loaded membrane skins of both roof domes. A compression ring, as shown in Section A-A of Figure 4-13, is used at the dome/cylinder intersection of the main cylindrical shell; a similar arrangement is used for the airlock cylindrical shell and roof dome. At their chordal intersection, the roof domes are welded to a common reinforcing element which also is used to support the upper edge of the internal airlock bulkhead as shown in Section K-K of Figure 4-13. As for the end domes in Configuration 3B, external stiffeners attached to the skins of both roof domes provide the locations for fastening the standoffs for the micrometeoroid bumper.

The inboard bulkhead, located in the plane of the intersection of the two cylindrical shells, has a symmetrically located 42- by 57-in. elliptical opening for the airlock door. It is aluminum flat honeycomb approximately 4 in. deep with a 3 to 4 lb/cu ft core and tapered face sheets which have a maximum thickness of 0.060 in. The forward vertical legs of the Z direction main frames are connected to the bulkhead and thereby help minimize the deflection of the edge reinforcing ring around the opening. The bulkhead is attached to the cylindrical shells at their intersections with a common reinforcing element similar to that used at the roof dome intersection. The connection between the bulkhead and the pressure floor is provided by a single line attachment of the bulkhead edge member to an I-beam integral with the floor. Therefore, no bending moments due to deflection of the bulkhead are transferred to the floor. The arrangement of this lower edge connection is shown in Section K-K of Figure 4-13.

c. Shelter Floor--The pressure retaining floor is an aluminum flat honeycomb 3 in. deep with a 3 to 4 lb cu ft core and tapered face sheets which have a maximum thickness of 0.050 in. As shown in Section A-A of Figure 4-13, an edge member is used to provide continuous structural connection between cylindrical shells and the floor. An integral I-beam accommodates the pressure tight structural connection of the airlock bulkhead to the floor.

d. Docking Ring and Tunnel--The docking tunnel connection to the main cylinder roof dome and accommodation of an in-flight access hatch is similar to that described for Configuration 3B.

The docking ring for this configuration is supported by four trusses made from 2-1/2-in.-dia by 0.063-in.-wall-thickness aluminum tubing. The trusses are connected to the docking ring at four equidistant places about its periphery and to the stiffened main cylindrical shell at the four intersections of the main frames as shown in detail G of Figure 4-13. A fiberglass fitting is used at the shelter end of each truss member to provide thermal isolation between the docking ring and shelter.

The method used to transfer the loads from the eight legs of the main frames through the floor to the LM/Truck tie-down fittings is shown in details E and J of Figure 4-13. The legs of the frames terminate slightly above the inner face sheet of the floor. At each leg location, the floor contains a fitting which has a tongue that protrudes through the inner face sheet of the floor to allow a mechanical connection to the frame leg. Pressure integrity of the floor is maintained by a sealing weld around the tongue where it passes through the face sheet. Each tiedown fitting is attached to the fitting integral with the floor by bolts which pass through the lower face sheet.

The outboard equipment structural arrangement for Configuration 4 is shown in Figure 4-14. As in Configuration 3B, the equipment consists of two main groupings, one related to shelter operation and the other to extra-shelter activities.

e. Cryogenic Tanks--It was assumed that each cylindrical cryogenic tank would have end cones with support points at each apex; the upper support point would have torque restraint provisions. As shown in Figure 4-14, the X direction flight and landing loads on the forward H_2 tank and the O_2 tank are carried by fittings connecting their lower support points to the LM Truck cruciform beam. Two 0.020-in.-thick shear webs connecting the cylindrical section of the aft H_2 tank to two legs of the shelter main frames carry all the X direction loads on that tank. The Y and Z direction loads on the forward H_2 tank and the O_2 tank are carried by a common truss between the tops of all the tanks and the shelter structure and by the fittings, under the tanks, to the LM/Truck cruciform beam. The Y and Z direction loads on the aft tank are carried by the upper common truss and a truss connecting the lower support point to the shelter floor at two frame leg locations.

For post-landing support of the X direction loads on the forward H_2 tank and on the O_2 tank independently of the LM/Truck, a separate compression strut for each tank carries the loads from a fitting at the cone periphery/tank interface to the edge member of the honeycomb floor. A lower truss, with the same configuration as the upper truss, provides the Y and Z direction support of these tanks independently of the truck.

The truss members carrying the flight and landing loads on the O_2 tank are 1-1/2-in.-dia aluminum tubes with an 0.030-in. wall thickness; all other truss members are 3/4-in.-dia aluminum tubes with an 0.030-in. wall thickness. All truss and shear web connections to the shelter are thermally isolated from it.

f. Fuel Cell Assemblies, Power Conversion and Electronic Equipments--As in Configuration 3B, a common structural frame is used to contain two fuel assemblies, FCA collector tank, power conversion, and electronic equipments. All the loads on the container/frame are transferred to the shelter by horizontal and vertical shear webs. The vertical webs are connected to the vertical leg of the forward transverse main frame and to the reinforcing element at the common intersection of the cylindrical shells and ther internal bulkhead. The horizontal webs are connected to the floor edge member and the roof dome/cylindrical shell compression ring; the frame extends above the equipment contained in it to allow the latter connection.

g. Thermal Control Radiators--The lateral loads on the radiators are carried by four fittings connecting their inner edges to the intersections of the four main frames at the roof dome. The vertical loads are carried by the four fittings carrying the lateral loads and six struts connecting the outer periphery of the radiators to four main frame legs and to the two vertical door posts of the overboard airlock door opening. The struts are 0.75 in. aluminum tubes with a wall thickness of 0.028 in.

h. Scientific Equipment--As in Configuration 3B, the scientific equipment is housed in structural container/frames.

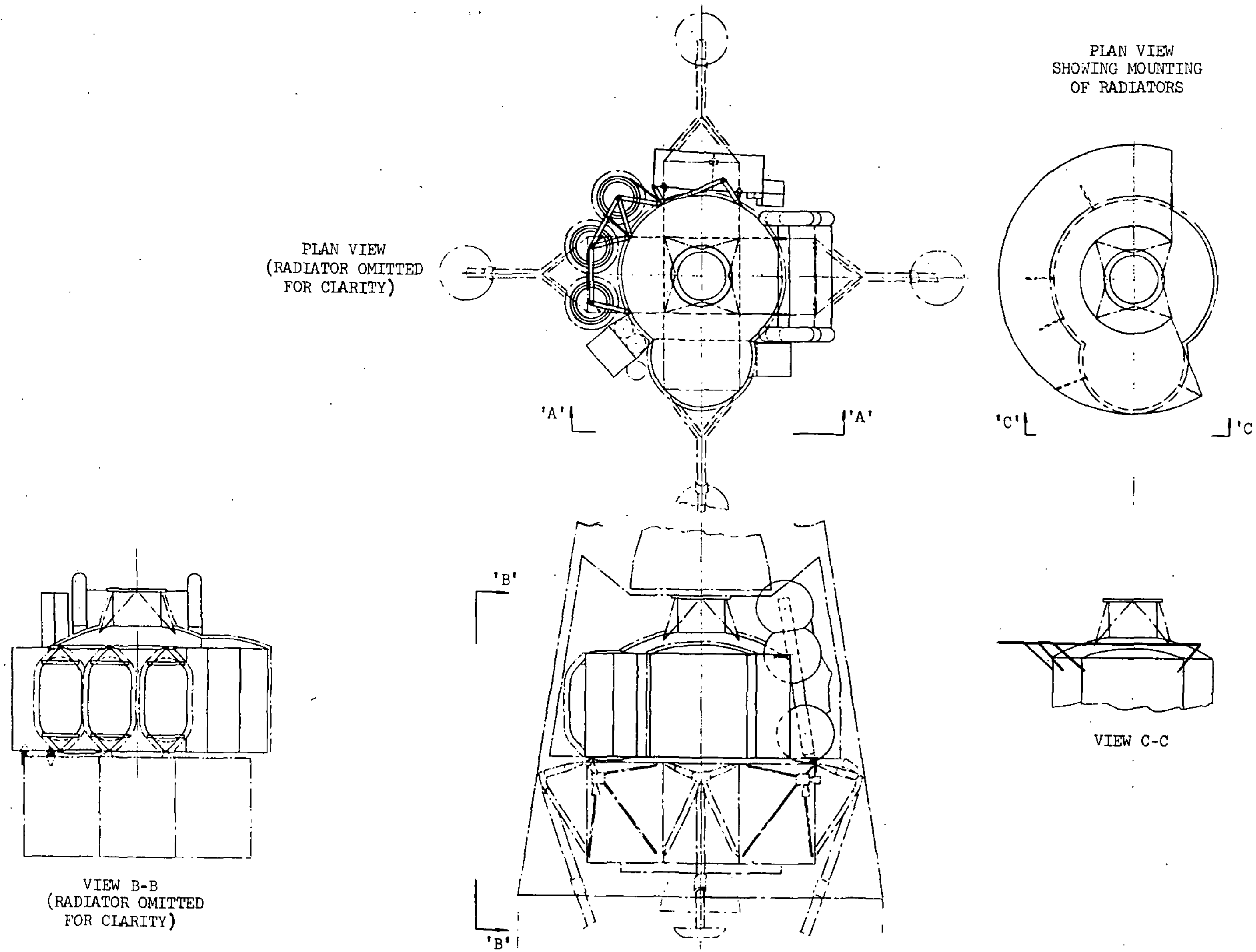

Figure 4-14. Configuration 4 Vertical Cylinder Outboard Equipment Structural Arrangement

The grouping of scientific equipment forward of the LSSM is supported in a manner similar to that used for supporting the fuel cell assemblies, etc. The vertical shear webs are connected to the vertical stiffening member of the skin shear panel and the reinforcing element at the common intersection of the cylindrical shells and airlock bulkhead. The horizontal shear webs are connected to the floor edge member and the horizontal intercostal located at the mid height of the airlock stiffened skin.

The equipment grouping aft of the LSSM is supported in a manner similar to that used for the above grouping.

The container/frame of equipment located aft of the shelter is connected to the cruciform beams by two fittings and to the two aft legs of the Z direction main frames, near the dome compression ring, by two struts. The truck beams carry the X and Y loads; they Y direction loads are reacted differentially. The Z direction loads are carried by the truck fittings and the two fittings to the frame legs.

i. LSSM--The same assumptions for the LSSM in the storage mode for Configuration 3B were applied in this configuration.

The LSSM is supported at the forward end of the chassis by two fittings mounted directly to the LM/Truck beams at ±27Z, ±81Y and at the aft end by two fittings from the LSSM main chassis to the intersections of the dome/shell compression ring and the vertical legs of the transverse main frames. The two fittings connections to the LM/Truck beams carry all the LSSM loads in the X and Z directions. The Y direction loads are carried by the forward end fittings to the truck and the main chassis fittings to the compressing ring/leg intersections.

Mass Summaries

The mass summaries for Configurations 3B and 4 are shown in Table 4-3. To provide a broader base for comparing the two configurations, the summaries include the structural and protection provisions directly related to shelter configuration and overall payload arrangement such as outboard equipment supports and micrometeoroid protection provisions.

The following paragraphs discuss or describe the considerations pertinent to the masses shown in the table.

The weights of the shelter structure are for the machined skin method of providing a stiffened aluminum (2219-T87) skin.

As discussed previously in this section, shelter internal equipment and supplies provide the majority of the required shielding for a radiation refuge. Since the equipment and supplies are the same for both configurations and the resulting refuge configurations are also approximately the same, the additional shielding required is the same. Early in the study, it appeared that 400 lb of aqueous liquids would be on board; the 170 lb shown in the table is for polyethylene and additional water.

TABLE 4-3

MASS SUMMARIES CONFIGURATIONS 3B & 4

Equipment	Configuration 3B - Horizontal Cylinder KG	(LBM)	KG	(LBM)	Configuration 4 - Vertical Cylinder KG	(LBM)	KG	(LBM)
Shelter Structure			372	(820)			420.0	(926)
Pressure Skin and Hands	88.5	(195)			59	(130)		
Stringers and Longerons	18.2	(40)			27.2	(60)		
Frames	47.6	(105)			56.7	(125)		
Airlock Inner Bulkhead, Door and Mechanism	65.8	(145)			68.1	(150)		
Overboard Door and Mechanism Penalty	25.0	(55)			22.7	(50)		
Floor and Supports	43.1	(95)			113.4	(250)		
Docking Structure and Hatch	38.6	(85)			36.3	(80)		
Viewing Ports	27.3	(60)			27.2	(60)		
Fittings	18.2	(40)			9.5	(21)		
Meteoroid Protection (Exclusive of backup sheet)			61.2	(135)			52.2	(115)
Bumper Panel	36.3	(80)			29.5	(65)		
Standoffs	4.5	(10)			4.5	(10)		
Foam	20.4	(45)			18.2	(40)		
Thermal Insulation (30 sheets SI)			11.3	(25)			10.9	(24)
External Equipment Supports			122.5	(270)			106.8	(235)
Internal Equipment Supports			100.0	(220)			100.0	(220)
Radiation Refuge Additional Provisions			77.1	(170)			77.0	(170)
Equipment Unloading, Crew Access			43.1	(95)			43.1	(95)
Total			788	(1735)			810	(1785)

The weights for the internal structural provisions were assumed to be the same for both configurations and were estimated based on reviews of previous studies, LM, and AAP studies.

The thermal protection weight was based on the AiResearch specified requirement of 1/2 in.-30 sheets of super insulation covering the total external surface area of the shelter. The micrometeoroid protection weights shown are in addition to the backup sheet requirements. For Configuration 3B, the total surface area of the shelter minus the area protected by the LM/Truck (lunar surface) was considered as requiring protection. For Configuration 4, the total surface area of the shelter minus the flat floor area was considered as requiring protection. For both configurations, the reduction of exposed area due to the protection afforded by the external equipment was not considered; the effective shadow areas are dependent on the 'as landed' position, some of the equipment would be removed at the beginning of staytime and it was considered that the foam would still be retained in the shadowed areas to provide a smooth surface for the superinsulation. Similarly the bumper would protect the insulation during equipment unloading or crew inspection of the shelter. The potential weight saving by not using the bumper in the shadowed areas is comparatively small.

The unloading, handling provisions and walkways are for the deployment of the LSSM, scientific equipment, and crew access between the truck mounted shelter and the lunar surface.

Recommended Configuration

The Horizontal Cylinder 3B was selected as the recommended configuration based on the following considerations:

- Greater volume at a lower weight
- Form factor, i.e., length to diameter ratio, allows more favorable arrangement of equipment and duty stations from crew habitability viewpoints
- Structural arrangement easily accommodates changes in volume goal, with minimum redesign, by simple changes in length of horizontal cylindrical shell
- More readily adaptable to derivative modes such as addition of mobility systems
- Alternative large experiment payloads, e.g., optical astronomy package, more easily accommodated by the chordal volume rather than annular volume between the side of the shelter and the payload envelope
- Simpler to fabricate

STRUCTURAL CRITERIA AND LOADS

A review of the structural criteria used on the AAP shelter program with those given in the study guidelines (Reference 1) shows that there are some differences in design levels which do not appear to have a significant impact on the structural design for this study. It is estimated that these differences will not vary the structural member sizes by more than a few percent in material thickness and, hence, the estimated weight. In view of the above, and in order to make the results of this study more readily comparable with those of the AAP shelter program, the ELS design study used the structural criteria and loads of the AAP shelter.

Design Loads Criteria

1. Design Factors

At mission levels times the ultimate factor of safety there shall be no failure of structural members. The ultimate factor shall not be less than 1.5 applied to mission levels.

Pressure vessels shall be designed to a burst pressure which is equal to twice the maximum pressure. For purposes of this design the cabin structure will be designed using the above criteria.

The design limit factor for the vibration conditions is 1.3 applied to the g and double amplitude and $(1.3)^2$ applied to random vibrations (g^2 per cps) for fatigue critical structure.

For strength-critical structures, the factor is 1.5 applied to g and DA and $(1.5)^2$ applied to random vibrations (g^2 per cps).

Mission Level Loads and Accelerations

1. Launch and Boost Conditions

Launch and Boost C-5	X		Y		Z	
Acceleration (2)	g	Rad/sec^2	g	Rad/sec^2	g	Rad/sec^2
List off condition	+1.60	--	±0.65	--	±0.65	--
Maximum q condition (S-IC)	+2.07	--	±0.30	--	±0.30	--
Boost condition (S-IC)	+4.90	--	±0.10	--	±0.10	--
Cut off condition (S-IC)	-1.70	--	±0.10	--	±0.10	--
Engine hardover (S-II)	+2.15	--	±0.40	--	--	--
Engine hardover (S-II)	+2.15	--	--	--	±0.40	--
Earth orbit	0	0	0	0	0	0

Vibration

The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

INPUT TO EQUIPMENT SUPPORTS

From Exterior Primary Structure

Random

10 to 23 cps	12 db/octave rise to 0.0148 g^2/cps
23 to 80 cps	
80 to 105 cps	12 db/octave rise to 0.044 g^2/cps
105 to 950 cps	
950 to 1250 cps	12 db/octave decrease to 0.048 g^2/cps
1250 to 2000 cps	

Sinusoidal

5 to 18.5 cps	0.154 in DA
18.5 to 100 cps	2.69 g peak

20 → 2000 cps

From Interior Primary Structure

Random

10 to 23 cps	12 db/octave rise to 0.0148 g^2/cps
23 to 80 cps	
80 to 100 cps	12 db/octave rise to 0.0355 g^2/cps
100 to 1000 cps	
1000 to 1200 cps	12 db/octave decrease to 0.0148 g^2/cps
1200 to 2000 cps	

Sinusoidal

5 to 16 cps	0.154 in DA
16 to 100 cps	1.92 g peak

For design purposes the above random spectrum applied for 5 min along each of the three mutually perpendicular axes X, Y, and Z when applied in addition to the corresponding sinusoidal spectrum acting for 5 sec at the natural frequency of the equipment being designed will adequately represent the environment.

During the launch and boost phase of flight, the LM is exposed to random vibration of varied levels and spectra for 17 min. During all but approximately 2.5 min of this period, the intensity of the random vibration is of such low level that it is considered to be of negligible design significance. In addition, the launch and boost environment is considered to include peak vibration levels which are represented by the above sinusoidal vibration envelopes. The number of sinusoidal peaks for design can be considered to be one percent of the natural frequency of the equipment being designed times the number of seconds of exposure. For design purposes, the above random spectrum applied for 5 min along each of the three mutually perpendicular axes X, Y, and Z, when applied in addition to the above sinusoidal vibration for 300 sec exposure time, will adequately represent the vibration environment.

Vibration levels may be lower at specific equipment locations due to the reaction of equipment on primary structure. Therefore, a rationally demonstrated reduction in those levels may be used for LM equipment design and test.

<u>Launch and Boost C-5</u>

Acoustics:
(sound pressure levels in db external to LM) (re 0.002 dynes/cm^2)

Octave Band, cps	C5 at Maximum q Level, db
9 to 18.8	136
18.8 to 37.5	142
37.5 to 75	146
75 to 150	143
150 to 300	139
300 to 600	135
600 to 1200	130
1200 to 2400	125
2400 to 4800	119
4800 to 9600	113
Overall	150

	X		Y		Z	
Acceleration	g	Rad/sec^2	g	Rad/sec^2	g	Rad/sec^2
SM prop system operating	-0.36	--	±0.062	±1.99	±0.062	±1.99
SM prop system not operating	0	0	0	0	0	0
Shock						
Condition transposition	-0.052	--	±0.065	±0.10	±0.065	±0.10

Vibration

SM prop system operating — N O N E

Plume Effects

Due to engines
Due to RCS
} to be supplied

In addition to the loads resulting from the above accelerations, the primary structure is subjected to the forces resulting from docking maneuvers and the mid-course correction maneuver during translunar flight. Most of the primary structure is designed for the mid-course maneuver condition with the loads applied to the docking collar at station 317. For the local docking structure the critical condition is axial load = 14,900 lb, moment = 548,000 in.-lb, and shear = 3030 lb ultimate. The value of 548,000 in.-lb corresponds to 366,000 in.-lb limit. The original value of 306,600 in.-lb limit was revised to 366,000 in.-lb. Subsequent to the calculation of these loads, the AAP loads due to mid-course maneuver were revised downward, therefore the use of the above is conservative and satisfactory for this analysis. It should be noted that a final analysis will include the changes in mass properties as compared to AAP. The current AAP values are included in the table below for reference.

MIDCOURSE CORRECTION MANEUVER - LIMIT INTERFACE LOADS

Interface Loads \ Condition	SPS Nominal Thrust Buildup			SPS Maximum Thrust Buildup		
	Maximum Moment Shear Torsion	Maximum Axial	Minimum Axial	Maximum Moment	Maximum Axial	Minimum Axial
Bending moment	174,000	52,800	144,000	46,400	8,230	13,100
Shear	940	230	390	320	66	110
Axial load	-15,400	-19,350	-4,000	-13,800	-24,600	19,900
Torsion	-15,200	-13,800	-3,960	0	0	0

The shear and binding loads may be applied about any axis in the Y-Z plane.

3. <u>Descent and Landing</u>

Accelerations	X		Y		Z	
	g	Rad/sec^2	g	Rad/sec^2	g	Rad/sec^2
Descent engine operating	+0.82	±0.19	±0.08	±0.65	±0.08	±0.65
Transfer orbit	0	0	0	0	0	0
Landing: Steady State at CG of LM						
Case 1	0.798	±0.036	±1.778	-0.016	0	±14.56
Case 2	0.798	0	0	17.60	1.778	0
Case 3	0.857	±15.82	±0.095	9.05	-0.421	± 0.573
Case 4	2.74	0	0	±28.1	±0.514	0
Case 5	2.74	±0.01	±0.514	-0.055	0	±23.3

Shock:	X		Y		Z	
	g	Rad/sec^2	g	Rad/sec^2	g	Rad/sec^2
Landing: 20 ms Rise Time 200 ms Dwell Time - 40 ms Decay						
Case 1	8.0			±14.0		
Case 2			±8.0			±14.0
Case 3				±14.0	±8.0	
Case 4	8.0					±14.0

Vibration: The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

INPUT FROM PRIMARY STRUCTURE

(Appropriate Account Must be Taken for Transmissibility of Secondary Struct.)

To Ascent Stage Equipment Support

Random

10 to 20 cps	12 db/octave rise to 0.02 g^2/cps
20 to 100 cps	
100 to 120 cps	12 db/octave decrease to 0.01 g^2/cps
120 to 2000 cps	

Sinusoidal

5 to 17 cps	0.10 in. DA
17 to 100 cps	1.5 g peak

To Descent Stage Equipment Support

15 to 100 cps	0.031 g^2/cps
100 to 175 cps	6 db/octave decrease to 0.010 g^2/cps
175 to 2000 cps	

Sinusoidal

5 to 20 cps	0.10 in. DA
20 to 100 cps	1.92 g peak

For design purposes the above random spectrum applied for 12-1/2 min along each of the three perpendicular axis X, Y, and Z, when applied in addition to the corresponding sinusoidal spectrum acting for 12-1/2 sec at the natural frequency of the equipment being designed will adequately represent the environment.

Cabin Pressure

The internal pressure used for the design of the basic pressure shell is 5.8 psia times a safety factor of 2.0 for ultimate burst pressure. This value is 11.6 psia ultimate. Where the pressure load is combined with other loads, the safety factor is 1.50.

Vibration and Acoustics

For preliminary structural design, sinusoidal levels can be used to obtain g load factors for equipment support structures.

Design load factors as a function of equipment weight for LM equipment have been collated and are presented in Figures 4-15, 4-16, and 4-17. This data may be used for first-cut sizing of comparable ELS equipment supports. Since AAP and LM sinusoidal levels at low frequencies are higher than NASA guideline values these loads should be conservative. It should be noted, however, that load factors are a function of equipment and backup support structure stiffness as well as mass, and stiffness effects should be accounted for as soon as preliminary sizing information becomes available.

In-situ Deployment

For all in-situ deployment operations an overall safety factor of 2.0 on the lunar surface applied loads is used.

This was considered adequate for powered as well as manual operations since in the former case all accelerations and transients would be very small and the drive mechanisms would have inherent shock attenuating elements such as wire rope cables.

AIRESEARCH MANUFACTURING DIVISION
Los Angeles, California

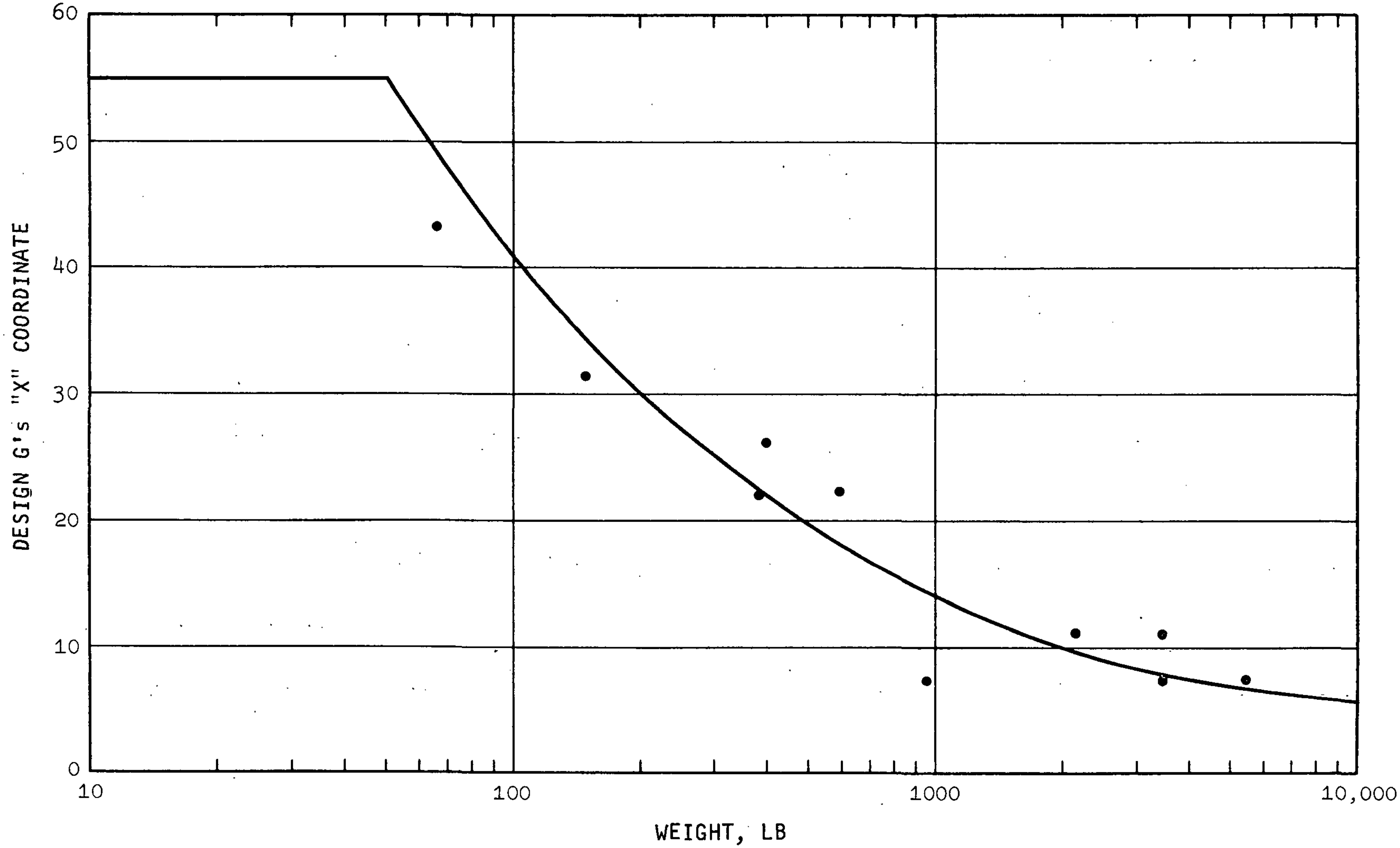

Figure 4-15. Vibration Response Weight vs G's X Coordinate

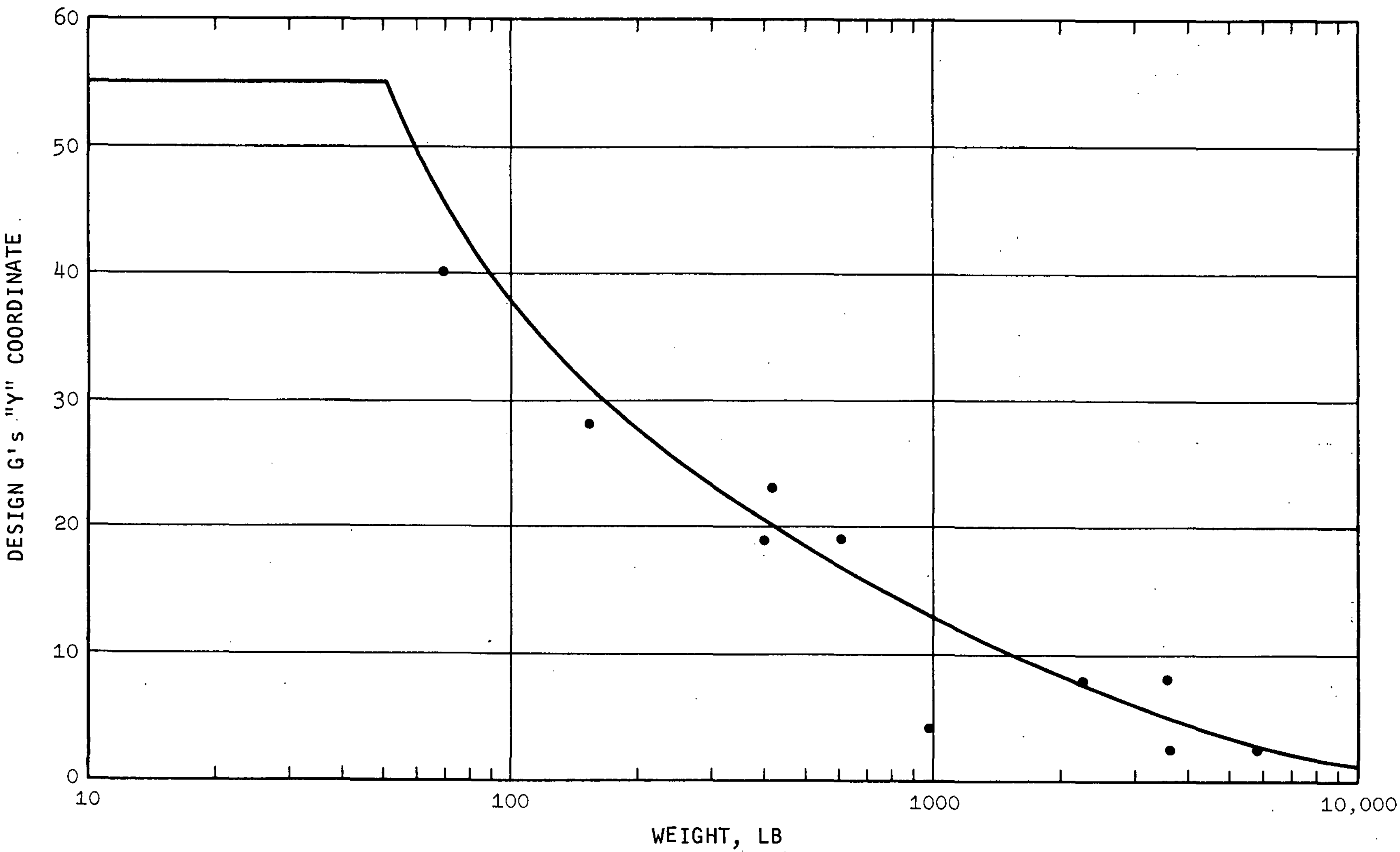

Figure 4-16. Vibration Response Weight vs G's Y Coordinate

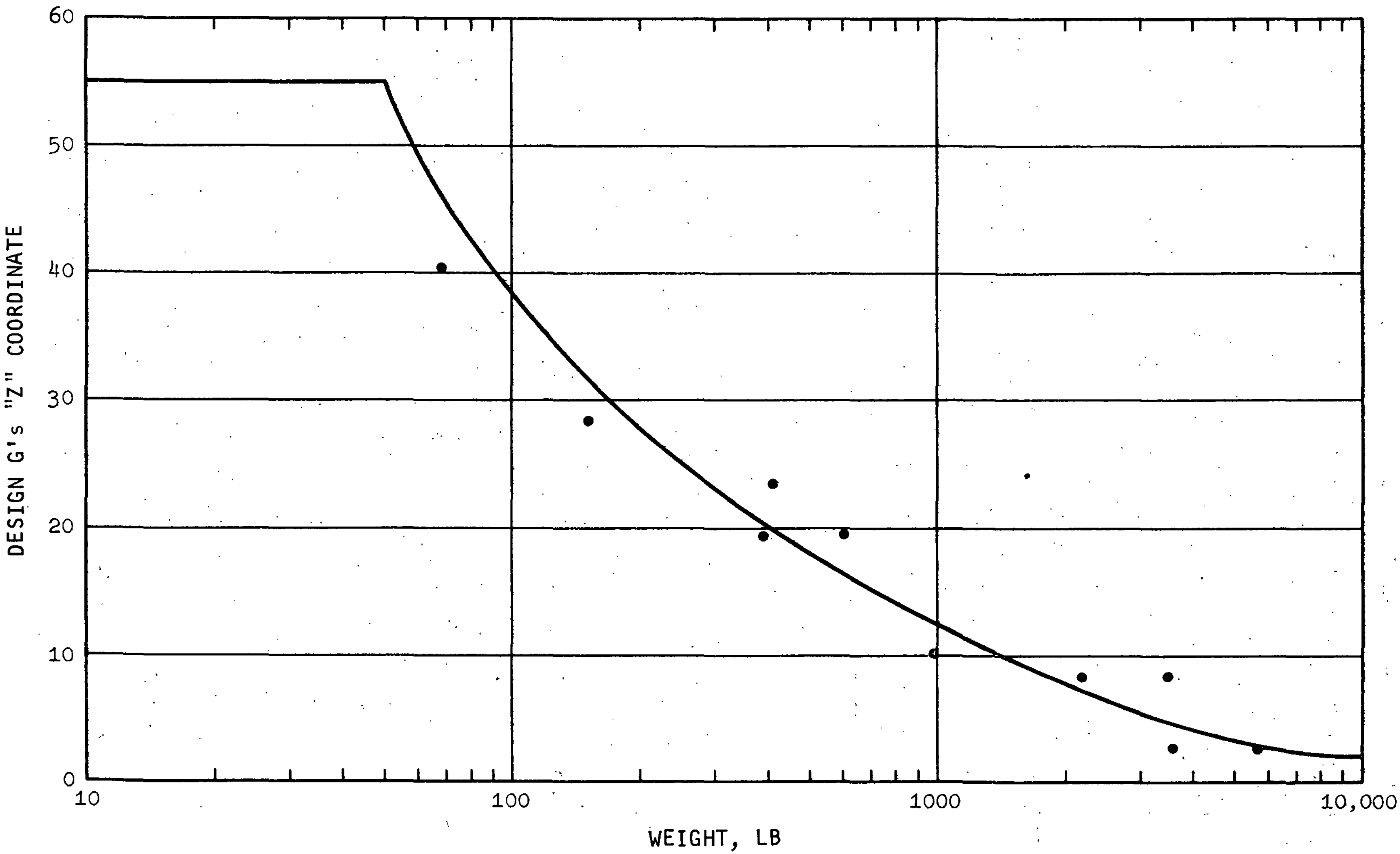

Figure 4-17. Vibration Response Weight vs G's Z Coordinate

CONCEPTUAL DESIGN STRUCTURAL CONSIDERATIONS

The primary considerations pertinent to the structural conceptual design of the shelter are:

- Materials
- Pressure element form/construction
- Location of primary structural elements
- Pressure wall penetrations

Materials

A qualitative evaluation of candidate materials was based on the following criteria:

Minimum weight for total mission time and environment

Compatibility with methods of construction

Where compatible with mission constraints, use of materials qualified for the Apollo program or those for which extensive use experience and data are available

Accommodation of extensions in mission time, quiescent and staytime, with minimum degradation of performance

As a result of a general survey, structural alloys of the following metals were selected as candidate materials: aluminum, beryllium, magnesium, stainless steel and titanium.

In addition to the usual strength to weight considerations, these materials were compared on an equivalent weight for equal meteoroid protection basis as subsequently discussed in this section. The results, as given below, show the lower density materials to be preferable for meteoroid protection.

Material	Weight Factor
Beryllium	0.68
Magnesium	0.98
Aluminum	1.00
Titanium	1.35
Stainless steel	1.65

Based on the criteria specified for evaluating candidate materials, in general, aluminum alloys are preferred for structural applications. Beryllium was eliminated because of its lack of weldability, and the marginal weight advantage offered by magnesium was considered offset by its inferior strength to weight ratio, except for shear panel use, and by the requirement for heated forming. A comparison of the characteristics and properties of aluminum alloys with the requirements of specific applications led to the following recommendations:

Alloy-2219-T87 for all structural elements requiring a comgination of welding, machining and forming operations. Properties: isotropic strength, 50,000 psi yield, 63,000 tensile ultimate, with minimum elongations; 5 percent longitudinal, 4 percent long transverse, 3 percent short transverse

Alloy 7079 for all mechanically attached fittings, typical of the support fitting to the LM truck

Alloy 7075 for all structural trusses using tubing as the primary elements

Form/Construction of Pressure Elements

The major pressure elements of the shelter are the stiffened skin of the cylindrical shell, end domes, and internal bulkhead. Only the internal bulkhead may be subjected to a ΔP across it in either direction.

1. Stiffened Skin of the Cylindrical Shell

The criteria used in selecting the preferred form/construction of the stiffened skin are as follows:

Pressure integrity

Minimum weight

Ease of fabrication

Since the loading criteria, thermal environmental, requirement for external and internal support structure integration, and curvature of skin are similar to that of LM, much of the information generated in selecting the form/construction of the pressure shell on LM was relatable to this study.

The following design concepts for a stiffened skin were investigated:

Machined skin with integral stiffeners, skin curvature formed after machining

Preformed skins with all stiffeners welded or mechanically fastened

Combinations of partially machined skins and welded or mechanically fastened stiffeners

Honeycomb framed core panels

The above concepts differ significantly in detail and subassembly fabrication, however, for all cases it was considered that the cylindrical shell would be fabricated as three equal length sections and the same amount of pressure-tight fusion welding would be required to join the sections for the final assembly.

a. Machined Skin--The longitudinal and circumferential stiffeners are integral with the thin skin as a result of milling the shear panels out of a plate approximately 1 in. thick by 4.5 ft wide by 25.5 ft long. After machining, the plate would be formed into a cylindrical shell, welded together and the required built-up frames and longerons welded or mechanically fastened to the outstanding stiffeners without requiring penetrations of the thin pressure shell or causing degradation of its properties. Bosses may be similarly integral with the skin and by means of blind tapped holes allow transfer of loads through the skin without penetrations or welding.

A similar approach of using machined skins on LM had been studied and determined not applicable because the required skin thickness of only 0.015 in. placed unrealistic demands on tooling and machining operations. However, this shelter's skin thickness of about 0.030 in. mitigates this cause for rejection.

As shown by the following discussions of the other design concepts, a machined skin with integral stiffeners is preferred since it provides maximum pressure integrity, offers minimum weight and can be fabricated using current capabilities and techniques.

b. Methods of Attaching Stiffeners to Skins--The preformed skin and partially machined skin concepts require stiffeners to be attached directly to the thin skin. Four methods of attaching structural elements, i.e., stiffeners to the skin were considered, namely:

Riveting

Bonding

Spot Welding

Fusion Welding

As indicated by its extensive use on LM, riveting is most appropriate where structural complexity at joints precludes automated fusion welding and complete access to both sides of the weld for inspection. However, this condition is not prevalent in the recommended shelter configuration; therefore, riveting, which requires penetrations through the skin, was rejected as a general method of structural attachment.

Bonding is considered acceptable only for honeycomb panels and lightly loaded structural members. It is considered unacceptable for use where high concentrations of shear flow occur across relatively small areas as in longeron or frame caps.

A review of the applicability of spot welding revealed the following reasons for its rejection as a general method of structural attachment to the pressure skin. There is very little data available on its use in curved tension field shear panel design. As a result, thicker lands (obtained by machine or chem-milling of the skin sheet) appear necessary and therefore is a step toward a machined skin. Also, thicker flanges may be required for spot welding to the thicker lands; testing would be required to determine a satisfactory combination. Alternatively, a 50-to 75-percent increase in the number of stiffeners would be required to maintain fully shear resistant panels. The unpredictability of leakage due to spot weld porosity and possible pull through of spot welds under load would further complicate the precautions and operations in fabrication, testing, and possible repairs. The lesser reduction of material properties caused by spot welding is applicable to only a small percentage of the total surfaces and is negated by the preceding considerations requiring thicker lands or more stiffeners.

Although fusion welding causes the greatest reduction in material properties, the simple shape of the shell and the orthogonal orientations of the stiffeners relative to the curvature of the shell allow fusion welding to be readily accomplished. Also, the simple shape and size of the shell allows direct and conventional methods of weld inspection.

Therefore, by the process of elimination, fusion welding is preferred over the other methods of attaching structural elements directly to the skin.

c. Preformed Skin and Welded Stiffeners--This concept has a minimum amount of skin machining operations but the greatest number of detail parts which require approximately 490 ft of welding directly to the pressure skin.

The reliability, testing, and repair requirements as a consequence of possible blow through associated with this extensive welding and the consideration that all load transfers occur through a welded joint were the dominant factors for rejecting this concept.

d. Combinations of Partially Machined Skins and Welded Stiffeners--The following alternatives within this concept were considered:

Machined circumferential stiffeners/welded longitudinals

Machined longitudinal stiffeners/welded circumferentials

The comparison of these alternatives was based on:

Linear feet of welding

Ease of fabricating machined skins

Weight

The possible use of extruded skins with integral circumferentials was abandoned based on the limitations of width and significant amounts of machining/chem milling.

For recommended configuration, the comparison of partially machined skins and welded stiffeners is summarized as follows:

Criterion	Machined Circumferentials/ Welded Longitudinals	Machined Longitudinals/ Welded Circumferentials
Linear feet of	340 ft of simple straight line welding, details easily fitted.	150 ft of circumferential welding. Fitting and welding of details more difficult.
Ease of fabricating machined skins	4.5 by 25.5 ft plate machined to provide 3 integral stiffeners, each 25.5 ft long. Easily formed into cylindrical shell.	4.5 by 25.5 ft plate machined to provide 26 integral stiffeners, each 4.5 ft long. Requires more extensive machining operations. More difficult to form into a cylindrical shell.
Weight	Equivalent of 32 lb of stringers/longerons subjected to a 25 percent degradation. *Relative weight penalty of 8 lb.	Approximately 100 lb of frames subjected to 20 percent degradation. *Relative weight penalty of 20 lb.

*Compared to a fully machined skin

Within this concept of a stiffened skin, the machined circumferential stiffeners/welded longitudinals was selected as the preferred alternative. Its machining and forming requirements are simpler, it has a slight weight advantage, and the simplicity of fitting and welding straight line longitudinals outweighs the disadvantage of more footage of welding.

e. Honeycomb Framed Core Panels--The shelter structural arrangement using honeycomb panels for the stiffened skin is shown in Figure 4-18. This concept of providing a stiffened skin was eliminated based on a comparison of the resulting shell weight with that of a machined skin concept, as shown in the following summary.

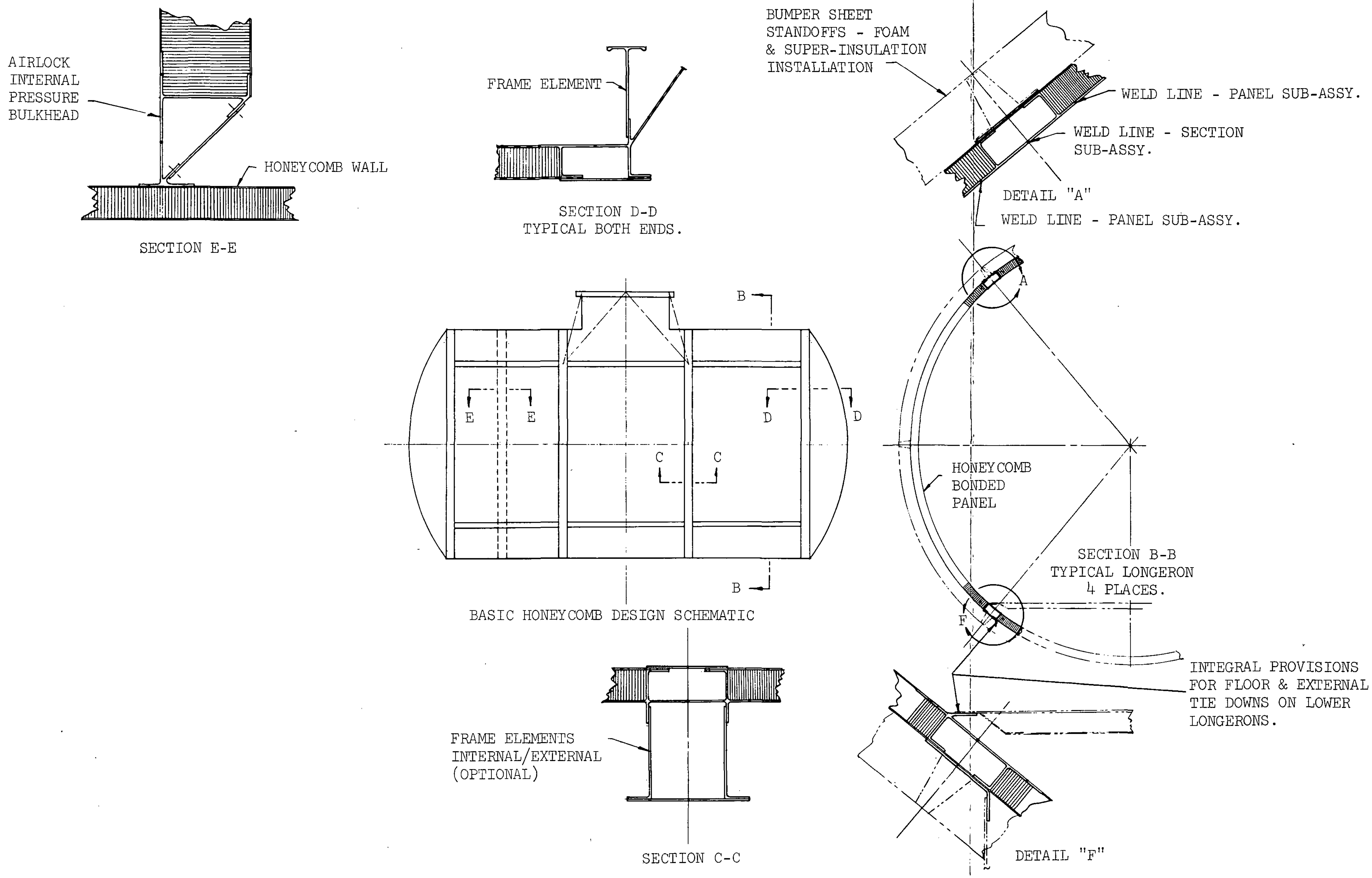

Figure 4-18. Configuration 3B Shelter Structure Arrangement - Honeycomb Design

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Weight Comparison - Honeycomb vs Machined Skin

Item	Honeycomb Framed Core Weight-lb	Fully Machined Skin Weight-lb
Skins (0.030 Equivalent) including 5 percent allowance for lands	150	150
Core - 1.5 in. thick 2 lb/sq ft density	82	---
Glue Lines - 0.10 lb/sq ft	33	---
Edge Members - Longitudinal 52 ft at 0.75 lb/ft	39	---
Edge Members - Radial 100 ft at 0.75 lb/ft Reduced 50 percent for frame contribution	38	---
Longitudinal and Radial Ribs 490 ft at 0.05 lb/ft Reduced 30 percent for frame contribution	---	17
Longeron Reinforcements 105 ft at 0.12 lb/ft	---	13
	Total 342	180

2. <u>End Done/Bulkhead</u>

The following end done/bulkhead configurations, with and without door penetrations, were considered:

Flat-Honeycomb and Framed

Elliptical

Spherical Sector

a. <u>Flat Bulkhead</u>--The use of flat bulkhead end closures for the pressure shell was rejected because of the loss of shelter volume and the weight penalty as compared to domed end closures. If the flat bulkheads were used, due to the constraints of the payload envelope form factor, the overall centerline length of the recommended configuration would be reduced to approximately 13.5 ft with a consequent volume loss of about 60 cu ft. The weight penalty for using flat end bulkheads as compared to domed ends would be approximately 60 lb.

Initially flat bulkheads, using a honeycomb or beam stiffened skins, were considered applicable for the internal airlock bulkhead based on the consideration that under emergency conditions the ΔP across the bulkhead could be opposite in direction to that of normal use and that a flat bulkhead allows maximum utilization of the separated available volumes. However, further study indicated that the use of a spherical sector internal bulkhead, suitably reinforced, would be lighter than the flat bulkhead and cause only a minor degradation of the general utility of the volume in close proximity to the dome - cylindrical shell intersection. This approach is discussed further later in this section.

b. <u>Elliptical and Spherical Sector Domes</u>--An investigation of the applicability of elliptical and spherical sector domes led to the selection of spherical sector domes based on the following considerations:

Spherical sector domes provide more usable volume for the restricted length of shelter available as compared to elliptical domes of reasonable eccentricities of minor to major axis, i.e., 0.3 and greater.

The requirement for the use of 0.030 in. thick skins is greatly in excess of the stress requirements imposed by pressure loads, so there is no weight advantage from the use of elliptical domes.

Spherical sector domes, unlike elliptical domes, maintain constant membrane stress which allows simpler door framing design and member installation, particularly when off-center doors are desired/required.

Ring frames, as opposed to a thickened peripheral edge radius, for the spherical sector domes are effectively free of weight penalty since they may be incorporated as part of the non-simultaneous pressure load requirements. These are the normal requirements for satisfying externally applied loads due to support of external equipment and the Shelter-LM/Truck tie-down. In addition, the ring frames can be located to match desirable locations on the LM/Truck structure (i.e., the end bulkheads) for load transfer.

Spherical sector domes are easier to fabricate by spinning or hydroforming.

The compound curvature of the domes precludes the use of fully or partially machined skins to support door framing or reverse loading on the membrane; fusion welding would be used for structural member connections to the skin.

Location of Primary Structural Elements

The investigation of locating the primary structural elements, such as frames/rings and longerons/stringers, internally or externally to the pressure shell considered potential follow-on variations of the shelter/mission as well as the considerations pertinent to the recommended shelter.

As shown by the following discussions, external location is preferred for the recommended shelter and for follow-on variations. For the candidate configurations there were no significant differences in cost, fabrication techniques, functional reliability, and weight for either location.

1. Recommended Shelter

The influence of the following considerations on the location of primary structural elements were examined:

Pressure Shell

External Equipment

Internal Equipment

Docking Ring Loads and Shelter-Truck Connection

a. Pressure Shell--The preferred fully machined skins are more easily formed into cylindrical shells with the integral stiffeners located externally; therefore the primary structural elements would also be externally located. External location of structural elements for the other concepts of stiffened single skins provides the advantage of constraining membrane and pressure loads in hoop fashion, precluding the tendency to produce tension loads across welds as would occur with internally located structural members.

b. External Equipment--The many support points required on the shelter structure for sway bracing or accommodating in-toto the loads imposed by external equipments are best provided by externally located structural members with tangential introduction of the loads at the frame/longeron intersection centroids to minimize eccentricities and bending moments.

Internally located structural elements with integral skin bosses or fittings welded to the skin would reduce the capability of accommodating changes in size and mass of external equipment. Also, the eccentricities of the load paths would require a slight increase in structural weight.

c. Internal Equipment--The loads from heavy internal equipment are primarily carried by the shelter floor and therefore by its structural supports. Internally located primary structural elements are preferred for this condition/requirement. However, externally located structural elements can provide satisfactory supports for the internal equipment. Floor support segments may be welded or bolted to integral bosses coplanar with the exterior main frames and mechanically fastened to the end dome and airlock dome compression rings. These supports carry the vertical and lateral loads and skin ties carry the longitudinal loads.

Integral bosses approximately coplanar with external frames and longerons, and light convenience frames bonded to the skin could be used to carry the loads from wall mounted equipment too high above the floor for efficient attachment to it.

The use of externally located structural elements also results in an inner wall surface comparitively free of protrusions thereby facilitating the in-situ movement of consoles and equipment to allow easy inspection and possible repair of wall surfaces.

External location allows more internal headroom and usable volume since the nominal 3 in. provided for backup sheet-bumper spacing can also be used to accommodate the radial depth of the members.

d. Docking Ring Loads and Shelter/Truck Connection--External location of structural members is preferred; the reasons given for external equipment support also are valid for these considerations. The possibility of using removable internal structure to reduce frame weights is a tradeoff of weight vs flexibility of interior shelter arrangement and crew activities; it does not alter the preference of external location of shelter structural members.

2. Shelter/Mission Variations

The shelter may be designed to accommodate the following extensions in capability:

- Transportable on the lunar surface by the addition of powered wheels. The attachment of wheel suspension is best accommodated by externally located structural elements.

- Increased shelter volume by extension of concentric, internally stowed section of the shelter. To achieve maximum internal diameters (and volume), allow for the support of the extension guides and mechanism, and accommodate adequate sealing flanges, external location of structural elements is preferred for both inner and outer sections.

Pressure Wall Penetrations

In addition to the large penetrations required by the airlock doors and docking tunnel hatch, a number of smaller penetrations will be required for viewing ports and service lines such as fluid and electrical lines, and shelter atmosphere dump valves.

1. Airlock Doors and Docking Tunnel Hatch

Circular configurations for both airlock door openings are preferred to elliptical or rectangular configurations based on the following considerations:

For circular penetrations through spherical sector domes the reinforcing edge members are in-plane circular rings subjected primarily to uniform tension loads (or under emergency conditions of reverse loading on the inboard dome, uniform compression loads) with almost no out-of-plane forces.

The local out-of-plane forces in the skin where it is joined to the reinforcing ring are comparatively minor and less significant than for other shapes of openings.

The circular in-plane opening allows simple seal and door latching designs with minimum relative distortions of the seal clamping surface.

Although the "width" of a circular door is considerably greater than that required for elliptical or rectangular doors given in previous discussions and more than half the "width" of the shelter, the preferred pressure aided sealing and translational opening motion of the overboard door into the airlock can be accommodated as follows. The door opening is horizontally offset from the end dome center and the curvature of the inboard spherical dome results in a longer cylindrical wall section in the airlock.

The required clearance for the hinged inboard door is also satisfied by horizontally offsetting the door opening in the dome.

The arrangement and kinematics of flat 56 in. dia inboard and outboard doors based on the above considerations are shown in Figure 4-19. The two doors and their latching mechanisms are identical, although the loading on them can be different. Under emergency conditions of the airlock pressurized and the remainder of the shelter non-pressurized, the inboard door can accommodate a loading of 7 psi; for the normal conditions of pressure aiding the sealing of the door the maximum (burst) loading is 11.6 psi. Each door is constructed of flat aluminum honeycomb approximately 3 in. deep with a 3.5 lb core and 0.020-in.-thick face sheets.

The inboard door is offset horizontally 7 in. from the center of the dome and is hinged to open into the work/living area. A slotted hinge joint allows the door to translate normal to the sealing surface during latching or unlatching of the door.

The overboard door is also offset horizontally 7 in. from the center of the end dome. This door is mounted to rollers constrained in curved tracks located above and below the door opening. The shape of the tracks allows the door to translate normal to the sealing surface during latching or unlatching of the door as well as minimizing encroachment of airlock volume during the opening/closing.

In the full open position the overboard door overlaps the door opening but still provides a suitable clear opening at mid-height of 43 in.

Sealing is achieved by a multiple striker on the door contacting and preloading a silicone rubber - silastic seal mounted on the seal supporting lip of the dome opening reinforcing edge member. This location allows easy inspection of the seal and the multiple striker approach provides some protection against inadvertent contact during ingress/egress.

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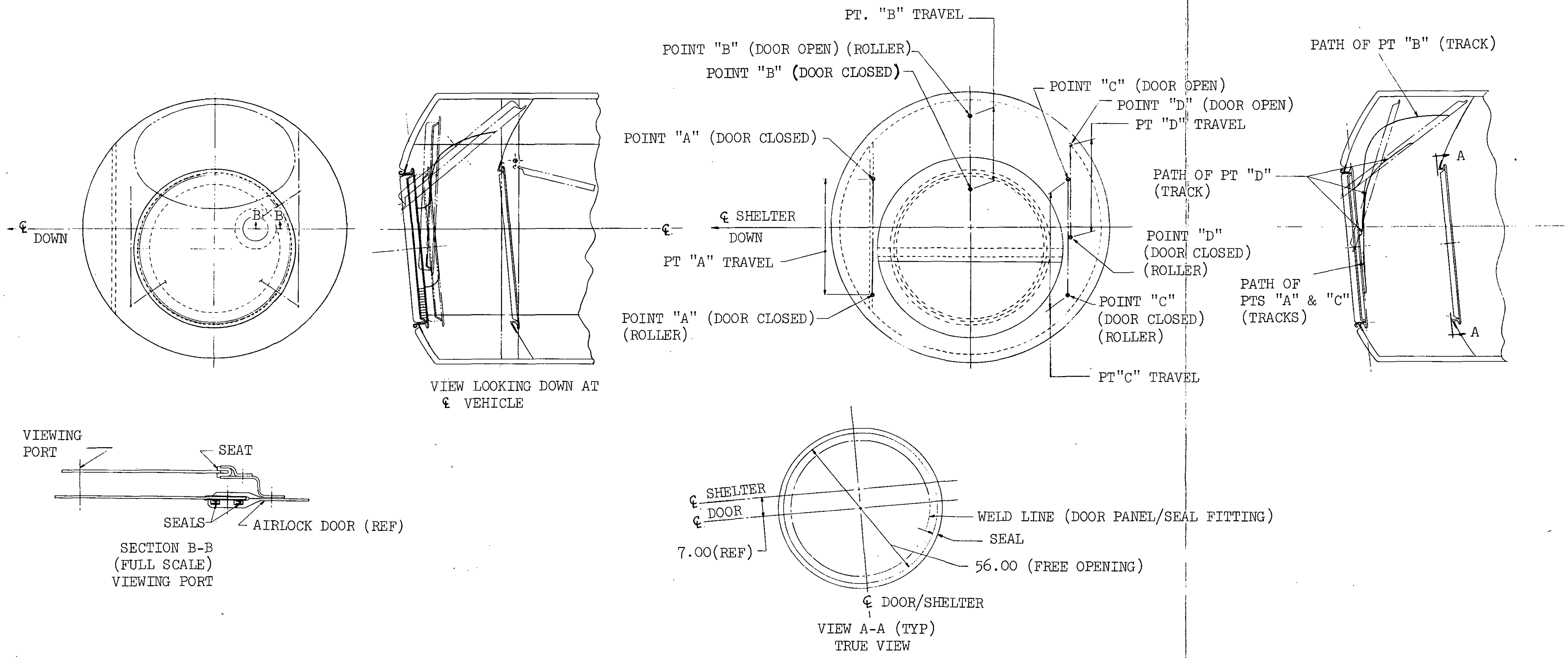

Figure 4-19. Configuration 3B Airlock Door

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The door latching/seal clamping mechanism is shown in Figure 4-20. It consists of a two piece marmon type clamp with compound toggle over-center mechanisms to load, synchronize the motion, and irreversibly latch the clamp. The two-piece clamp is symmetrically located about the vertical center line of the door and provides almost full peripheral clamping.

A harmonic drive gear box, manually driven by an astronaut from either side of the door, is used to drive the latching mechanism. The harmonic drive is located in the center of the door and connected by bell cranks/links to the linkages which further load and synchronize the motions of the ends of both halves of the clamp. When the latching mechanism is 'opened,' it releases the tension in the clamp and moves each half radically outward to allow the clamp to clear the seal supporting lip on the dome.

Since normal operation of the latching mechanism can take approximately one min, squib powered actuation or squib bolts and springs to move the clamp can be used for emergency rapid opening. In either approach the differential pressure aiding the sealing would have to be reduced to probably only several psf to allow a crewman to move the door, without mechanical aids, from a sealed position.

The docking tunnel circular shape, diametral dimension and unobstructed accessibility to it from inside the shelter results in the obvious selection of a round docking tunnel hatch.

Since it is normally used only for in-flight checkout and is required to take only unidirectional pressure loads during the mission, a hatch design similar to that of the LM docking tunnel hatch would be used.

Service Lines

The service line penetrations are shown in Table 4-4. The table shows only fluid and electrical power service requirements but undoubtedly penetrations will also be required for electrical instrumentation and communications.

Bulkhead fittings such as used on LM are suitable for these applications on the shelter. A typical fluid line bulkhead fitting assembly, as used on LM, is shown in Figure 4-21. It consists of a bulkhead penetration fitting, bulkhead nut, O-ring, and two fitting ends. Each fitting end consists of a fitting nut, seal, and female fitting to which the tubing is swaged.

A typical electrical power bulkhead fitting, as used on LM, is also shown in Figure 4-22. The individual electrical feed-throughs are hermetically sealed to the body of the fitting. Fittings for instrumentation and signal wires are similar, the primary difference is that the feed-throughs are pins on both sides of the fitting as compared to a pin and sleeve used in power fittings.

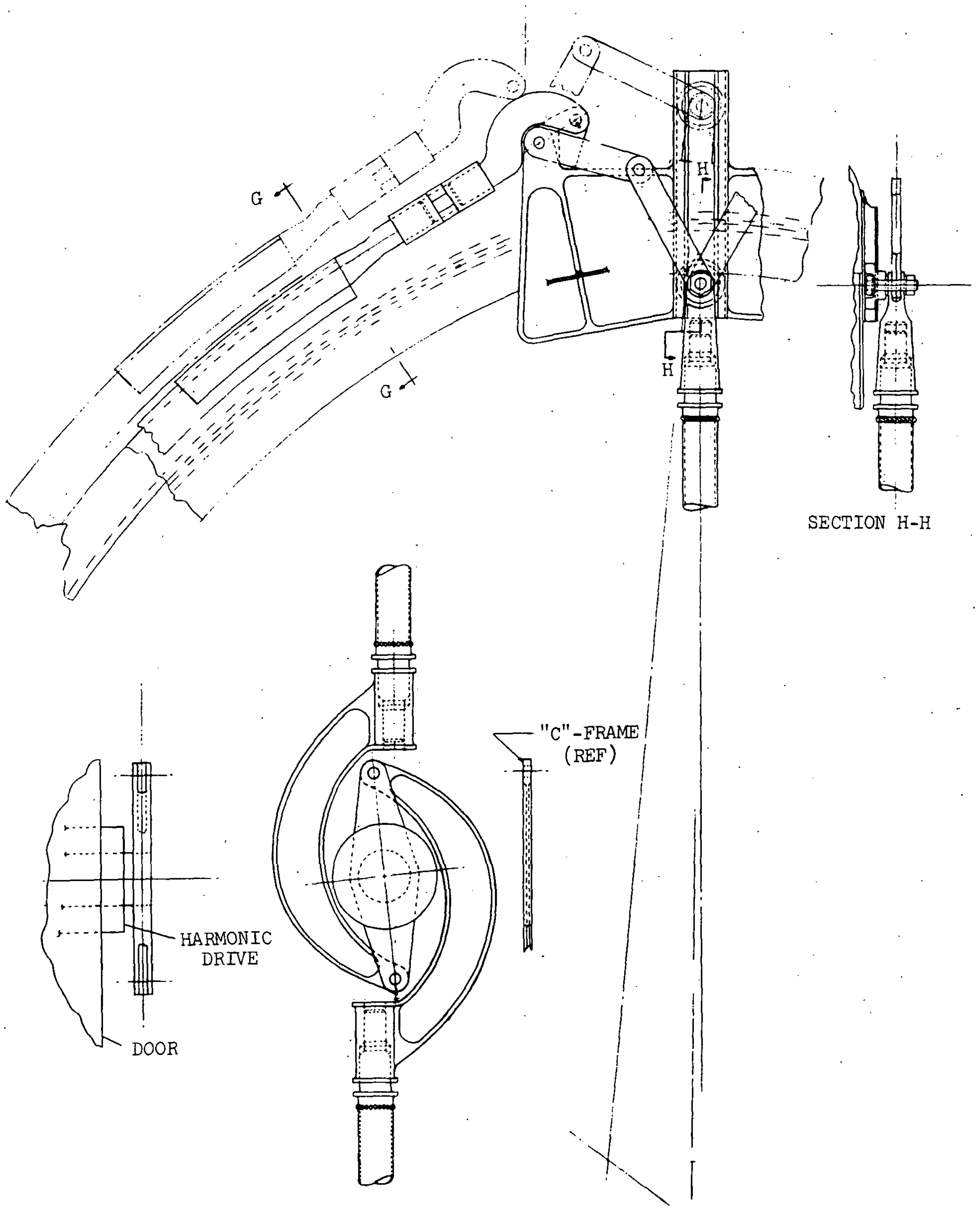

Figure 4-20. Configuration 3B Airlock Door Latching Seal Clamp

TABLE 4-4

PRESSURE WALL SERVICE LINE PENETRATIONS

No. of Penetrations	Hole Size (in)	Location	Wall Penetrated	Line Contents	Line Function
4	3/8"	Near ECS	Cabin-Exterior	heat transfer fluid	cabin thermal control
3	1"	near command and control console	"	electric leads	power
1	1/2"	near FCA	"	"	power
1	3/8"	near floor	"	potable H_2O	FCA water
2	1/4"	near ECS	"	oxygen	oxygen supply
1	2"	near ECS	"	O_2 and H_2O vapor	pressure relief and H_2O boiler vent line
1	1/4"	near floor	Cabin-Airlock	Oxygen	airlock oxygen supply
1	1-1/2"	near floor	"	airlock pump	airlock pump
2	1-1/4"	waist level	"	oxygen	suit ventilation
1	1/4"	floor level	"	urine	toilet drain
2	3/8"	roof level	"	heat transfer fluid	airlock thermal control
1	1/2"	waist level	Airlock Exterior	-	airlock dump
1	1/4"	floor level	"	-	odor removal from toilet
1	1/4"	waist level	"	oxygen	PLSS emergency hook-up

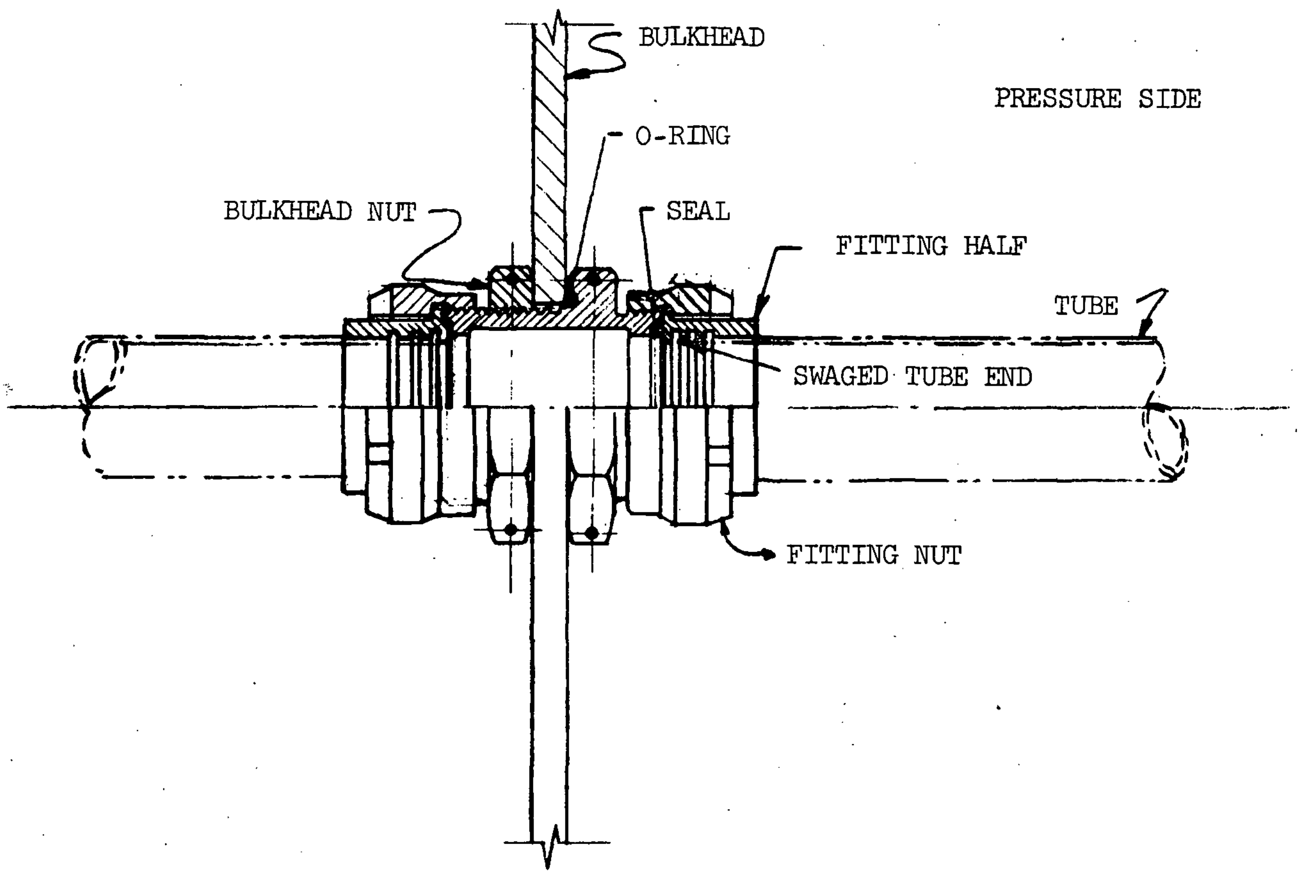

Figure 4-21. Bulkhead Fluid Fitting

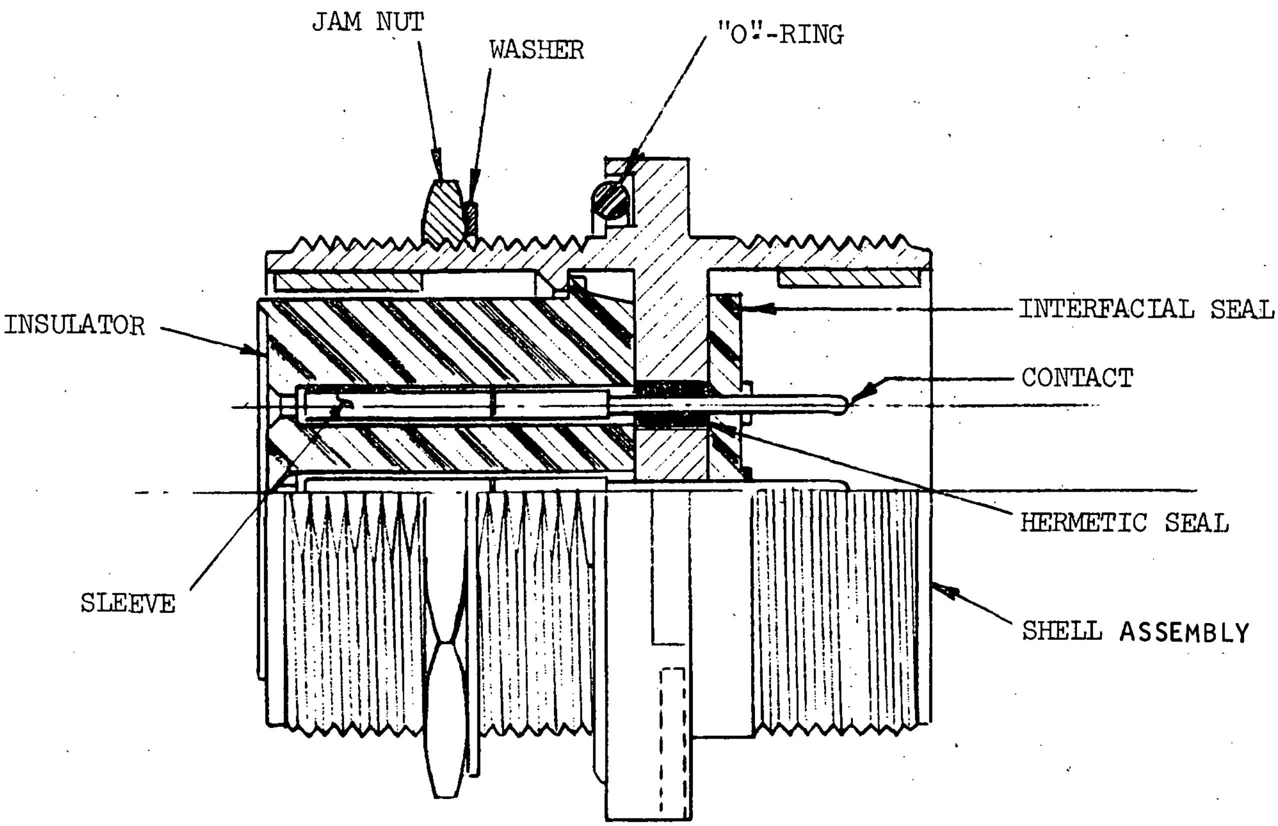

Figure 4-22. Bulkhead Electrical Fitting

Parallel-plane surfaces for the sealing O-ring and fitting nut would be machined from local bosses or thick sections of the pressure walls, the smaller size fittings can be used through walls up to 1/4 in. thick.

In addition to the normally used airlock atmosphere dump valve line given in Table 4-4, large flow area dump valves, operable from both sides of the pressure wall, are necessary to allow rapid unloading of the pressure aided sealing of the airlock doors or docking tunnel hatch under emergency conditions. Also, to allow opening the docking tunnel hatch for in-flight checkout, a manually operable valve would be located in the hatch similarly to LM.

Typically, the penetration required for a dump valve would be significantly larger in diameter than those for the above electrical or fluid lines and the method of securing it to the pressure wall would be different. A machined flange for the sealing O-ring and a series of blind tapped holes, radially inboard of the O in the valve body, would be used to mount the valve to a matching flange machined from a local boss in the pressure wall.

Viewing ports would be used to monitor activities in the airlock from the work/living area as well as to view extra shelter activities. If this latter use is supplemented with a periscope, the periscope penetration of the pressure wall would be similar to that used for the LM alignment optical telescope; namely, a flanged static seal with no requirements for rotating seals external of the optical device.

The method of accommodating the viewing ports in the pressure wall would be the same as used on LM which is designed to take tension as well as pressure loads.

A cross-section of the viewing port is illustrated in Figure 4-23. A curved pane (1) of chemcor high strength glass is sandwiched between two edge strips (2) of Kovar with a Kovar spacer (3) bonded between them. A 1/16 teflon filler (4) is inserted between the edge of the glass and the spacer to eliminate the risk of cracking due to the spacer and glass accidentally being bonded together. Kovar was used as an edgemember since it has the same coefficient of expansion as the Chemcor glass

A 2219 aluminum alloy machined frame (5) is butt welded to a cut out in the pressure wall, and the glass assembly is clamped into place with an aluminum ring (6) which is bolted to the machined frame. Sealing is achieved by two O-ring seals (7) located in grooves in the machined frame.

A fiberglass frame (8) is bolted to the main frame assembly and carries an exterior pane (9) of Vicon (a soft glass) retained by a ring (10). The exterior pane is an optical filter and the space between it and the chemcor glass is vented.

PAYLOAD DEPLOYMENT

The proposed operational use of the shelter payload requires the majority of the scientific equipment and the LSSM to be deployed to the lunar surface,

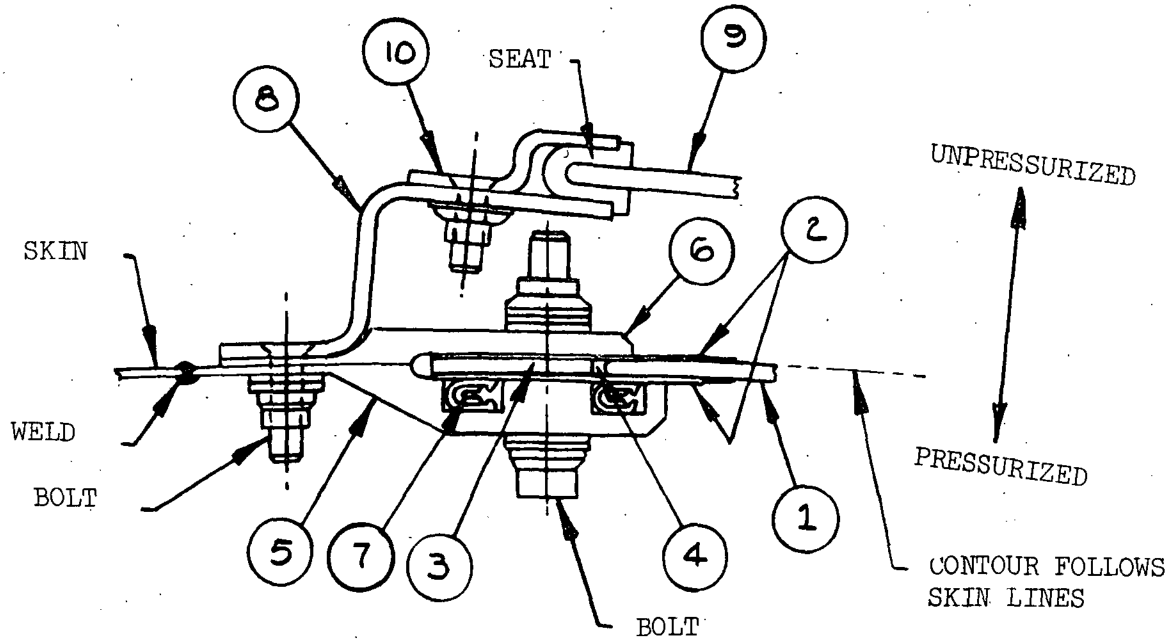

Figure 4-23. Cross Section of Viewing Port

and the subsequent crew activities to accomplish the mission operations require several cycles of shelter ingress/egress per day.

In satisfying these requirements, the as landed attitude of the LM/Truck and the height of the shelter payload above the lunar surface are of primary importance.

The as landed attitude and conditions specified by the study guidelines (Reference 1) are:

18 deg maximum slope of the LM/Truck horizontal plane relative to the local horizontal plane

5 deg general slope of the local lunar surface

18 deg maximum truck slope based on a landing leg primary compression stroke of a maximum of 25 in. and a local 24 in. protrusion or depression of the surface at the landed position

The as landed attitude and conditions are shown in Figures 4-24 and 4-25 for the two extremes of landing leg orientation relative to combined slope of 18 deg. Figure 4-24 illustrates the diamond pattern in which diagonally opposite legs are aligned along the direction of the slope; Figure 4-25 illustrates the square pattern in which adjacent legs are aligned along the direction of the slope. Although the LM/Truck slope is 18 deg for both orientations, the square pattern necessarily has less resistance to overturning than the diamond pattern; for leveling methods utilizing actuators integral with or attached to the landing legs the strokes are longer for the diamond pattern.

To eliminate the possible degradation of crew performance caused by operating in an off-level shelter, the shelter must be leveled to a maximum of 3 deg with respect to the local horizontal. Achieving this nominal horizontal attitude from a maximum of 18 deg off-level could result in the LM/Truck-Shelter payload interface being a maximum of approximately 12 ft above the lunar surface.

The study of payload deployment was divided into the following categories:

Shelter azimuth orientation and unloading

Shelter leveling

LSSM unloading

Scientific equipment unloading

Crew access

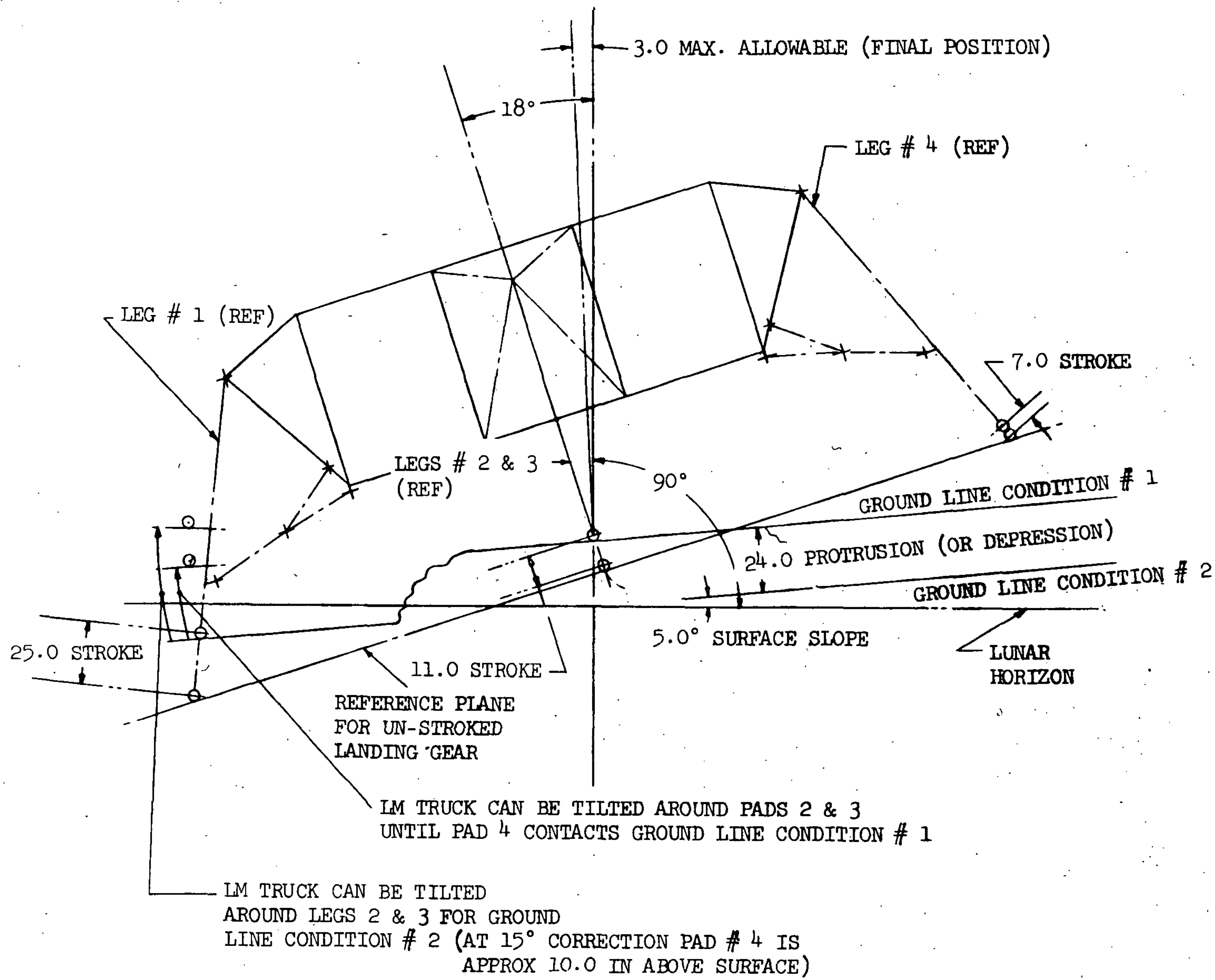

Figure 4-24. LM Truck As-Landed Diamond Pattern

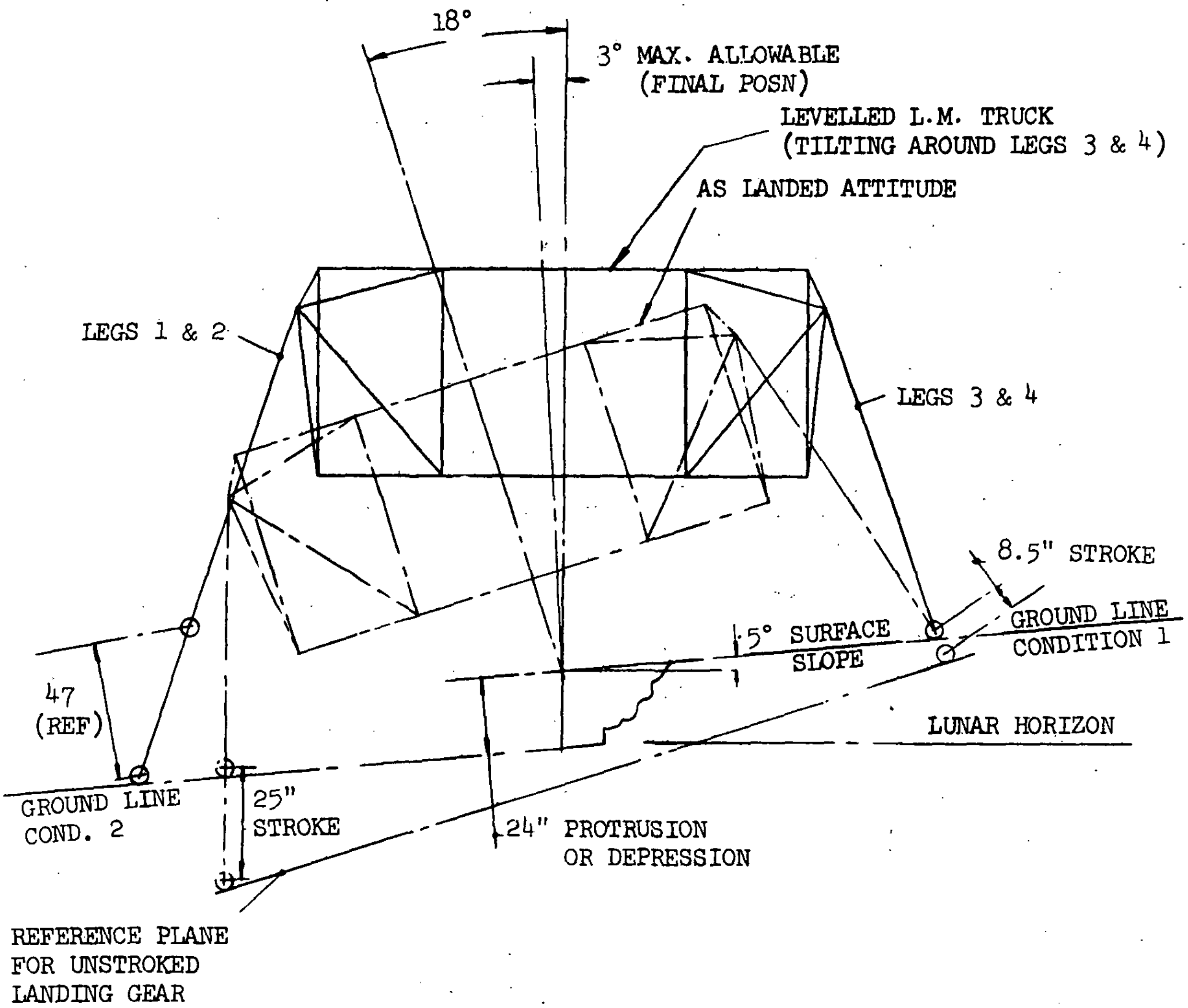

Figure 4-25. LM Truck As-Landed Square Pattern

Shelter Azimuth Orientation and Unloading

The ground rules noted below were followed for this deployment category:

Shelter to be unloaded to the lunar surface with all internal and external equipment (stored in the primary payload envelope) in place

Accommodate the as landed attitude and conditions specified by the study guidelines (no preleveling required)

Provide capability of 360 deg azimuth orientation to allow selection of most suitable area to deploy shelter

Flight and landing loads on shelter not carried by the unloading system

Methods of unloading the shelter using devices supported only by the LM/Truck were eliminated, since the moment exerted by the shelter on the truck, when the shelter is clear of the truck and the as landed attitude and 360 deg orientation ground rules are satisfied, would cause the LM/Truck to overturn.

An investigation of various combinations of turntables and folding or telescopic ramps simply supported by the LM/Truck and the lunar surface showed that a system consisting of an azimuth turntable and folding ramps was the most compatible with the existing payload configuration, was simple to operate, offered high reliability, and was lightest in weight. The method of folding the ramps and the turntable arrangement are similar to that described in NASA study report ALSS-TR-031 Volume II Book 8.

The selected azimuth orientation and unloading system is shown in Figure 4-26.

In general, it consists of two assemblies, one for azimuth orientation and the other for unloading. After the release of the shelter payload to LM/Truck tiedowns, the shelter paylaod is supported by four roller/guide shoes located near the intersection of two of the lower longerons and the end dome/cylinder compression rings. These roller/guide shoes are in contact with the two sections of the unloading ramp resting on the azimuth orientation turntable; these sections are connected by pivot pins to two legs of an A-frame connected to the turntable.

The turntable has a 70 in. outer dia and is constrained by eight roller assemblies which are supported from the LM/Truck cruciform beams. Each roller assembly has two horizontal rollers to react the shelter vertical loads and one vertical roller to keep the turntable centered about a vertical axis. Turntable rotation is provided by an electric motor operated capstan driving a wire rope cable wrapped around the turntable.

The unloading ramp consists of two arms, structurally cross braced, each having four sections which are hinged to facilitate stowage as shown in Figure 4-26. The outboard ends of the ramp arms are connected to a common ball and socket mounted bearing pad.

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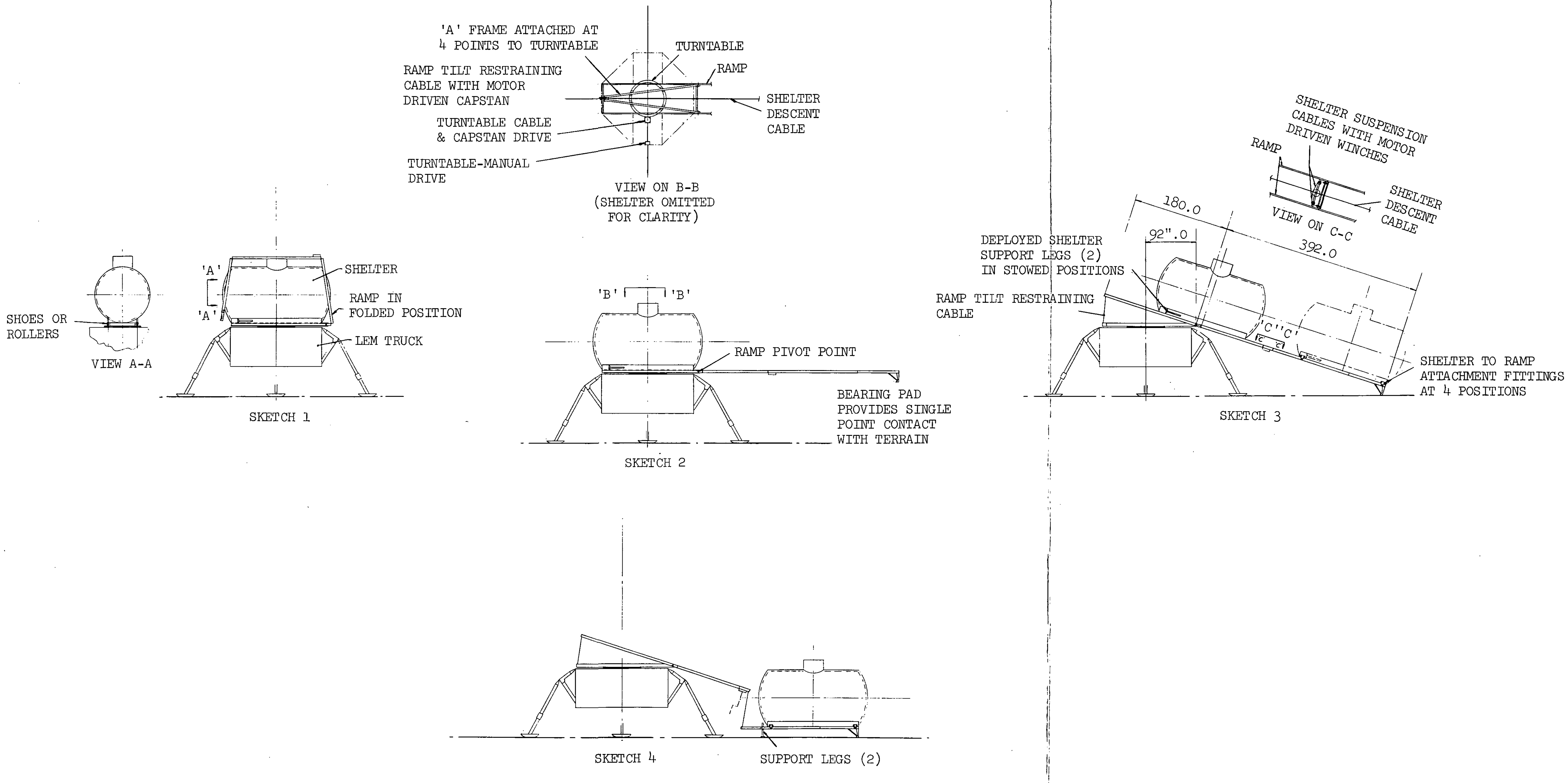

Figure 4-26. Azimuth Orientation and
Unloading of Shelter from Truck

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The previously mentioned A-frame connected to the turntable provides the pivot about which the ramp can tilt and reacts the cable load for controlling the angular rate of tilt.

Although Figure 4-26 shows the unloading of the shelter from a horizontal attitude, the same sequence of events would be followed if the LM/Truck were tilted up to 18 deg, the only difference being in the angle of tilt of the unloading ramp when it is in contact with the lunar surface.

Referring to Figure 4-26, the unloading sequence is as follows:

Sketch 1 The shelter is shown with its unloading ramps in the stowed position after the shelter tie-down fittings have been released.

Sketch 2 After azimuth rotation of the shelter to the most suitable position for unloading, the turntable is retained in that position by a power-off disc brake on the driving capstan. The ramp tie downs to the shelter are then released by squibs and the ramp sections are automatically unfolded to an extended position by springs at the ramp section hinges. When extended, the ramp sections are automatically locked together by spring loaded pins.

Sketch 3 An electric motor driven capstan mounted on the underside of the shelter moves the shelter along a cable connected between the inboard and outboard ends of the ramp. The shelter is moved outboard along the ramp until its cg is outboard of the ramp pivot point. The ramp is then allowed to tilt until the bearing pad at the outboard end of the ramp contacts the lunar surface. The rate of tilt of the ramp is controlled by a cable unreeled from a motor driven winch mounted on the end of the A-frame opposite the ramp pivot; the controlling cable is connected to the inboard end of the ramp. After tilting of the ramp is completed, the shelter is moved to the end of the ramp where spring loaded pins lock the shelter to the outboard sections of the ramp. The cable used to move the shelter along the ramp is then severed/disconnected from the inboard end of the ramp, thereby disengaging from the capstan.

Sketch 4 A pair of winches are in-situ pin connected inboard of the hinges of the last section of the ramp, and their cables are connected to the ramp sections supporting shelter. The hinged connection is then severed/disconnected. The cables from each winch are independently controlled to lower the shelter to an approximately horizontal attitude. In this position, adjustable length legs are socket-connected near the disconnected ends of the ramp sections supporting the shelter. The two support legs are adjusted in length and the suspension cables further lower the shelter until the legs support and stabilize the shelter in an approximately horizontal attitude. Manual overrides are incorporated in all powered drives.

The weight penalty for this system is summarized below:

	lb
Azimuth orientation assembly	65
Ramp and support structure	238
Ramp tie-downs and release	8
Ramp tilt restraint mechanism	9
Shelter rollers and brackets	15
Ramp arm lowering mechanism	10
	355

Shelter Leveling

The shelter can be leveled to within the specified maximum of 3 deg off the local horizontal by leveling the LM/Truck or leveling only the shelter leaving the LM/Truck in the as landed attitude.

For the latter approach the externally located equipment and consumables directly related to shelter operation and connected to it by electrical and fluid lines were considered as an integral part of the shelter.

Also, to minimize leveling subsystem weight, it does not carry the flight and landing loads on the shelter.

1. Leveling the LM/Truck

Previous studies of leveling an LM descent stage (Reference 8) concluded that the use of linear actuators between the descent stage/SLA truss and the lunar surface was preferred over the other methods studied, namely, pneumatic bags with adjustable blocking struts, A-frames and derrick type rigs, partial landing gear disassembly and rerigging, and jacking provisions built into the descent stage.

Since the as landed attitude and amount of correction required are less severe for this study, the above approaches were reconsidered and the recommended approach was not routinely adopted. In addition to satisfying the more severe correction requirements, its design concept was based on no modifications to the LM landing gear and consequently resulted in a fairly large mechanism.

For this study, which does not have the above constraint, the more desirable approaches of leveling the truck are those utilizing the landing gear legs to support or house leveling devices as discussed in the following paragraphs.

Electrically powered screw jacks were selected as actuators over hydraulic or pneumatic cylinders primarily because of the 6-month quiescent storage and the comparative ease of supplying electric power to an actuator inside the landing gear cylinder. However, no detail comparison of actuators was performed since it is beyond the scope of this study.

Technique No. 1 consists of the use of screw jacks housed in the lower cylinders of the four landing legs. The lower cylinders would have to be redesigned to provide a guiding surface for the jack extension and to react the jacking loads. The jacks would not carry the landing loads, but would utilize the landings pads as bearing pads during leveling; this requires a redesign of the pad support-to-landing leg connection to allow in-situ disconnection.

The jack strokes and the maximum lateral scuffing motion of the pads to accomplish leveling of the shelter are shown in Figure 4-27. A length of about 61 in. is available within the landing gear cylinder, when the gear is in a compressed position, to house the screw jack. This available length limits the stroke of a single stage actuator to approximately 48 to 50 in. Therefore a two state screw jack would be required.

Technique No. 2 consists of a screw jack arrangement in each landing leg cylinder similar to that of Technique No. 1, but, as shown in Figure 4-28, it only requires a stroke of 48 in. and imposes negligible lateral motions on the landing pads. This is achieved by in-situ disconnecting/severing the locking geometry of the secondary landing struts and the uplock to allow the landing legs to pivot about points A. Although this provision must be incorporated in the four legs, only the locking geometry on the leg requiring the maximum stroke and one adjacent to it need be freed to reduce the lateral scuffing to a negligible amount. Tension ties are manually installed between diagonally opposite legs to preclude outward slippage of the pads when the legs are free to pivot.

In Technique No. 3, three single stage screw jacks are stored in the shelter payload envelope and are in-situ mounted to fittings located on the lower end of the landing leg upper cylinders. Therefore, compared to Techniques 1 and 2, this approach requires the minimum amount of modification to the landing gear.

Since the jack pads must clear the landing pads, they can be mounted radially inboard of the landing leg pads and thereby require a maximum stroke of only 45 in. as shown in Figure 4-29.

To permit some selection of jack bearing pad location on the lunar surface, the fittings on the leg upper cylinder have multiple locations for accepting the jack brackets and the jacks may be inclined several degrees off vertical at the initiation of the leveling operation. During the leveling operation the jacks are allowed to pivot in their brackets thereby reducing lateral scuffing to a negligible amount.

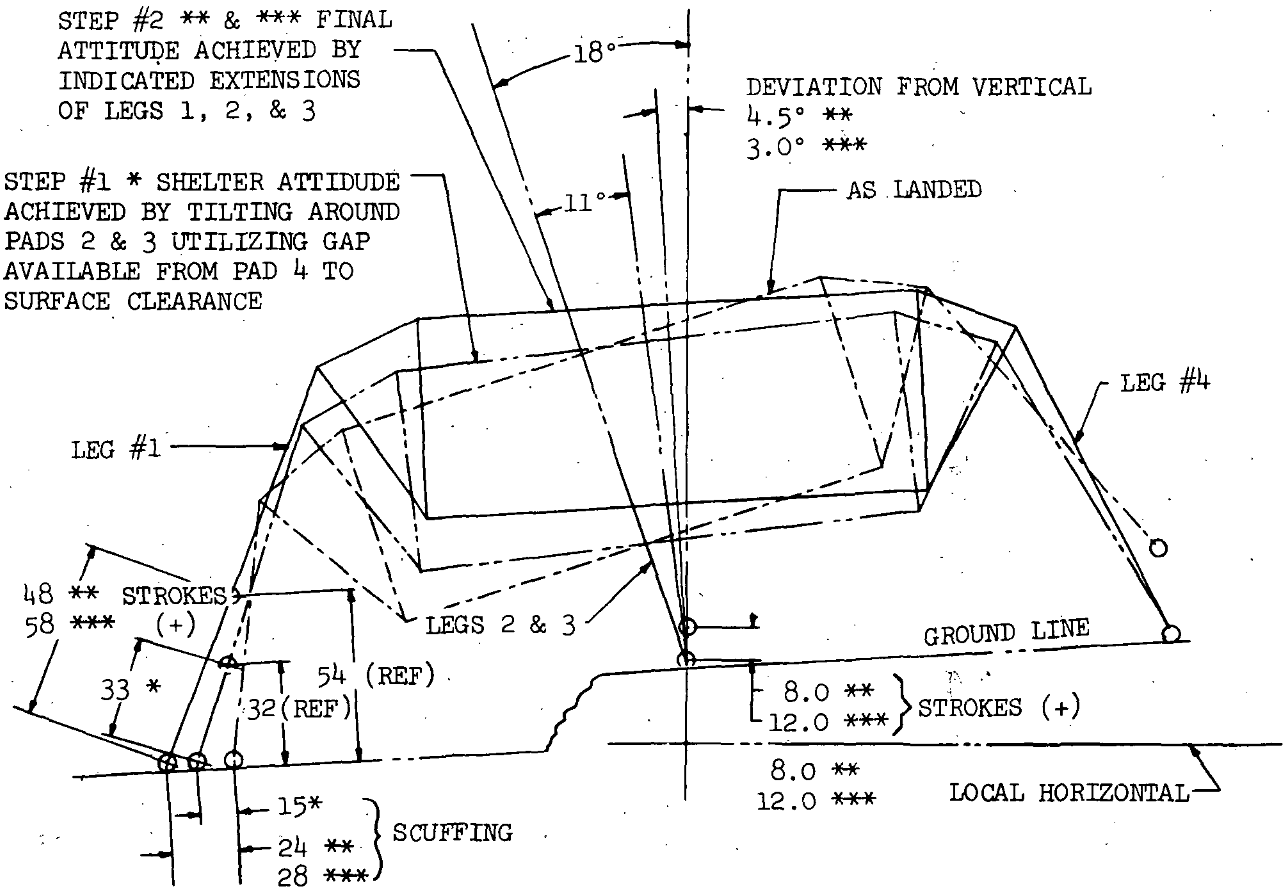


Figure 4-27. LM Truck Levelling Technique No. 1

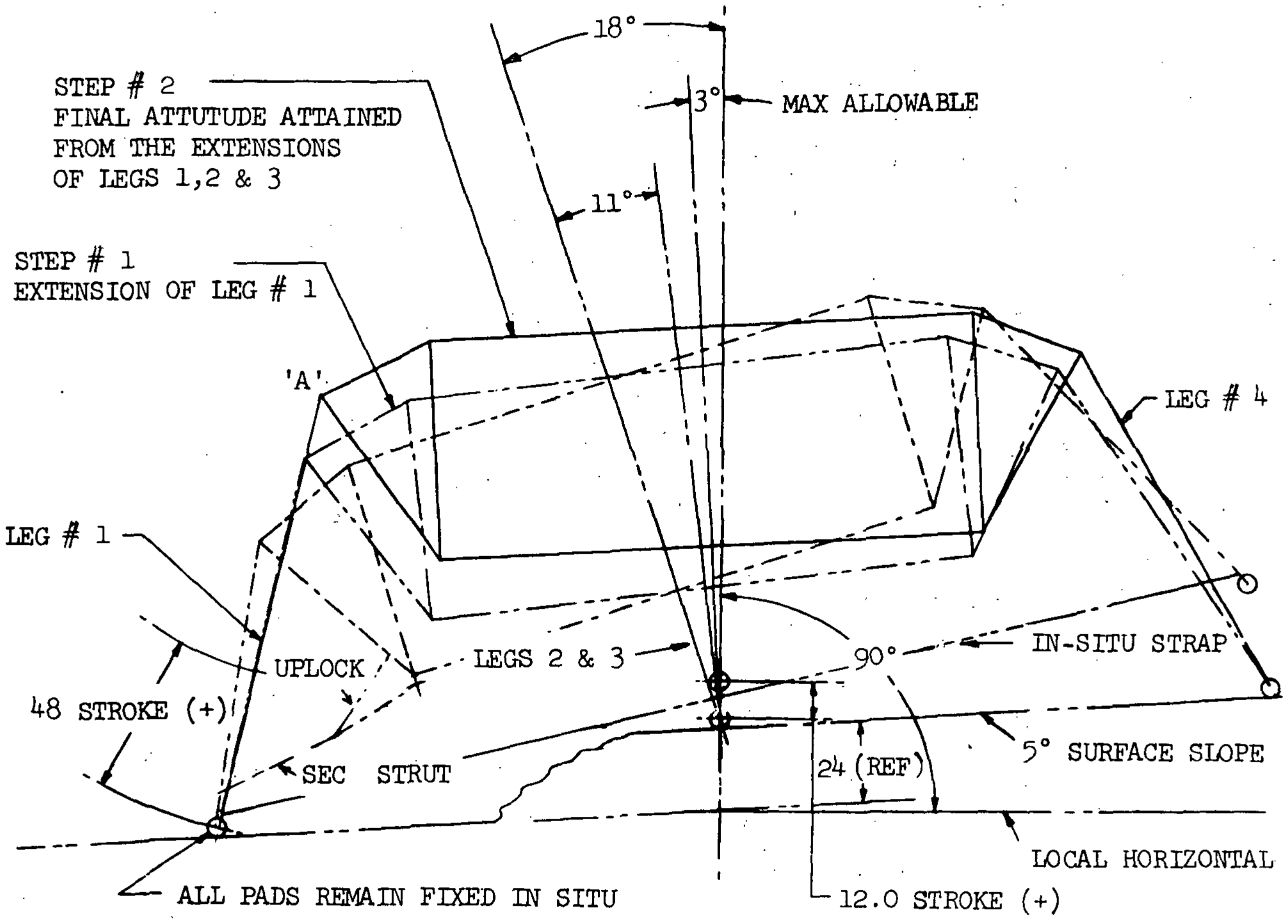


Figure 4-28. LM Truck Levelling Technique No. 2

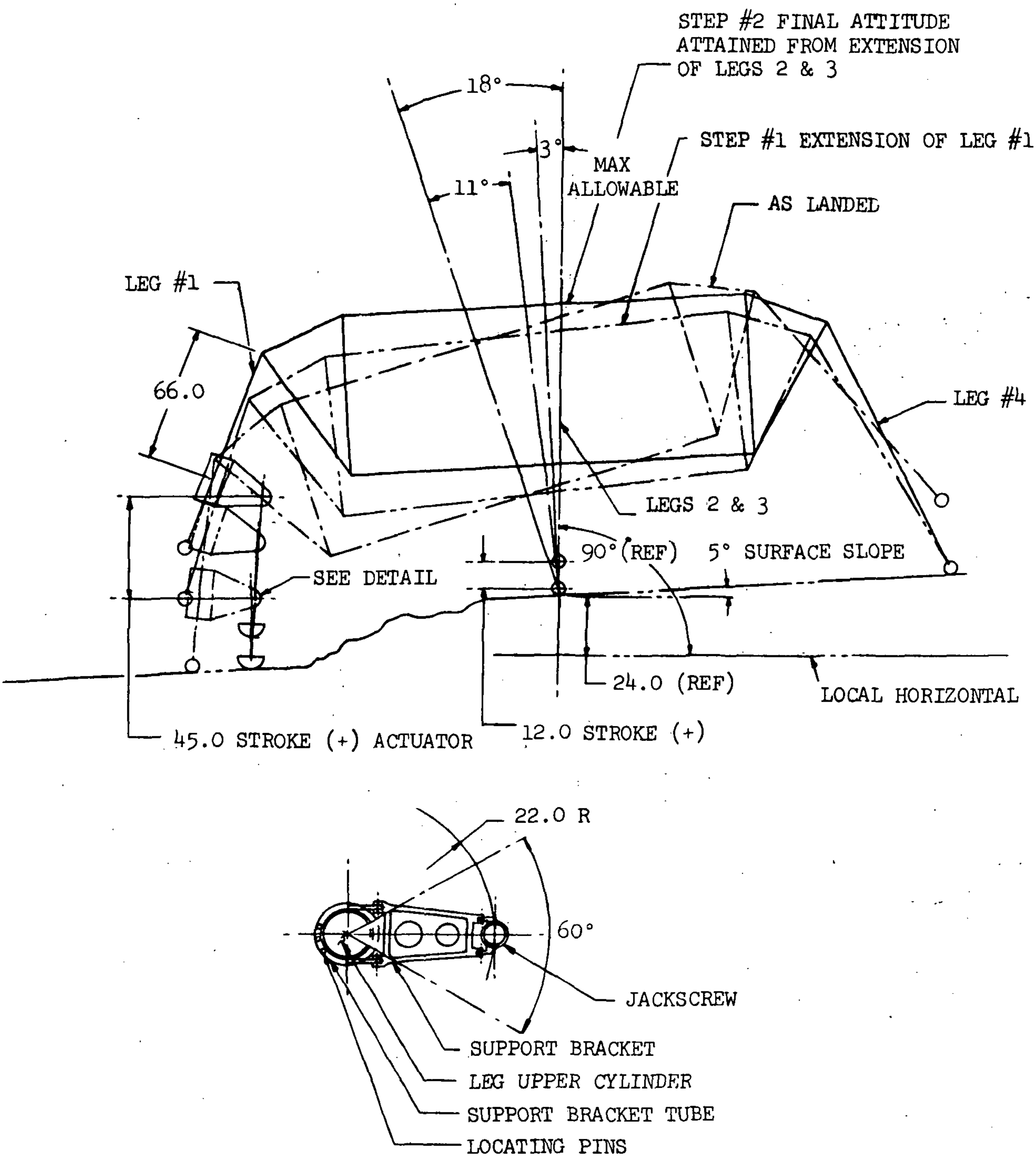


Figure 4-29. LM Truck Levelling Technique No. 3

2. Leveling Only the Shelter

The recommended method for leveling only the shelter is shown in Figures 4-30 and 4-31. It consists of an azimuth orientation turntable, two shelter support beams, and a single axis actuator to tilt the shelter about the support beam pivots.

Other concepts which were investigated included jack screws mounted at the inboard intersections of the LM/Truck beams and two axis gimbal arrangements using parallel motion linkages, ball and socket support of the shelter, and multiple actuators for raising the shelter to provide clearance and subsequent two axis leveling. In general, these concepts were either excessively complex or could not be housed in the available volumes.

The sequence of operation and a description of the recommended system is discussed in the following paragraphs.

Assuming a severe shift in payload and truck cg could occur due to mission operations, prior to leveling the shelter, a manually adjustable length column can be placed under an off-surface leg to stabilize the truck, as indicated in Figure 4-30.

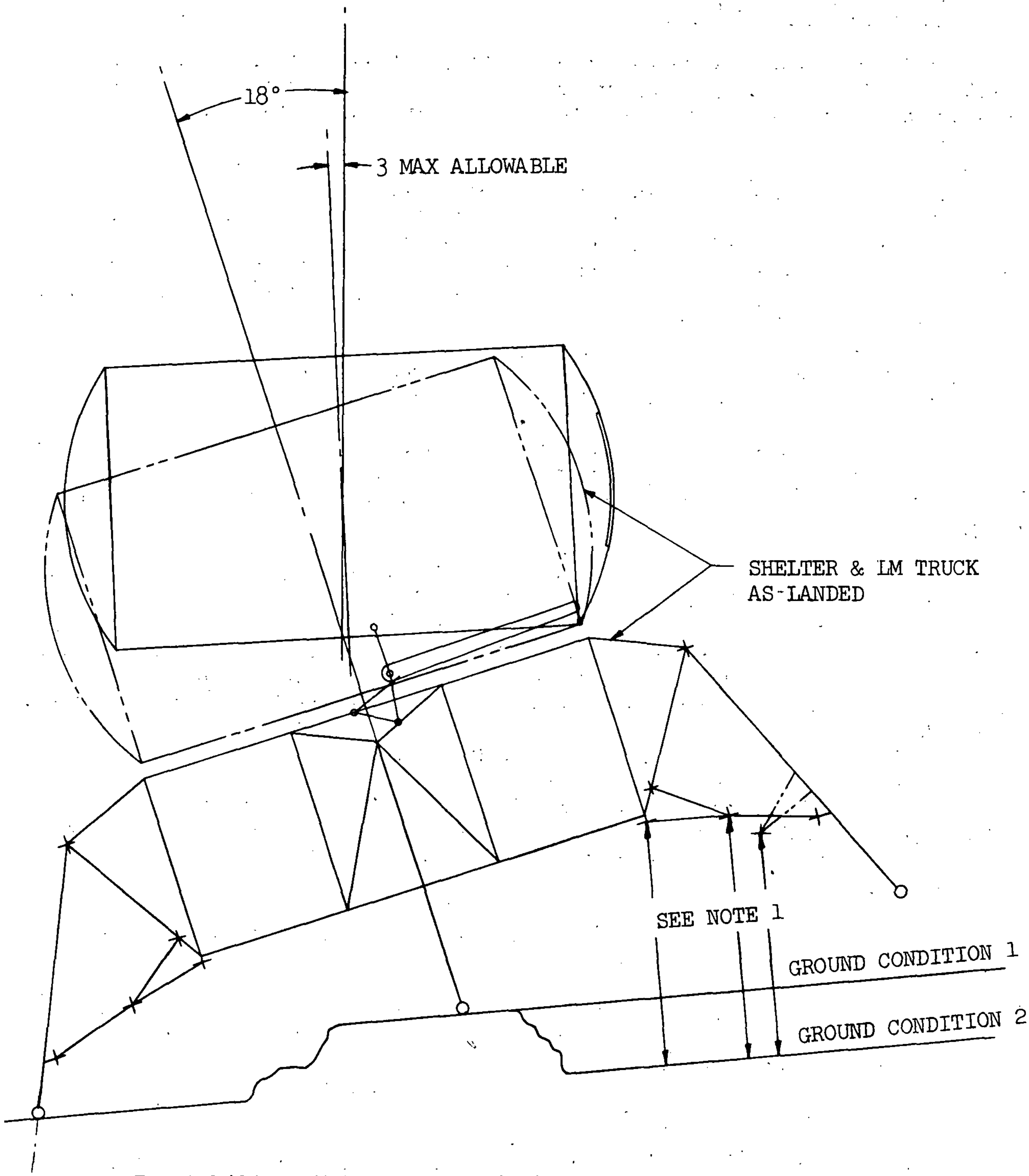
After the release of the shelter to LM/Truck tie-downs, the shelter is supported near the intersection of two of the lower longerons and the airlock end dome/cylinder compression ring by two pivot fittings on the shelter support beams and by the tilt jack screw located below the floor level at the middle of the shelter. The two support beams are attached to the turntable. The turntable assembly and method of support from the LM/Truck are similar to that described for use in shelter payload unloading. The shelter is rotated by the capstan driven turntable until the airlock end of the shelter faces in the up hill direction of the as landed slope; the shelter is retained in that position by a power-off disc brake in the capstan drive. The shelter is then off-level about only one axis. The jack screw between the shelter and a torque tube connecting the support beams is extended to tilt the shelter to the specified nominal horizontal attitude.

As in shelter unloading, all actuators for this system have manual overrides.

Subsequent to leveling, the capstan driven turntable can be used to provide shelter azimuth orientation but with the drawback of having nutation about a vertical axis rather than rotation.

3. Preferred Method of Shelter Leveling

The preferred method of leveling the shelter is by leveling the LM/Truck using Technique No. 2, screw jacks integral with the landing legs and allowing the legs to pivot to preclude lateral motion of the pads.



1. To stabilize LM truck, one simple, manually adjustable length column can be placed under the off surface leg (approx 6 places are easily adaptable to form socket for column)

Figure 4-30. Shelter Levelling/Truck As-Landed

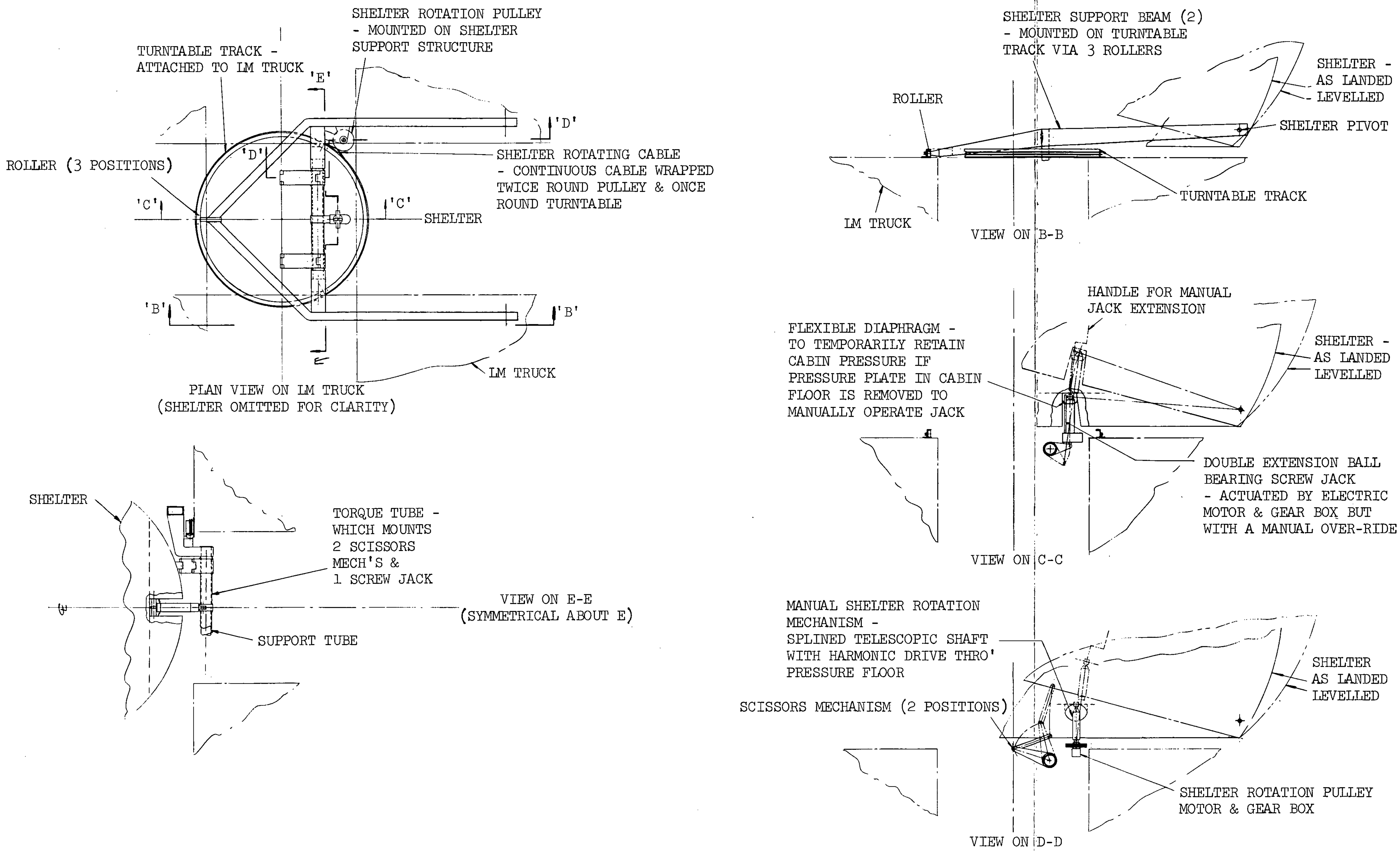


Figure 4-31. Shelter Levelling Mechanism

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The following criteria were used in comparing the various leveling methods:

In-situ surface activities required

Dependence on local surface characteristics/conditions

Weight penalty

Effect on shelter payload complement

The differences in mechanism reliability, cost, and fabrication requirements were second order terms for the purposes of this study.

Using the above criteria the preferred method was selected based on the following considerations.

Technique No. 1 although requiring a minimum of in-situ surface activities for the activation of the leveling subsystem was most dependent on local surface characteristics/conditions since the pads move laterally during the leveling operation. The maximum leveling stroke of 58 in. and the necessity for a two-stage jack in each leg results in the highest weight penalty of 225 lb; the other methods have weight penalties of approximately 100 lb.

Technique No. 2 requires only an in-situ surface activity to latch tie straps between diagonally opposite pairs of landing pads/legs, and, since no lateral pad motion occurs, it is independent of the local surface characteristics/conditions.

Technique No. 3 requires the greatest amount of in-situ activity to mount the leveling jacks to three of the landing legs. Since the jacke have their own surface pads and the choice of bearing area is limited, this system is dependent on local surface characteristics but to a much smaller degree than Technique No. 1; pad lateral motions are considerably smaller or negligible depending on the azimuth position of the jack relative to the landing leg.

The concept of leveling only the shelter is independent of the surface characteristics/conditions and requires the least in-situ surface operations for the actual leveling operation. However, since the shelter moves relative to the truck, external equipment supported jointly by the shelter and truck and/or in a location which prohibits the motion must have its structural ties disconnected/severed from the truck and be supported completely by the shelter and/or be unloaded in the as landed attitude.

The requirement for disconnectable/severable supports and a redundant supporting mode for the external equipment to allow leveling not only increases the complexity and weight of the supporting structures, it also reduces the flexibility of accommodating changes in external equipment. As discussed later, the methods of unloading the LSSM and scientific equipment are independent of the as landed attitude, however, unloading from a leveled payload is simpler and less arduous for the crew. Furthermore, the nonpredetermined final position of the shelter relative to the truck severely reduces the possibility of using truck mounted supports for inspection/maintenance of the shelter and external equipment.

LSSM Unloading

As stated previously, the LSSM storage configuration was considered as a rigid structural unit with its suspension system locked out and the wheels deflected by a self contained force system.

The ground rules noted below were followed for this deployment category:

Flight and landing loads on the LSSM not carried by the unloading system

Accommodate the as landed attitude and conditions specified by the study guidelines (no preleveling required)

Initial studies showed that because of the gross size, mass and location of the LSSM in the payload, as compared to the scientific equipment, the use of two separate systems for unloading the LSSM and scientific equipment would result in a lower total weight and less in-situ activities.

The methods which were considered for unloading the LSSM included overhead cranes, ramps, and parallel motion linkages either separately or in combination.

The possibility of providing 360 deg azimuth orientation for unloading the LSSM independently of rotating the total shelter payload was ruled out because of excessive size and weight of the system. To clear other components of the shelter payload and the truck legs, it would require a boom about 17 ft long mounted on a turntable near the docking tunnel.

The recommended method of unloading the LSSM is shown in Figure 4-32. It consists of an A-frame to control the outboard positioning of the LSSM, a compression strut to pivot the A-frame, and a motor driven capstan wire rope arrangement to control the A-frame motion and lower the LSSM.

The A-frame is supported at its lower end by two pivot fittings connected to the LM/Truck cruciform beams, and near its outer end by a small truss connected to the shelter structure. One end of the compression strut is pinned to the A-frame above the pivot fittings and the other end pinned to a guide in a housing mounted on the LM/Truck beam. The motor driven capstan is mounted on the shelter near the docking tunnel. In the as launched configuration the hinged outer end or extension to the A-frame above the shelter support is folded to fit within the payload envelope.

In reference to Figure 4-32, the unloading sequence is as follows:

Sketch I The LSSM with its deployment mechanism is shown stowed in the as landed position.

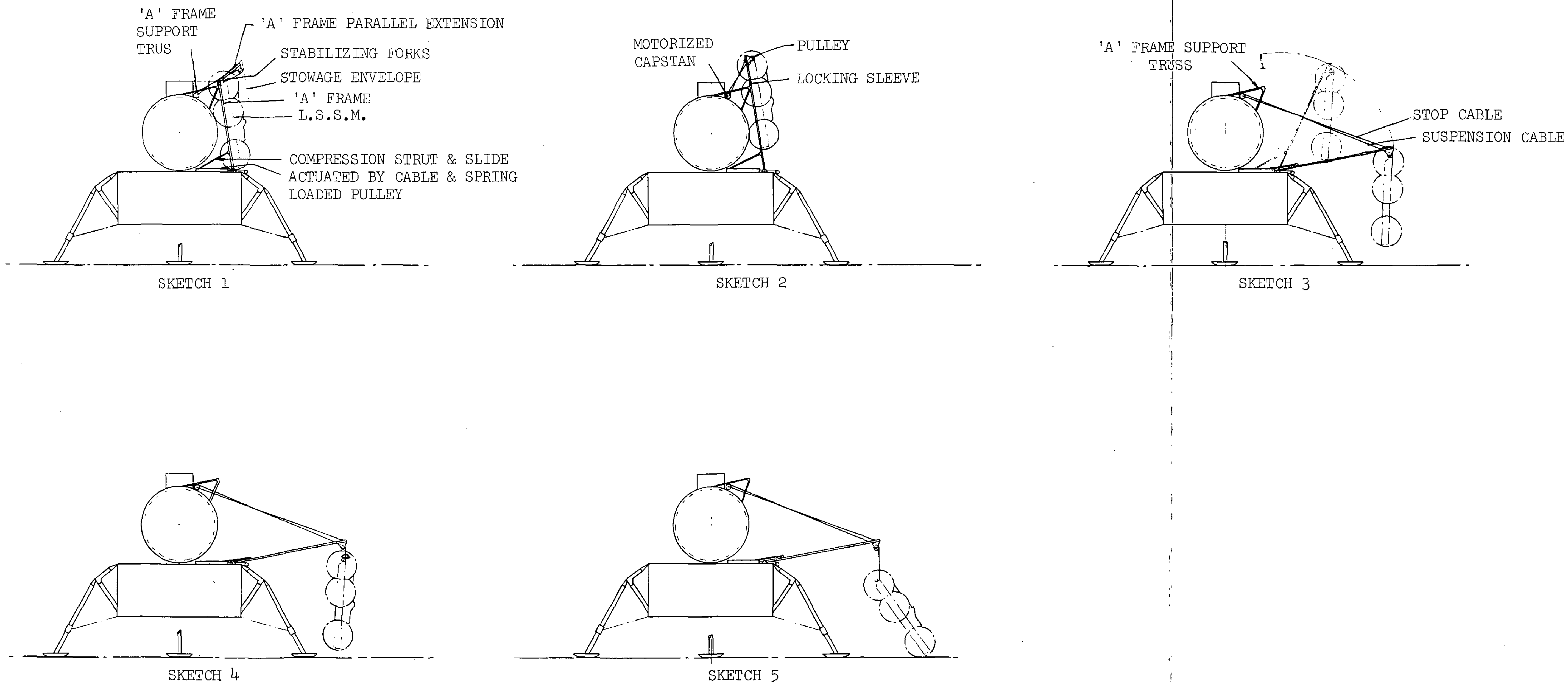

Figure 4-32. Unloading of LSSM

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Sketch 2 The A-frame extension tie-down is released and a spring rotates the extension until it is coplanar with the rest of the A-frame under the LSSM chassis; a spring loaded sleeve slides over the rotation joint to lock it. The LSSM in-flight tie-downs to the LM/Truck are released, and the capstan driven cable raises the LSSM along the A-frame until stabilizing forks on the upper end of the LSSM engage a cross bar at the end of the A-frame. The LSSM is constrained to the straight parallel sections of the A-frame by guide shoes which allow relative motion only along the length of the frame until the cross bar is engaged. As the forks engage with the cross bar, they trip spring loaded catches which allow the LSSM to rotate about the longitudinal axis of the cross bar.

Sketch 3 The A-frame is squib released from its tie-down to the support truss. The spring loaded compression strut rotates the A-frame outboard, the rate of rotation being governed by the rate at which the suspension cable is paid out. The resulting LSSM angular motion about the A-frame pulley cross bar is damped by a wire snubber. The A-frame rotation continues until a guy wire from a hardpoint on the shelter to the tip of the A-frame is taut. This releases the spring loaded catches holding the LSSM stabilizing forks to the A-frame pulley cross bar and the LSSM is held now only by the suspension cable. The controlling length of the guy wire is in-situ adjusted as a function of the as landed attitude.

Sketch 4 The LSSM is lowered by the suspension cable until its stabilizing forks are clear of the A-frame. The forward wheel deflection straps are released, and the LSSM may be rotated about the axis of the suspension cable by an astronaut standing on the surface until it faces the most suitable position for unloading.

Sketch 5 The LSSM is lowered by the suspension cable until its leading wheels rest on the surface. These wheels are then energized or allowed to free wheel while the suspension cable continues to lower the LSSM until all wheels contact the surface. The suspension cable is then removed from the LSSM chassis.

The fitting holding the LSSM in a contracted configuration may be released just prior to the aft section contacting the lunar surface.

The estimated weight for this method of unloading the LSSM is 40 lb.

Scientific Equipment Unloading

The lunar weight of the individual scientific equipment packages is within the lifting and carrying capabilities of a suited astronaut. However, the shape or bulk of some of the packages combined with their locations in the payload envelope would require the astronaut to assume precarious positions if equipment were unloaded without any mechanical aids.

The majority of the equipment storage locations are directly accessible from above and therefore the equipment could be easily removed by an overhead hoist. The few packages between the lower section of the shelter and the truck beams are sufficiently low in weight to allow complete manual unloading or positioning them for mechanical unloading.

With the air of an overhead hoist, each container/frame housing experiment package can be removed as a unit, thus reducing the number of unloading operations.

A simple portable manual/motorized jib boom hoist mountable in sockets at any of four positions on the shelter provides sufficient coverage with a 66 in. boom to unload all the scientific equipment. Its operation can be controlled locally at the mast or from other positions by an electric cable-connected control box. The jib boom hoist, in an installed position on the shelter, is shown in Figure 4-33.

The boom is hinged to the top of the mast to allow folding for initial storage in the payload envelope and subsequent ease of repositioning at any of the four positions on the shelter.

The estimated weight of this unloading arrangement is 31 lb.

Crew Access

The requirements/ground rules to be satisfied by the crew access system are:

Provide for initial entry into the shelter in the as landed attitude

Provide for crew and equipment transfer between the shelter and the lunar surface during normal mission activities

Provide accessibility to scientific equipment to facilitate unloading

Provide for transfer of incapacitated astronaut between lunar surface and shelter

Provide access to the exterior of the shelter paylaod for inspection/maintenance

Methods of providing crew accessibility by means of inclined ramps, inflatable staircases, mechanized lifts and simple ladders were investigated. The recommended approach consists of using two ladders and the scientific equipment jib boom to satisfy the above requirements/ground rules. Initial entry to the shelter would be by means of a portable extendible ladder which is initially located on the LM/Truck face. As shown in Figure 4-24, if the truck lands such that the airlock is in the four leg position, a fixed ladder on that leg may not be accessible to an astronaut from the surface. However, a multisection ladder stored on an LM/Truck face would be accessible.

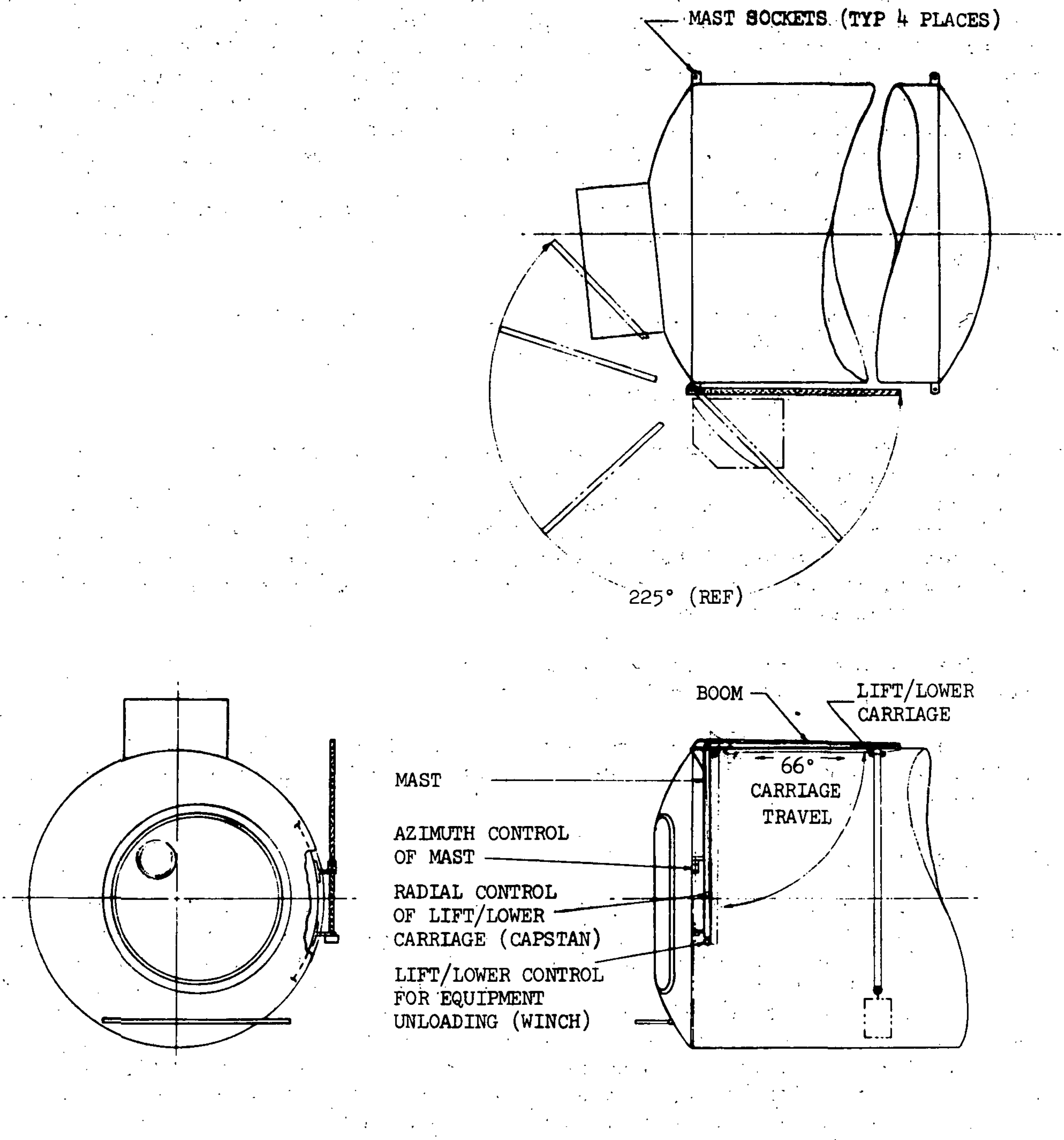

Figure 4-33. Equipment Unloading Device

Following detachment and extension of the ladder, its upper end would be latched into a connector on the truck below the airlock door, and its lower end placed in contact with the lunar surface. After climbing the ladder, the crewman releases a folded access platform below the airlock door, steps on the platform and proceeds to open the airlock door.

After the truck is leveled, a second multisection ladder is deployed from the access platform to the most suitable location on the surface and is used for all normal ingress/egress during the mission. The portable ladder which had been used for initial entry is therefore free to provide accessibility to the scientific equipment and for shelter payload inspection/maintenance. Areas which are inaccessible with the portable ladder are reached by means of a small platform which is supported and positioned by the equipment unloading hoist.

An emergency litter, foldable for storage, can also be attached to the hoist to carry an incapacitated crewman between the surface and the shelter airlock.

The estimated weight for the crew access system, exclusive of the equipment unloading hoist, is 64 lb.

RADIATION AND MICROMETEOROID PROTECTION

The radiation and micrometeoroid environments in space influence the design of manned lunar shelters since weight penalties, dependent on mission time and the probability of not receiving or exceeding specified limits of detrimental effects, are required to militate against the hazards associated with these environments. The probability aspect is particularly important since the number of hazardous events encountered is assumed to be proportional to the elapsed exposure time.

The micrometeoroid model environment and the penetration criteria as specified by NASA for LM and AAP missions were used for this study.

The radiation environment model as specified in the NASA TN D-2746 (Reference 3) was used since LM data does not extend to the mission duration considered in this study.

Radiation Analysis

The radiation sources potentially harmful to the lunar shelter personnel and equipment are solar flares, galactic cosmic rays, lunar surface radiation, solar wind, and nuclear power sources. For this phase of the study it was assumed that the power source would have adequate self-shielding and therefore not contribute any weight penalty to the radiation protection required. Of the remaining four sources, the galactic cosmic rays, lunar surface radiation, and solar wind are negligible when compared to the solar flare proton fluxes. Therefore, protection analyses were based on the solar flare environment and the total dose criteria as specified by the NASA work statement (Reference 2). Parametric studies have been performed to determine shield weight as a function of probability of not exceeding the specified dose limitations, dose to the blood forming organs and skin, and exposure time. The protection provided by refuge arrangements utilizing internal equipment and supplies, and supplementary water blankets is discussed in this section.

1. Solar Flare Protection Requirements

For manned missions, the radiation reliability was taken as the probability that the biological dose to the crew during the mission would not exceed the emergency limits. This is specified by the NASA study work statement to be 500 Rad for the skin and 200 Rad for the blood forming organs. Using the data from NASA TN D-2746 (Reference 3), the effect of radiation protection and total mission time on the biological radiation reliability is shown in Figure 4-34.

As an example of its use, consider a shelter radiation refuge with wall and roof area A (sq ft), then the weight of the refuge in pounds for a particular staytime, probability, and dose is 2.04 At, where t is the equivalent gram/cm^2 of aluminum. For the refuge shown in Figure 4-8, which has 105 sq ft of wall and roof area, and an average equivalent shield thickness, t of 10.3 gm/sq cm, the total equivalent aluminum weight of shielding is 2205 lb. If this is used to provide a shield of uniform thickness, the probability of not exceeding the specified doses for a 50-day stay time is less than 0.999. To achieve a 0.999 probability of not exceeding the specified BFO dose, which at a 50-day stay time is the more critical, the equivalent weight of aluminum shielding would have to be increased by 365 lb. However, it is highly improbable that the equipment and supplies available for shielding can be arranged to provide a uniform shield. The radiation weight penalty, therefore, is that weight necessary to bring all surfaces equivalent to the average shield thickness $\bar{t}$ for a given stay time, probability, and dose.

Since it is difficult to fix physiologically a value beneath the specified skin and BFO emergency doses, and psychologically an area of comfort, one can consider two approaches to the problem of designing a radiation refuge. One approach would be to tradeoff dose and weight to the point where the weight becomes unacceptable, and the dose level is appreciably under that which has been specified. If the dose were sufficiently under that specified, consideration might be given to continuing the mission once the solar flare has passed. The second approach is to determine the desired protection for a single large flare and design the shield for minimum comfort and minimum weight for a given dose, probability, and stay time. The following paragraphs discuss these two approaches and present the parametric curves for trading-off shield weight, probability, stay time, and dose.

The dose is computed by obtaining from the model environment the solar proton probability fluxes for five different mission durations at two-week intervals, converting the fluxes from a 30 MEV to a 100 MEV particle cut-off energy, and finding the thickness of aluminum needed to yield a particular dose (Reference 9). Shown on Figures 4-35 through 4-39 are the skin and BFO doses as a function of aluminum thickness and probability for various stay times. The dose includes an estimate of the contribution from secondary particles and are for one-half the free space flux. The lunar surface is assumed to shield the remaining one-half of the free space flux. For the BFO curves, the equivalent aluminum shield thickness is in addition to the 5-cm protection afforded by the skin.

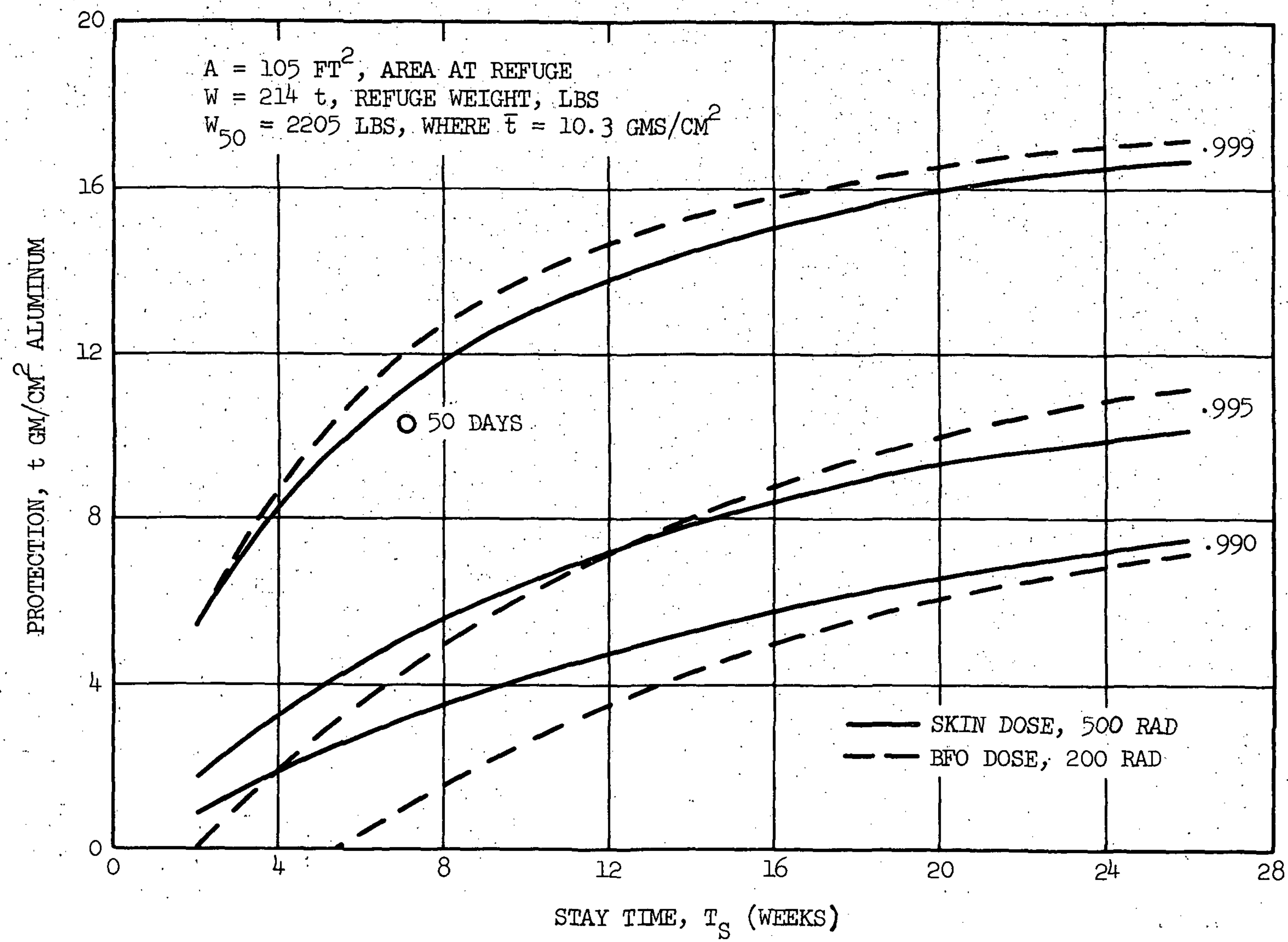

Figure 4-34. Solar Flare Protection

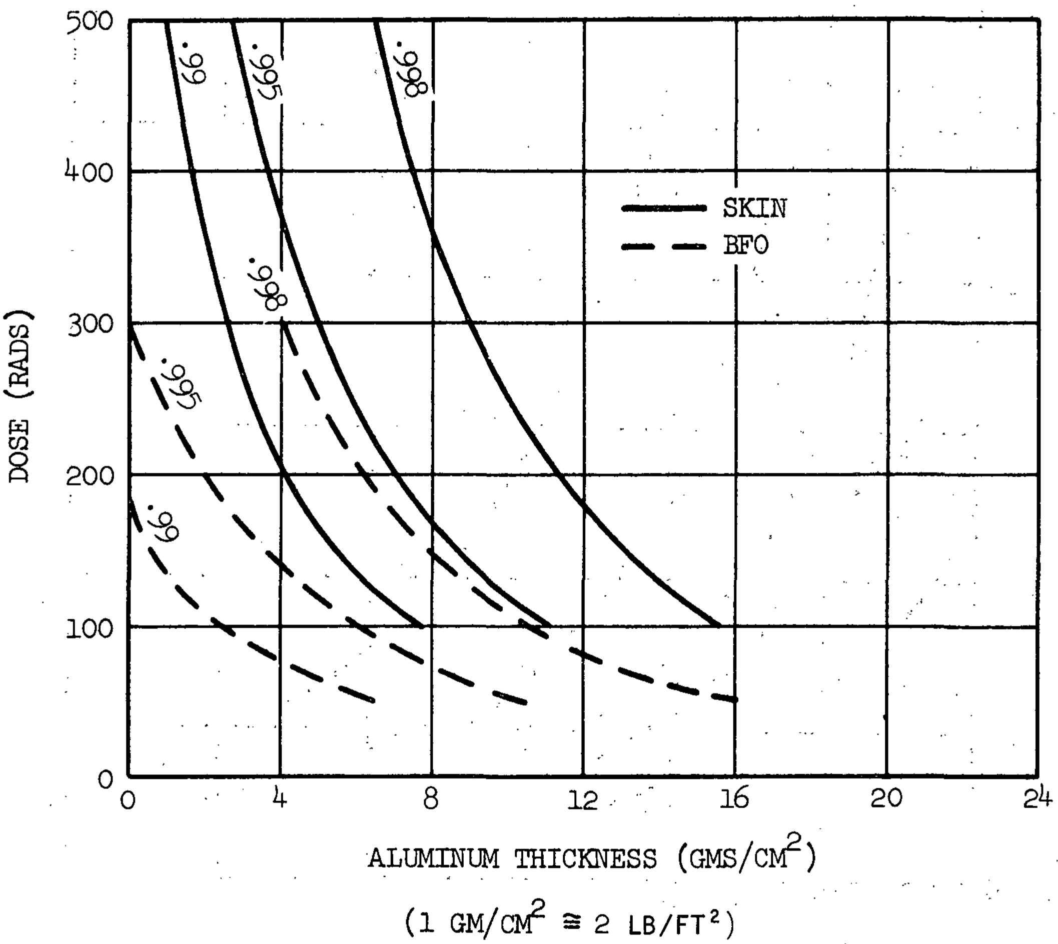

Figure 4-35. Solar Flare Radiation Shielding, 4-Week Exposure

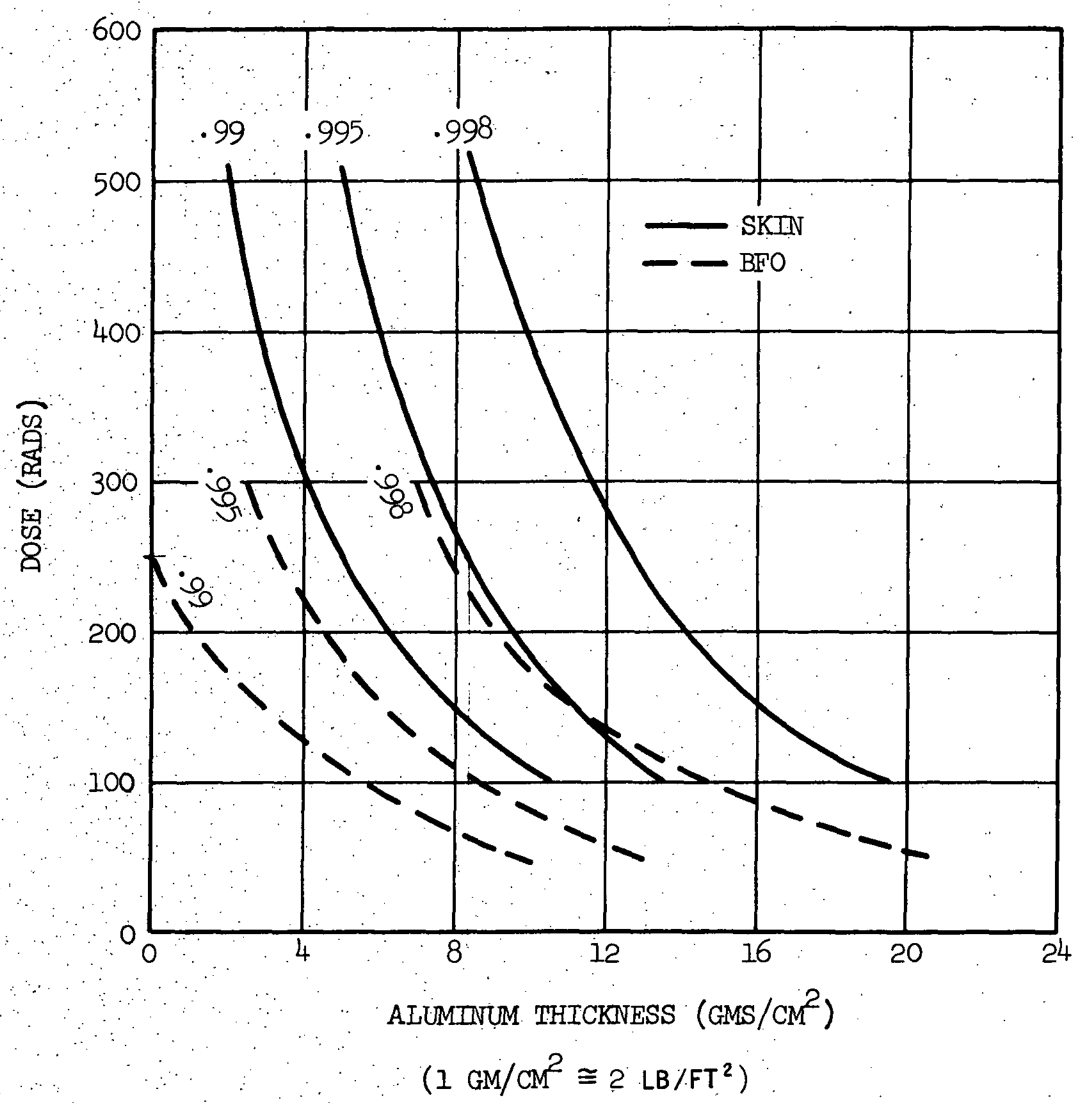

Figure 4-36. Solar Flare Radiation Shielding, 6-Week Exposure

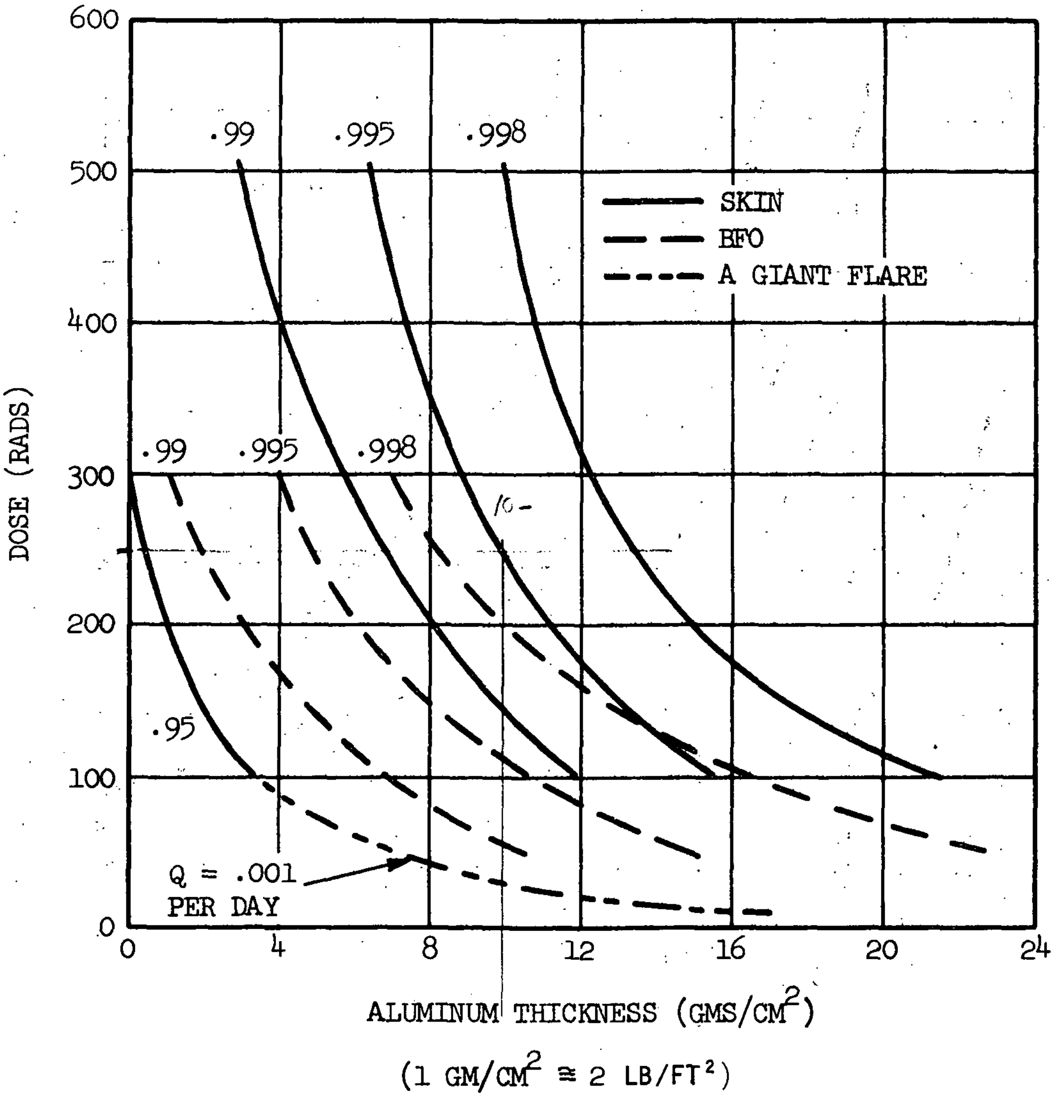

Figure 4-37. Solar Flare Radiation Shielding, 8-Week Exposure

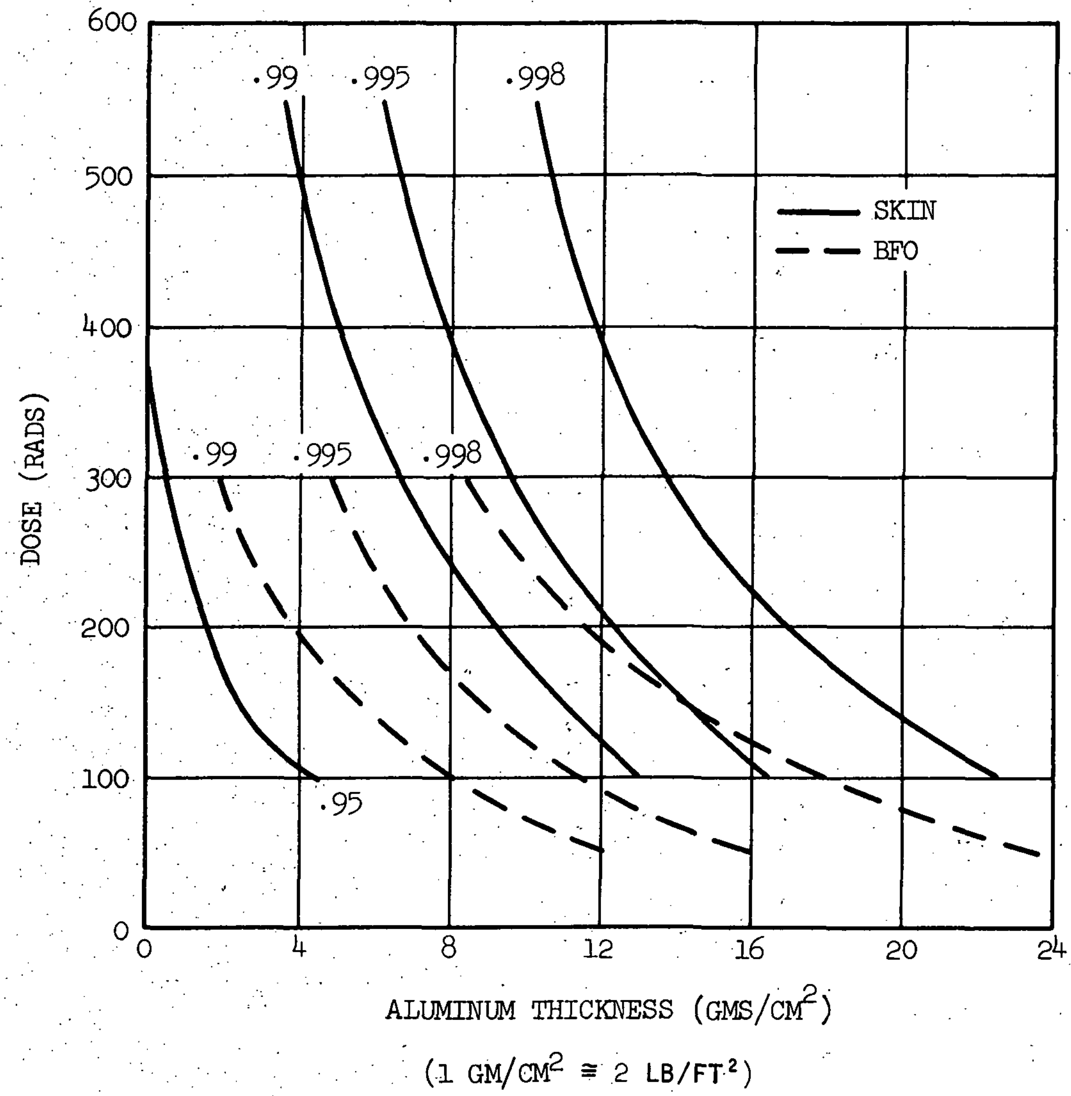

Figure 4-38. Solar Flare Radiation Shielding, 10-Week Exposure

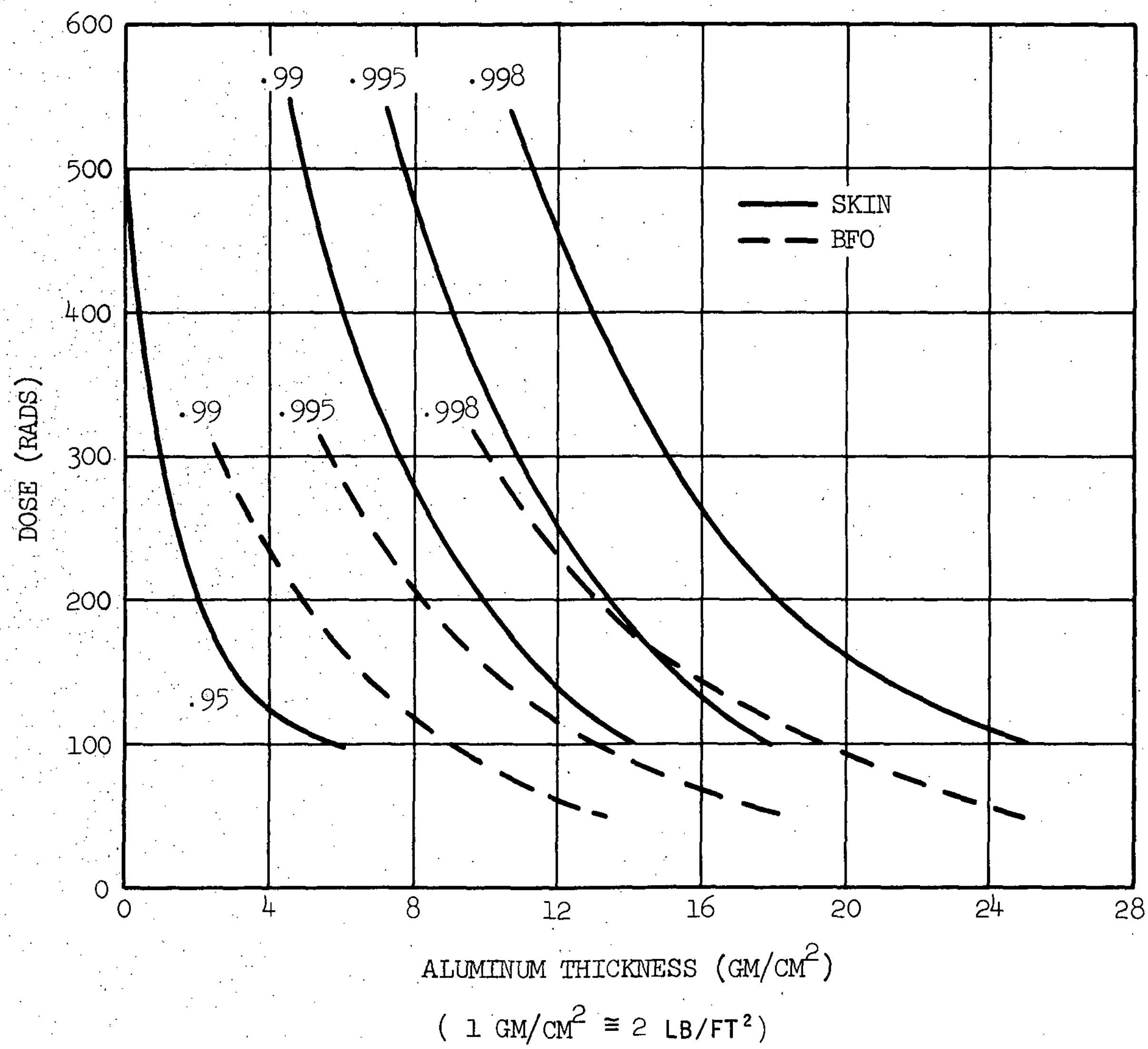

Figure 4-39. Solar Flare Radiation Shielding, 12-Week Exposure

A refuge, which is enclosed by walls constructed of internally stored equipment and supplies, may be estimated in terms of its equivalent worth of aluminum thickness. For this value a dose is determined from the appropriate curves depending on the exposure period. Because each wall has its own slab thickness the total protection of the refuge is a sum of each wall weighted by the solid angle it subtends. If the total protection is insufficient, water panels can be added to attain the desired dose level. It is the weight of these panels that is traded off against probability and dose to achieve an acceptable reliability rating for completing a successful mission. If the panel weights are maximized to the payload constraint, and the dose is still evaluated to be too high, mission length and reliability can be traded off to lower the dose level.

The second approach is to determine the protection for a single large flare and design a shield to enclose a minimum volume. This would provide the minimum control requirements to the crew. However, if a flare were to occur that was of smaller magnitude then designed for, the mission may continue rather than be aborted. Shown on Figure 4-37 is the 0.95 skin dose curve, for a giant flare assumed to have an integrated intensity of protons, having energies greater than 30 MEV, of 2×10^9 per sq cm. The probability that the crew will receive such a flare on any day is 0.001, and the probability for any number of days, T, is simply 0.001 (T).

It is readily apparent that this approach reduces the dose by a substantial amount. But it also considerably reduces the probability that a long mission will be completed. For example, an 8-week mission has less than a 0.95 chance of not seeing a giant flare.

2. Radiation Refuge

The two refuges shown in Figure 4-40 are based on the design condition of 50-days stay time shown in Figur 4-34 and using internally stored supplies and equipment in conjunction with water filled polyethylene blankets for shielding. The water filled blankets, holding the LiOH cartridges in sleeves, would be contoured in thickness such that the combined worth of the depth of the circular cross section LiOH and water blanket at any particular point is a constant. The austere volume of the quonset hut arrangement requires about 300 lb of water blanket to provide 8 gm per sq cm equivalent Al thickness protection. The seated arrangement, which allows the crew comparatively high freedom of movement, requires about 650 lb of water blanket to provide 8 gm/sq cm equivalent Al thickness protection. The surrounding shelter wall structure provides an additional 2 gm per sq cm equivalent Al thickness for either arrangement. The net weight penalties are the above weights minus the water on board at the beginning of staytime.

Micrometeoroid Analysis

To provide a means for comparing various meteoroid protection designs NASA has specified, for LM and AAP missions, a mathematical description of the micrometeoroid particles present within the near-earth, cislunar, and near lunar regions, and has prescribed the mathematical criteria to be used in

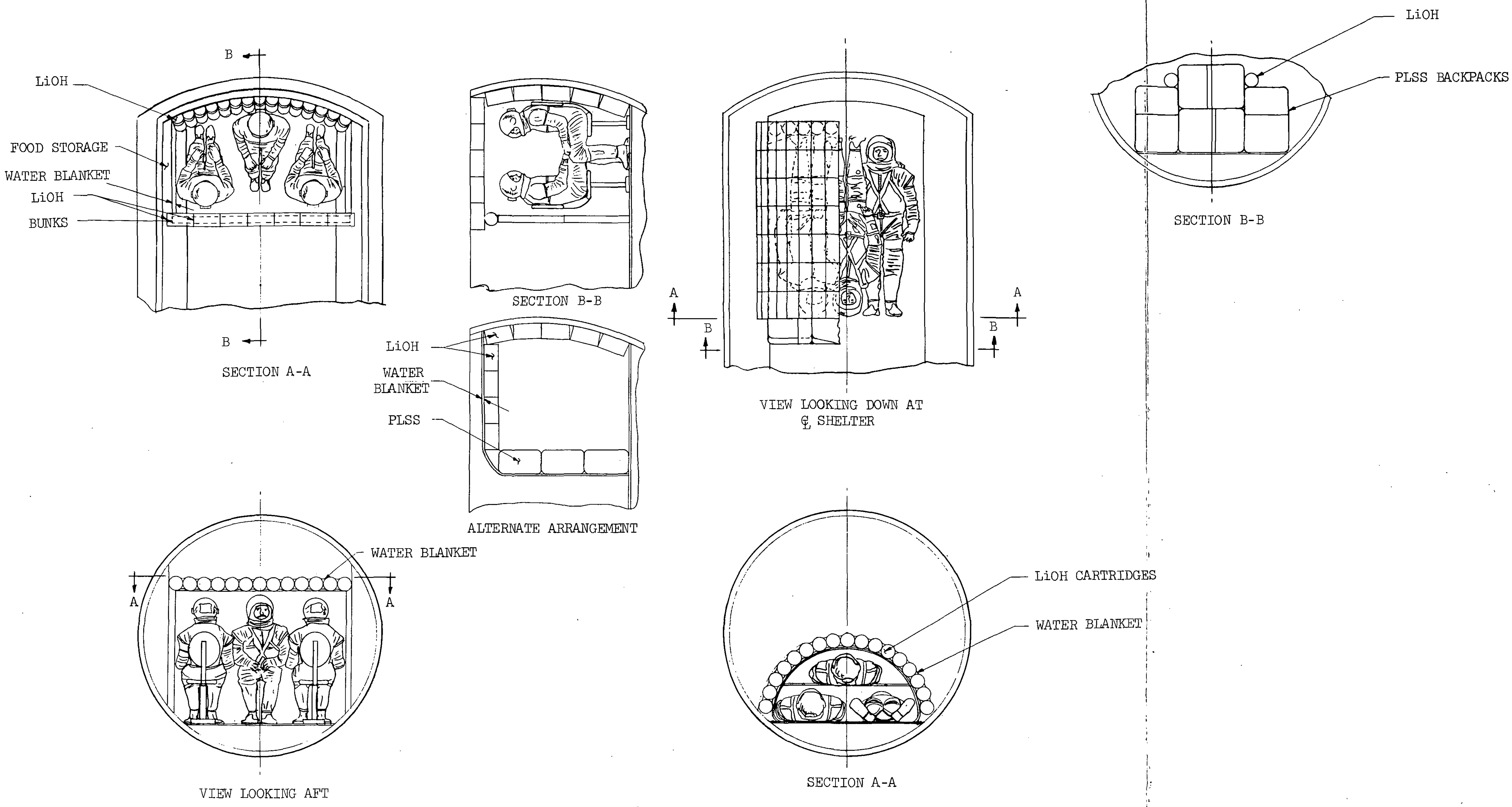

Figure 4-40. Radiation Refuge Arrangement

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determining their penetrating capabilities. The following sections describe the use of this data in determining an optimization technique for the micrometeoroid protection, present a meteoroid probability assessment for the recommended shelter, and discuss the applicability of materials for protection and possible self-sealing techniques.

I. Optimization of Micrometeoroid Protection

Micrometeoroid protection requirements have been specified as 0.997 probability that the structure will not be penetrated during its lunar mission. This probability is the product of two others; the probability of no penetration by a primary meteoroid and the probability of no penetration by a secondary meteoroid. These secondary particles are of a much lower velocity and are what is more commonly referred to as ejecta particles. Because they strike the vehicle at all angles they are defined as being random and isotropic. The optimization procedure results primarily from (1) operating in these two different kinds of micrometeoroid environments; one composed of high velocity particles, the other low velocity particles, each having their own penetration criteria, and (2) specifying that the protection configuration and its reliability requirement are held constant throughout the mission. Because the environment being considered is primarily composed of high velocity particles only, a spaced bumper-backup sheet configuration is used and the AAP penetration criteria used for the bumper selection.

The optimized or minimum shield thickness occurs when the reliabilities apportioned to each environment result in the same shield weight or thickness. The argument to support this is best expressed in terms of Q, the unreliability. Because the sum of the apportioned unreliabilities must equal the specified Q, an increase in either apportioned Q means a compensating decrease in the other apportioned Q, and since the unreliability is inversely proportional to skin thickness, any decrease in an unreliability means an increase in the corresponding skin thickness.

Based on the foregoing rationale and the analytical approach specified for the Apollo program (References 10 and 11), a set of curves for rapidly estimating the required meteoroid protection is shown on Figure 4-41. The specified value for Q is found on the ordinate, and a line may then be drawn across the plot from this point. A value for the total shield thickness (Σt) is selected for a first estimation, and a line may then be drawn vertically from this point on the abscissa. Where this line crosses the straight line plotted for the secondaries is the value of Q_s apportioned to secondaries. Subtracting this value from Q gives, Q_p, that portion of Q assigned to the primaries. The intersection of the line drawn horizontally from Q_p with the vertical line from the first estimates value for t gives the primary shielding configuration. If the spacing is larger than that desired, or if less shielding is desired, successive choices of Σt are tried until a combination of Q_s and Q_p is found which gives the minimum Σt.

When the chosen AT, referred to as $(AT)_c$, is different than the one used to obtain the curves, the chosen Q_c is normalized to Q_n by multiplying it by the ratio of the two AT values as shown on the plot. The above procedure is then executed using Q_n instead of Q_c.

For an example, use the nominal ELS values of 0.003 for Q_c, an effective area of 260 sq ft, and a mission length of 230 days. Then, $(AT)_c = 6 \times 10^4$ sq ft-days and Q_n from the formula on Figure 4-41 equals 0.00075. This line is shown on the curve. A minimum shielding thickness is given by the point of intersection of this line with the straight line for the secondaries. Σt for this point is 53 mils. Starting with a 3 in. bumper spacing, a first try might be where this line intersects the secondary line. For this point,

$$Q_n = Q_s + Q_p = 0.00044 + 0.00044 = 0.00088$$

and $\Sigma t = 60$ mils.

Maintaining this Σt would require an enlargement of the bumper spacing in order to reduce Q_p to,

$$Q_p = Q_n - Q_s = 0.00075 - 0.00044 = 0.00031$$

The required spacing is therefore 3-1/2 in. If larger spacing were tolerable, then Q_s could be increased, which would result in a reduced Σt.

If a spacing of 3 in. is desired, then a second guess for Σt might be 70 mils. But for this value,

$$Q_p = 0.00034 \text{ and } Q_s = 0.00024$$

This gives too severe a Q_n (equal to 0.00058). Very quickly one can see that for the correct Q_n the combined thickness must be:

$$\Sigma t = 64 \text{ mils}$$

Therefore the combined thickness of 64 mils is optimum for a bumper and backup sheet with no material in the spacing. Because a 15 mil bumper will satisfy the entire range of stay times projected for ELS missions, this thickness may be kept constant for the bumper. The backup skin thickness then becomes

$$t = 64 - 15 = 49 \text{ mils}$$

These requirements can be considerably reduced by consideration of foam in the spacing and a fibreglass bumper instead of the aluminum. This is discussed under bumpers and spacers in the materials discussion.

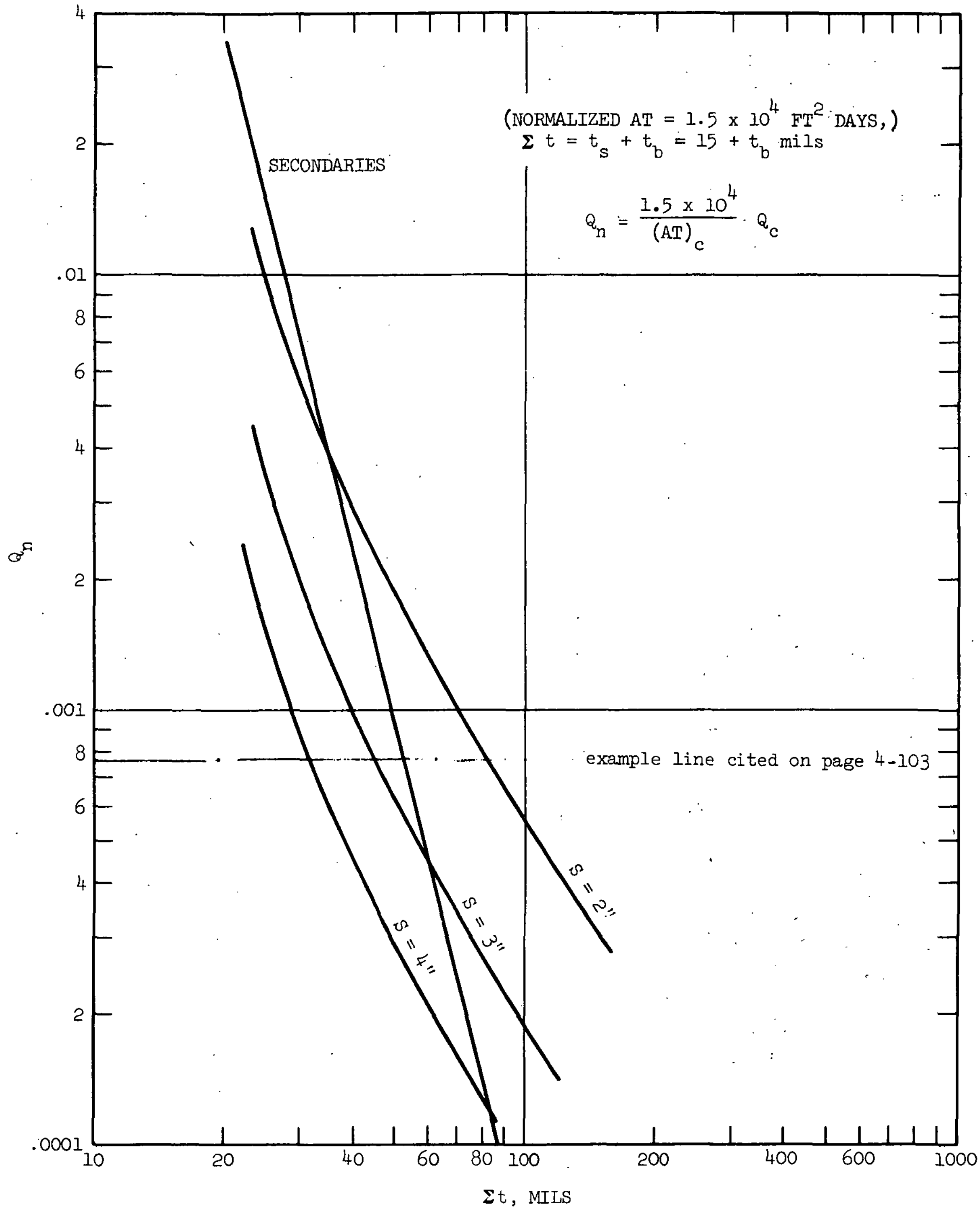

Figure 4-41. Micrometeoroid Protection Optimization

2. Probability Assessment of the Recommended Shelter

This analysis determines the probability of the recommended shelter successfully completing its mission. The mission was divided into two phases: a storage phase lasting six months plus three days for transit and a manned phase lasting 50 days.

Effective areas for the shelter were obtained by neglecting the docking hatch and estimating how much of the smooth cylinder was shadowed by externally stored equipment. The shadow shielded areas and the various external components are:

40 sq ft	Descent stage
61	ECS and FCA radiators
35	Tanks
11	FCA
6	PCE and EE
50	LSSM
14	Scientific Equipment

The effective areas are lso a function of the mission phase and the environment. During the manned phase, the last three items above will be removed from the payload,and the airlock will act as a bumper for the remainder of the shelter. Therefore, the airlock and one end of the cabin was not included in the analysis. It was also assumed that the men spend all their time in the work/living and sleep/rest sections of the shelter.

The above considerations result in three reference areas from which the various effective areas are determined by subtracting from the applicable reference area the appropriate projected areas of the externally stored components. The three reference areas are: total internal area of the shelter (440 sq ft), internal area of the work/living and sleep/rest sections of the shelter (390 sq ft), and the internal area of the latter minus the airlock bulkhead (340 sq ft).

The following table presents the results for a 15-mil bumper spaced 2.5 in. from a 30-mil backup sheet and does not include the attenuation effects of a spacer material such as foam.

Structure Reliability

(t_s = .015 in, s = 2.5 in, t_b = .030 in.)

Environment	Storage Phase				Manned Phase			
	A_{eff}	Q	P_o	$P_{o,1}$	A_{eff}	Q	P_o	$P_{o,1}$
Primary	233	.00440	.99560	.9999902	218	.001150	.998850	.9999993
Secondary	284	.00665	.99335	.9999780	308	.001754	.998246	.9999984
Combined		.01105	.98895	.9999348		.002904	.997096	.9999956

The symbols used in the table are:

A_{eff} = the effective area

Q = the probability of one or more punctures

P_o = the probability of getting no punctures

$P_{o,1}$ = the probability of getting no more than one puncture

The results show that tremendous gains in reliability are made if just one puncture is allowed. A natural counterpart of this is that more than one puncture is extremely unlikely; one chance in fifteen thousand for the storage phase, and one chance in two hundred thousand for the manned phase.

If one assumes that the mission will be continued should the puncture occur during the storage phase, than the probability of mission success is:

$$P_{ms} = P^s_{o,1} \times P^m_o = 0.9999348 \times 0.997096 = 0.997031$$

If a puncture is not permitted during the storage phase, the mission success is:

$$P_{ms} = P^s_o \times P^m_o = 0.98605$$

To raise this to 0.997 would require a 30-mil increase in the backup skin thickness to 55 mils. This would result in an 185-lb weight increase. As discussed previously, these requirements can be considerably reduced with the addition of foam between the bumper and backup sheets. These effects are discussed below.

3. Materials Discussion for Meteoroid Protection

For backup sheet thicknesses, four materials (berylluim, magnesium, titanium, and stainless steel) are compared by weight to aluminum by using the penetration criteria as specified for AAP missions:

$$t_b = \frac{42\ m\ V}{S^2} \left(\frac{70,000}{\sigma 0.7}\right)^{1/2}$$

where s = spacing between the bumper and the backup sheets.

$\sigma 0.7$ is the compression yield stress in psi equivalent to 0.7% of strain.

The weight comparison is made by forming the ratio:

$$\frac{W}{W_{Al}} = \frac{\rho t_b}{(\rho t_b)_{Al}} = \frac{\rho}{\rho Al} \left(\frac{\sigma Al}{\sigma}\right)^{1/2} = \frac{\rho}{0.101} \left(\frac{70,000}{\sigma}\right)^{1/2} = f$$

This is referred to as the weight factor. The following table gives the weight factors for the various materials.

Comparative Weight Factors

Material	Density (lb/cu in.)	Stress (psi)	f
Beryllium	0.067	66,000	0.683
Magnesium	0.0647	30,000	0.978
Aluminum	0.101	70,000	1.000
Titanium	0.171	119,000	1.350
Stainless Steel	0.277	195,000	1.645

Aluminum is the preferred material, because the potential weight saving offered by beryllium is offset by its lack of weldability and the marginal advantage available from the use of magnesium is offset by the requirement for heated forming.

The Goodyear Aerospace Corporation (GAC) for several years has been conducting experiments designed to determine the effectiveness of low density foam materials in destroying projectiles with velocities 18 to 22 thousand ft/sec (Reference 12).

For bumpers, tests showed that metallic skins erode upon impact, spraying a shower of fragments. Fiberglass cloth impregnated with an elastomer, such as silicone, did not shed particles and was more effective in shattering the projectile (pyrex sphere, used to simulate stony meteroroids). A fiberglass-silicone bumper weighing 0.17 lb/sq ft was sufficient to shatter projectiles weighing up to 70 milligrams. It was shown to be more effective than a 12-mil aluminum skin, its equivalent by weight.

For spacers, a number of materials and structural configurations were tested, but foam was clearly superior to anything else tried. GAC calls the various flexible and rigid foams mechanical atmospheres because they appear to destroy a projectile in much the same way out atmosphere destroys a meteroroid. In fact, the destructive efficiency increased as the foam density was decreased. However, as the density is reduced other factos such as vibration loads begin to play a role in the selection of a filler. GAC recommends as optimum a flexible polyurethane foam with a density of 1 lb/sq ft.

Though GAC (Reference 13) does not have a mathematical expression which yields required foam thicknesses to stop meteroroids of various descriptions, it has produced three points which are helpful in estimating foam thicknesses for the ELS mission.

Flexible Foam Spacers

Particle Mass (mg)	Inches of Foam	Bumper Required (mils of fiberglass)
70	3.5	10-15
17	2.0	10-15
5	1.0	none

The above table shows that a bumper is not needed for particles with masses on the order of 5 mg or less. This size includes the LM design meteoroid for primary particles. The weight of one in. of this foam is 0.083 lb/sq ft.

The primary design meteoroid (10 mg) of the ELS missions falls into the middle category. The two in. of foam used in the GAC test would convert the particle into a gas jet which would impinge on the structural wall. Though the experiments support this description, there is a serious question of their application to the higher velocity particles. Also unknown is the effect in the backup wall for less than the two in. of foam. The experiments nevertheless indicate that a fiberglass bumper is more effective than an aluminum wall of equal weight and that insertion of foam between bumper and backup sheet significantly reduces the size of the backup sheet as required by the previous optimization analysis. The ability of this protection to stop secondary ejecta is discussed below.

The GAC data for low velocity particles if very meager. However, two points were found for two in. of foam covered with a 5-mil dacron cloth and a 2-mil white surface coating. They are presented in the following table.

Low Velocity Projectiles

(= 3.5 gms/cm^3, V ≐ 830 ft/sec)

d < 0.18 in.	particle bounced off
d = 0.28 in.	penetration occurred

In Reference 11, three velocity groups are specified for secondary ejecta. The particle velocity specified for the middle velocity group is 820 ft/sec. The design meteoroid for this middle group is less than one tenth of an in. These particles and those of the lowest velocity group should bounce off the foam filler. The design meteoroid for the particles in the highest velocity group (5000 ft/sec) of Reference 11 is 0.0089 inches. As shown in the above table, this is less by a factor of three than the particle size required to penetrate the foam at 830 ft/sec. Also the density of the ejecta particles is 30 percent less than that of the experimental projectile used by GAC. Thus it is assumed that the ELS particle would be unable to penetrate a 15-mil fiberglass bumper and two in. of foam and then have enough energy left to damage the backup wall structure.

As discussed in Reference 14, several approaches have been examined for providing a self-sealing layer to the wall inner face to self-repair a meteoroid damage. One such method, reported in Grumman Aircraft Engineering Corporation LLS studies, which has been tested by U.S. Rubber in a vacuum with promising results, involves the use of a closed cell-type cellular rubber liner. When punctured, the resulting exposure causes the liner to swell, thereby effecting a seal. Weight of the liner is approximately 0.1 lb per sq ft.

More recently, a self-sealing rubber liquid, has been developed at the Air Force Materials Laboratory. The liquid hardens instantly and automatically when struck by a fast-moving projectile. Two liquid rubber reactants, packaged separately, are mixed by the outward flow of air after puncture, producing a hardened elastomeric mass that seals the puncture. The reactants could be contained between quilted, laminated sheeting which is fastened to the internal surfaces of the shelter walls. Further development work, however, is required in this area before benefits can be reliably assessed.

FINAL VERSION OF THE RECOMMENDED CONFIGURATION

A final version of the recommended configuration was generated to accommodate changes such as increased cryogenic tankage requirements and the results of continued study of the shelter payload.

Outboard Profile

The outboard profile of the final version of Configuration 3B is shown in Figure 4-42. The major changes from the corresponding earlier version, Figure 4-6, are discussed in the following paragraphs.

The cryogenics are stored in three separate tanks instead of the two previously required. The two H_2 tanks are positioned side by side, above and slightly inboard of O_2 tank; as before they are located symmetrically with respect to the Y axis on the -Y side of the shelter. The tank dimensions and weights are as follows. The O_2 tank is sperical, has an outside dia of 50 in. and the combined mass of the fluid and tank is 1575 lb. Each H_2 tank has 43 in. outer dia hemispherical end domes and a 12 in. straight section. The combined mass of each tank and its contents is 230 lb. All tanks have two orthogonal supporting girth rings, each three in. wide and two in. deep radially.

The thermal control radiators were configured to clear the two H_2 tanks to accommodate the larger envelope of the two H_2 tanks which protrude above the primary payload envelope. The combined surface area required was reduced to 110 sq ft and the corresponding total weight is 165 lb.

Other changes include the use of storage containers to house the majority of the scientific equipment packages and the storage of the equipment unloading boom adjacent to the 100-ft drill rod extensions on the +Y side.

Inboard Profile

As shown in Figure 4-43, significant changes and rearrangements were made in the airlock and work/living areas of the shelter to accommodate the spherical sector inboard airlock dome and the swinging motion of the 56 in. dia airlock door.

1. Airlock

The airlock has a volume of approximately 130 cu ft and is separated from the adjacent work/living area by a spherical sector dome, indentical in configuration to the forward end dome of the shelter, located 33 in. from the forward end dome. The increase in airlock volume is a result of using the spherical inboard dome in place of the flat bulkhead and maintaining adequate airlock linear dimensions to accommodate two suited men. The airlock has approximately 14 sq ft of free floor area, 85 percent of which has a head room of at least 75 in.

The inboard and overboard doors are both 56 in. in dia and are horizontally offset 7 in. in the +Y direction from the centers of the domes. Both doors have 12-in.-dia viewing ports. To allow clearance for the sliding overboard door, two of the three hard suits are stored above the inboard door on the face of the dome, and the third is located above the overboard door on the concave face of the end dome. The suit checking station is mounted on the face of the inboard dome, on the -Y side of the door opening.

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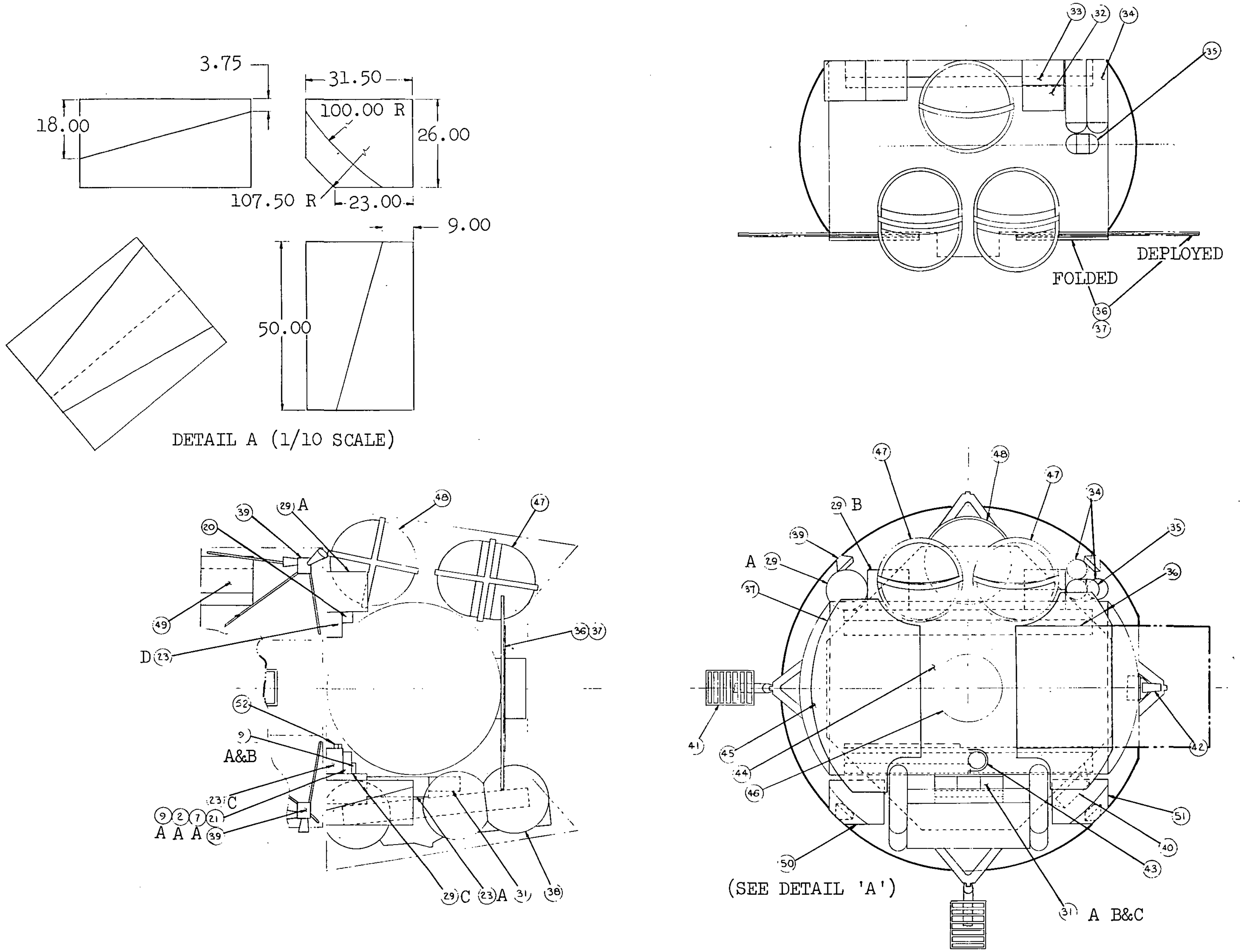

KEY

1. A) Theodolite
   B) Ranging Laser
2. A } Surveying Markers
   B
3. Sketchboard & Maps
4. Multiband Photography & Radiometry
5. Gravimeter
6. Magnetometer
7. A } Nuclear Measurement
   B
8. Sample Containers & Hand Tools
9. A) Surveying Staff
   B) Extra Battery
10. Data Handling & Interface Equip
11. Theodolite & Ranging Laser
12. Shelter Geology Equip
13. Work Table Area (N.A.)
14. Astronomy Experiments
15. Seismic Deep Refraction
16. Gas Analyzer
17. Penetrometer
18. Surface Electrical Package
19. Radiometry Package
20. 10' Drill
21. Sonic Velocity Logging
22. Electrical Induction Logging
23. A 11.8 x 35.8 x 42.1 } 100' Drill
    B 6 Dia x 12
    C 9 x 15 x 144
    D 9 x 15 x 144
24. Telluric Currents
25. Erosion Samples
26. Environmental Exposure Panel
27. Meteoroid Ejecta Detector
28. Tissue Equivalent Ion Chamber
29. A) 24 Dia x 24 } (RTG) Emplaced Scientific
    B) 24 x 24 x 24
    C) 18 x 24 x 48
30. Expendables For 100' Drill (Considered in Cryogenic Tankage)
31. A) 9 x 13 x 18 } Satellite ESS
    B) 9 x 13 x 18
    C) 9 x 13 x 18
32. Power Conversion Equip
33. Electronic Equip
34. FCA
35. FCA Collector Tank
36. FCA Radiator } THERMAL CONTROL RADIATOR
37. ECS Radiator
38. LSSM
39. RCS Jets
40. RTG Unit
41. Leg Ladders (2)
42. Star Tracker
43. Docking Target
44. Shelter
45. Shelter Airlock
46. Docking Port
47. LH Tank
48. LO Tank
49. STORAGE COMPARTMENT "A" SEE NOTE #1
50. STORAGE COMPARTMENT "B" SEE NOTE #2
51. STORAGE COMPARTMENT "C" SEE NOTE #3
52. EQUIPMENT UNLOADING DEVICE

NOTES:

1. Items 3,5,6,23B,17,18,19,22,26,27 & 28 are stored within item #49 (Storage Compartment "A")
2. Items 1A,1B, & 15 are stored within item #50 (Storage Compartment "B")
3. Items 2B,4,7B,8,14,24 & 25 are stored within item #51 (Storage Compartment "C")

Figure 4-42. Final Version Configuration 3B Outboard Profile

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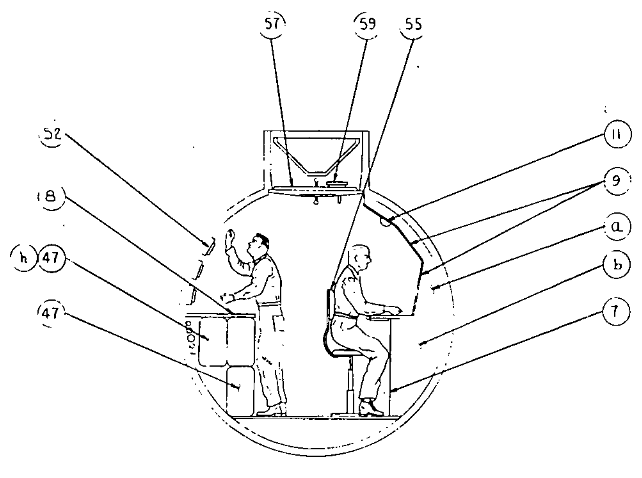
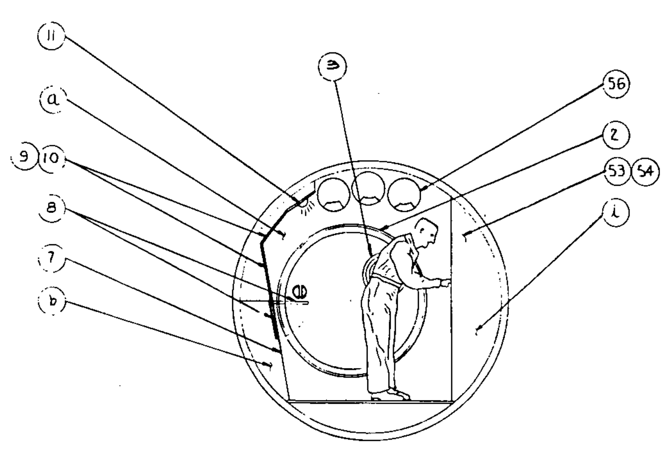
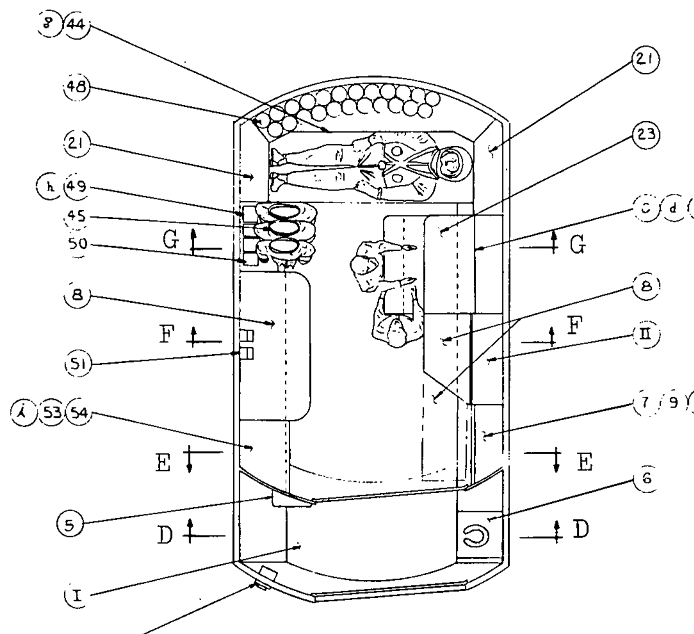


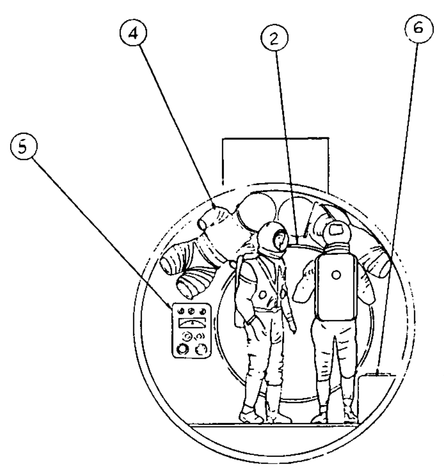
SECTION F-F



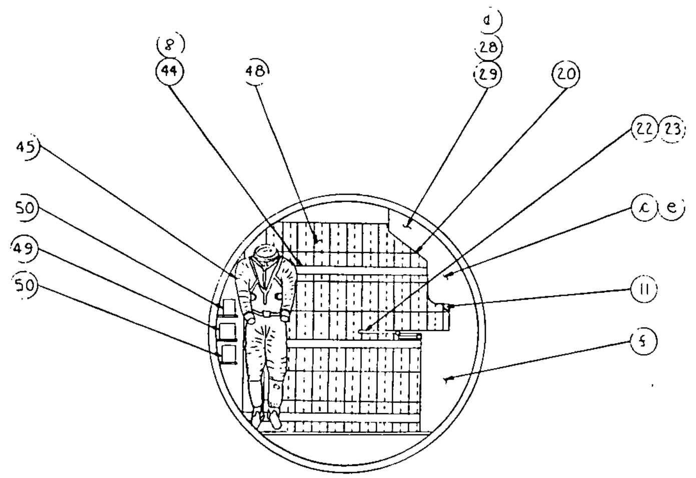
SECTION E-E
ROTATED 180° CCW



SECTION C-C



SECTION D-D



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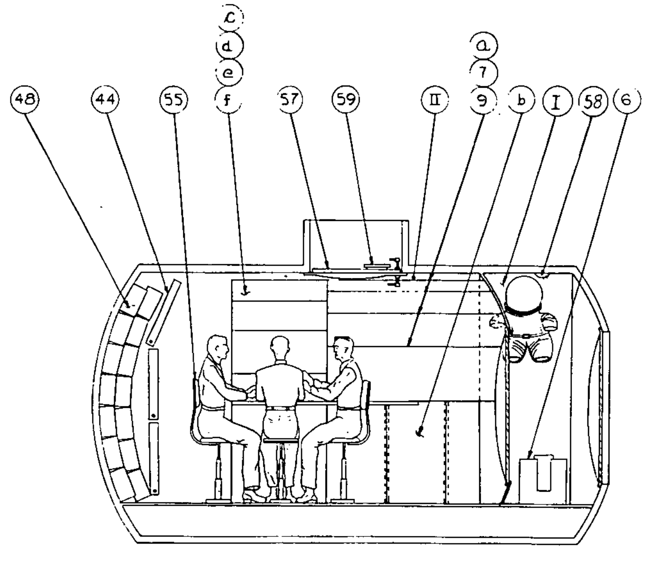
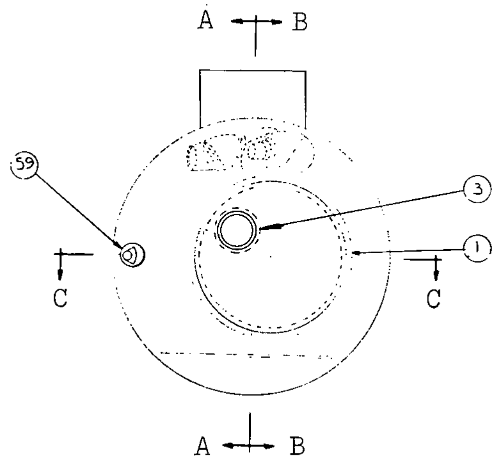
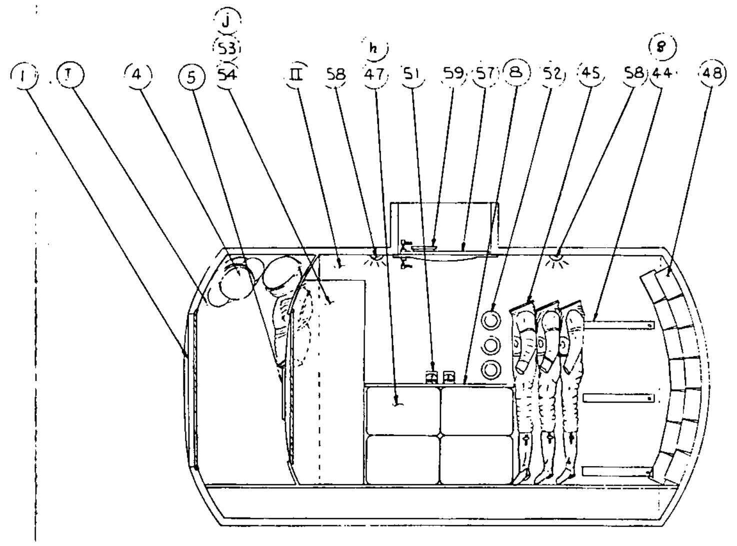


SECTION B-B





SECTION A-A

KEY

I. AIRLOCK
1. Door - External Sliding
2. Door - Internal
3. Window
4. Hard Suit (3)
5. Suit Checking Station
6. Waste Management System

II. SHELTER

a. WORK AREA (STATION)
7. Console - Equipment
8. Table - Work
9. Panels & Instruments
10. Radiation Dosimeter
11. Lights - Table (4)

b. SCIENTIFIC EQUIPMENT AREA
12. T.V. Camera
13. Movie Camera
14. Still Camera
15. Extra Film & Tape
16. Data Handling Interface Equipment
17. Theodolite & Ranging Laser
18. Shelter Geology Equipment
19. Gas Analyzer

c. EATING AREA
20. Console - Crew Provisions
21. Food Storage
22. Food Preparation
23. Table - Eating & Recreation
24. Water Probe
25. Hot Plate
26. Utensils
27. Dispenser

d. EXERCISE AREA
28. Hand Ergometer (Optional)
29. Bungee Cord (Optional)

e. RECREATION-STUDY AREA
30. Recreation Equipment

f. STORAGE AREA
31. Personal Storage
32. Personal Hygiene Facilities
33. Medical & Emergency Supplies (Station)
34. Housekeeping Provisions Package
35. Laundry
36. Anti-Meteoroid/Thermal Garments (3)
37. Liquid Cooled Garment (L.C.G.) (3)
38. Constant Wear Garment (C.W.G.) (48)
39. Eva Boots (3)
40. Eva Gloves (3)
41. Suit Spare Parts & Repair Kits
42. Intravehicle Slippers (3)
43. Tools

g. SLEEPING & REST AREA
44. Bunk Beds Removable (3)
45. Soft Suit (3)
46. Light-Portable (3)

h. PLSS CHARGING AREA
47. PLSS (6)
48. LiOH (150)
49. PLSS Battery Charger
50. PLSS Batteries (12)
51. PLSS Calibration Unit
52. Emergency Oxygen System (3)

i. ENVIRONMENT CONTROL AREA
53. ECS Package, Fan & Heat Exchanger
54. Umbilicals (3)

j. MISCELLANEOUS AREA
55. Seats - Foldable (3)
56. Helmets (3)
57. Hatch - Upper
58. Lights - Dome (3)
59. Pressure Dump Valve (2)

Figure 4-43. Final Version Configuration 3B - Inboard Profile

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2. Work/Living

The arrangement of the internal equipment is a mirror image, i.e., +Y and -Y locations interchanged, of the arrangement for the earlier version shown in Figure 4-8. This was done to provide clearance volume for opening the 56-in. dia airlock door and to locate the ECS suit and associated equipment on the -Y side, adjacent to the O_2 tank. The resulting arrangement provides an approximately rectangular floor area of about 45 sq ft and a total table surface of about 30 sq ft of which 1/3 is foldable.

3. Sleep-Rest/Radiation Refuge

The sleep-rest/radiation refuge arrangement is the same as previously discussed and as shown in Figure 4-8.

The "launch" arrangement of the Work/Living and Sleep-Rest/Radiation Refuge areas for the final version of Configuration 3B is shown in Figure 4-44.

Structural Arrangements

The shelter structural arrangement for the final version of Configuration 3B is shown in Figure 4-45. The overall configuration and dimensions are the same as previously shown in Figure 4-11. However, to take advantage of the existing diagonal bracing of the cruciform beams and a more direct load path to the outrigger support structure of the landing legs, the shelter structure is connected to the LM/Truck by four fittings trying the intersections of the two end dome compression rings and lower longerons to the LM/Truck beams at ±Z81, ±Y27.

1. Stiffened Cylindrical Shell

The general arrangement of the stiffened cylindrical shell, using a machined skin to provide for the structural connection of frames and longerons, is the same as shown previously in Figure 4-11.

2. End Domes and Airlock Bulkhead

The major changes from the earlier version are the use of a spherical sector dome similar to the forward end dome for the airlock bulkhead and the shape and location of the airlock door cutouts.

The airlock is separated from the work/living area by a 7-ft-radius spherical sector dome located 33 in. from the forward end-dome. It is attached to the cylindrical skin by means of its peripheral compression ring welded to a land on the skin. The dome skin is stiffened to carry a 7-psi ('burst') compression load under emergency conditions. The airlock door cutout is identical for both domes; a mounting surface for the airlock door seal is integral with the framing ring around the door cutout. A curved bead integral with the overboard side of the forward end-dome framing ring, as shown in Section A-A of Figure 4-45, can be used to retain a temporary fabric type closure over the opening to allow seal inspection/maintenance in a controlled environment.

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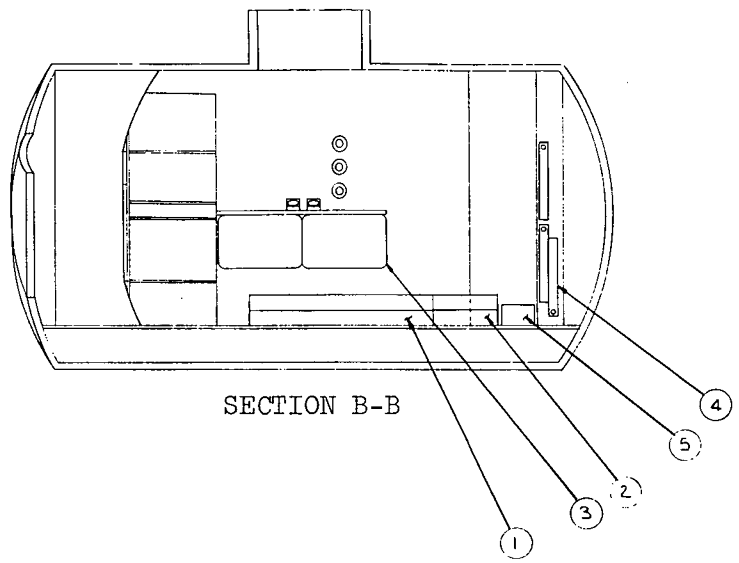
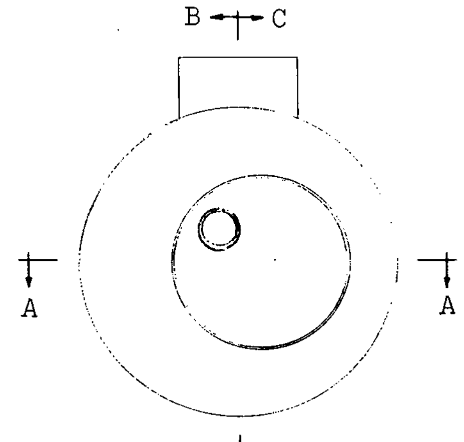
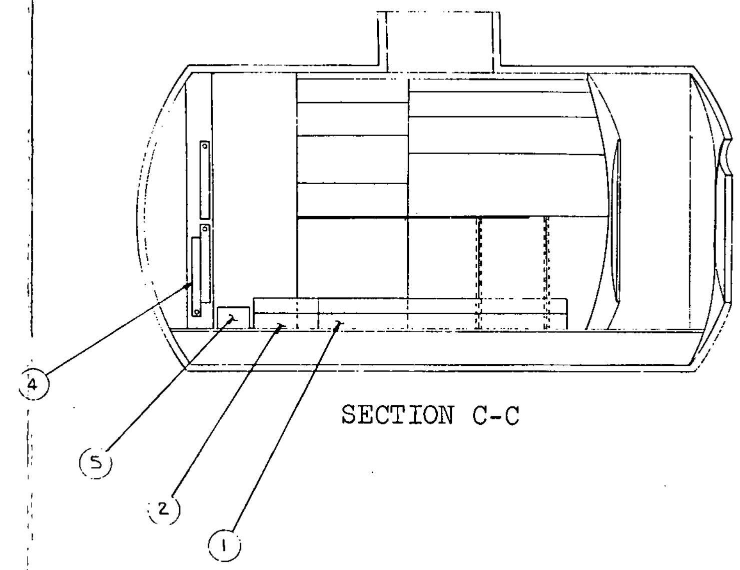


SECTION B-B

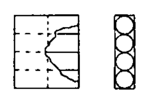




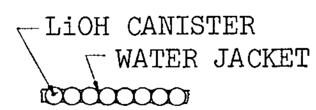
SECTION C-C

KEY:

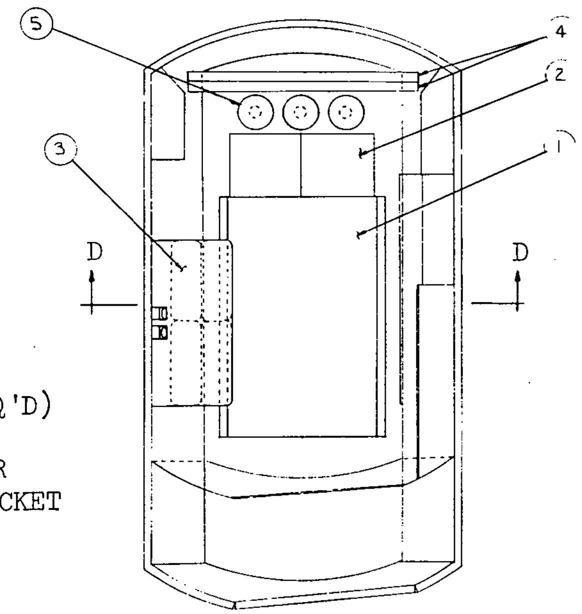
1. LiOH "BLANKET" (SEE DETAIL "F")
2. LiOH PACKAGE (SEE DETAIL "E")
3. PLSS BACKPACKS (4)
4. BUNKS (FOLDED)
5. SEATS (FOLDED)



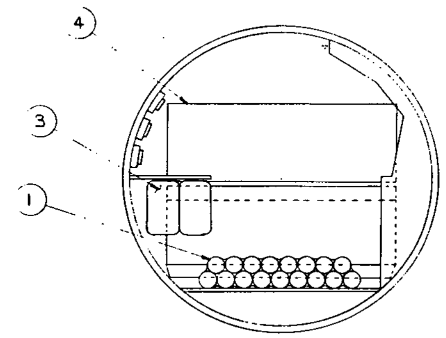
DETAIL "E"
LiOH PACKAGE (4 REQ'D)



DETAIL "F"
LiOH "BLANKET"



SECTION A-A



SECTION D-D

Figure 4-44. Final Version Configuration 3B Horizontal Cylinder Launch Arrangement

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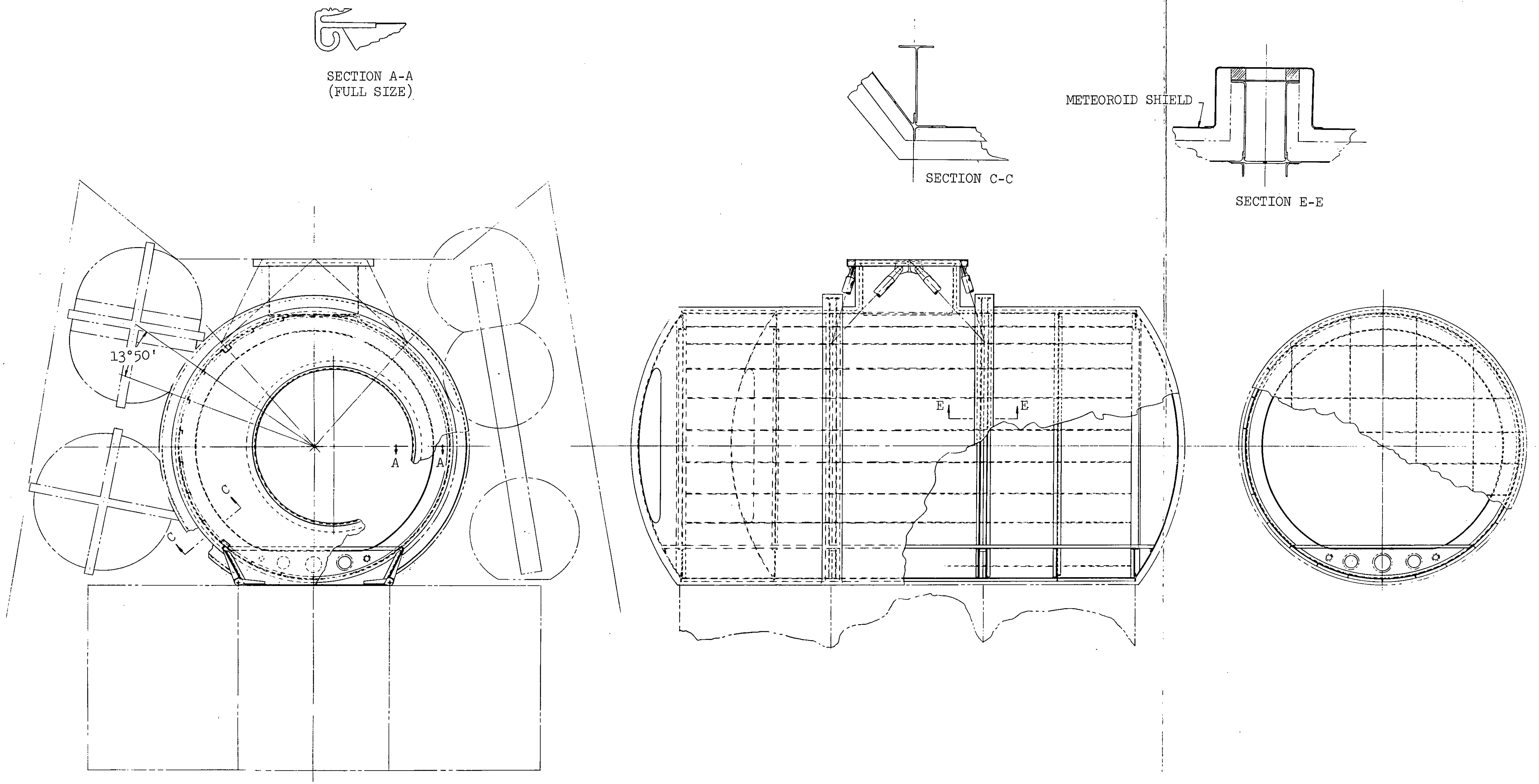

Figure 4-45. Final Version Configuration 3B - Shelter Structural Arrangements

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3. Shelter Floor

The shelter floor is the same as described previously for the recommended configuration.

4. Docking Ring and Tunnel

The docking ring, hatch sealing surface and tunnel structural arrangement are the same as described previously. The tunnel is welded to a flared section of the cylindrical shell skin outboard of the sealing surface edge member.

The outboard equipment structural arrangement for the final version of Configuration 3B is shown in Figure 4-46.

The primary changes from the earlier version are in the supporting structures for the shelter operational equipment i.e., cryogenic tanks, fuel cell assemblies, etc.

5. Cryogenic Tanks

Each cryogenic tank has three thermally isolated support points located at 90 deg intervals about a girth ring. The two main support points are 180 deg apart at the intersections of the two orthogonal girth rings; the third point provides the torque restraint.

As shown in Figure 4-46, the tanks are supported by a common machined aluminum frame. Vertical loads on the tanks are transferred by the frame to the LM/Truck cruciform beams at -Y 81, ±Z 27. The Y direction loads carried by the frame to truck beam connections and two struts from the center of the frame, at the H_2 tank mounting points, to the shelter main frames near the upper longeron. The Z direction loads are carried differentially by the frame to the truck beams and by the two struts to the shelter frames. Tank rotation about the axis through the main supports is prevented by a pinned connection to the frame flange; at the midpoint of the lower half of each H_2 tank girth ring and at the midpoint of the upper half of the O_2 girth ring.

If subsequent mission objectives require azimuth orientation of the shelter mounted on the truck, post landing support of the tanks independently of the truck can be easily adapted to the supporting frame. Four struts, two at the outboard main supports of the H_2 tanks and two at the main supports of the O_2 tank would transfer the post landing vertical and Y direction loads to the shelter at the intersection of longerons with main frames, aft convenience frame and airlock dome reinforcing ring, as shown in Figure 4-46. The Z direction loads would be carried by the two struts used for flight and landing loads, and by a fitting from the O_2 tank "horizontal" girth ring to a longeron on the shelter.

6. Fuel Cell Assemblies, Power Conversion and Electronic Equipment

The two fuel cell assemblies are connected by shear webs and the collector tank strapped to them to form a single assembly. As previously stated the third cell was illustrated in the outboard profile only to show how it could be accommodated, if necessary.

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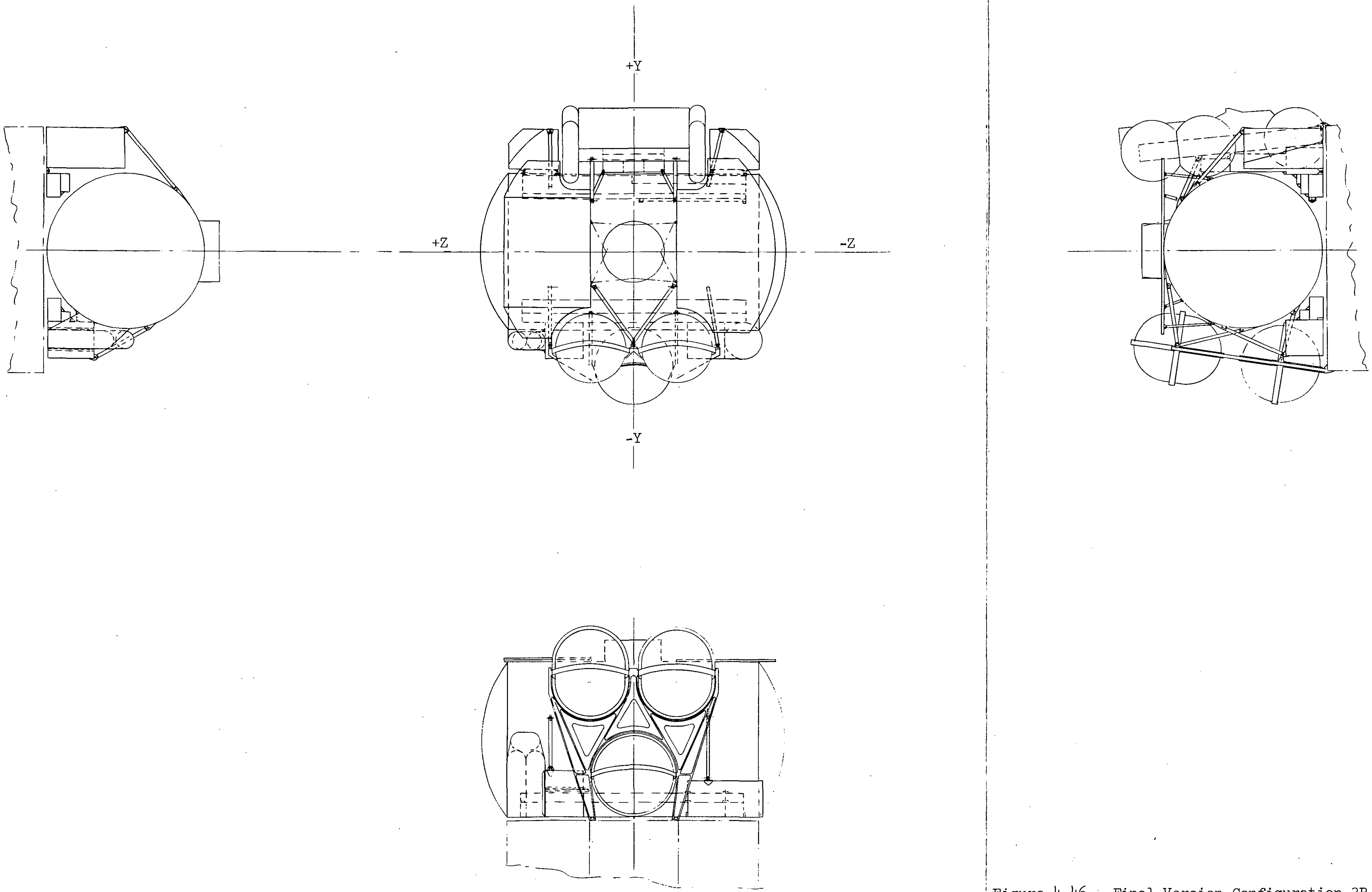

Figure 4-46. Final Version Configuration 3B
Outboard Equipment
Structural Arrangement

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The loads on this assembly are carried by a vertical shear web attached to the reinforcing ring of the aft end dome and by angle brackets to the power conversion and electronic equipment packages which are also structurally connected to form a single assembly. The loads of the power conversion/electronic equipment assembly are carried by a strut to the aft convenience frame on the shelter and fittings to the 100-ft drill rod extension package which transmits the loads to the truck beams. Secondary fittings from the power conversion/electronic equipment assembly to the shelter provide post landing support after the drill rod extension package is removed.

7. Thermal Control Radiators

The structural arrangement for supporting the thermal control radiators is the same as previously described.

8. Scientific Equipment

The two 100-ft drill rod extension packages are directly supported by the LM/Truck cruciform beams. The drill extension packages directly support other pieces of equipment, e.g., sonic velocity logging, surveying staff, etc.; they also are used as beams to provide a load path from the scientific equipment containers/frames to the LM/Truck beams. To react loads and moments not taken directly by the drill packages, struts and fittings are used to transmit the loads to the shelter frames or dome compression rings and longerons.

9. LSSM

The LSSM is supported by the LM/Truck beams, shelter frames and longerons as described previously.

To minimize the in-situ activities for unloading the equipment, squib bolts and pip pins are used in the fittings of the structural supports for the equipment packages and LSSM.

Mass Summary

The mass summary for the final version of the recommended configuration is shown in Table 4-5. The same considerations relative to the mass summary for the earlier version of Configuration 3B, are pertinent to this mass summary with the following exception. The additional radiation shielding provision of 60 lb is based on the previously discussed quonset hut arrangement for a radiation refuge and assumes a minimum of 240 lb of aqueous liquids on board during stay time.

As previously discussed the overall length and dia of the recommended shelter are constrained by the primary payload envelope and the externally stored complement of the payload. This latter constraint is most susceptible to change and can influence shelter diameter and length.

The change in weight of the final version of the recommended configuration as a function of change in volume, with shelter dia and length as parameters is shown in Figure 4-47.

TABLE 4-5

MASS SUMMARY - FINAL VERSION OF CONFIGURATION 3B

EQUIPMENT	KG	(LBM)	KG	(LBM)
Shelter Structure			386	(850)
Pressure Skin and Hands	88.5	(195)		
Stringers and Longerons	18.2	(40)		
Frames	47.6	(105)		
Airlock Inner Dome, Door and Mechanism	43.1	(95)		
Overboard Doors and Mechanism Penalty	15.9	(35)		
Floor and Supports	43.1	(95)		
Docking Structure and Hatch	38.6	(85)		
Viewing Ports	27.2	(60)		
Fittings	18.2	(40)		
Leveling	45.4	(100)		
Meteoroid Protection (Exclusive of backup sheet)			61.2	(135)
Bumper Panel	36.3	(80)		
Standoffs	4.5	(10)		
Foam	20.4	(45)		
Thermal Insulation (30 sheets SI)			11.3	(25)
External Equipment Supports			108.9	(240)
Internal Equipment Supports			90.8	(200)
Radiation Refuge Additional Provisions			27.2 *	(60)
Equipment Unloading, Crew Access			43.1	(95)
TOTAL			728	(1605)

* Based on 'quonset hut' arrangement and minimum of 240 lbs. aqueous liquids onboard during stay time.

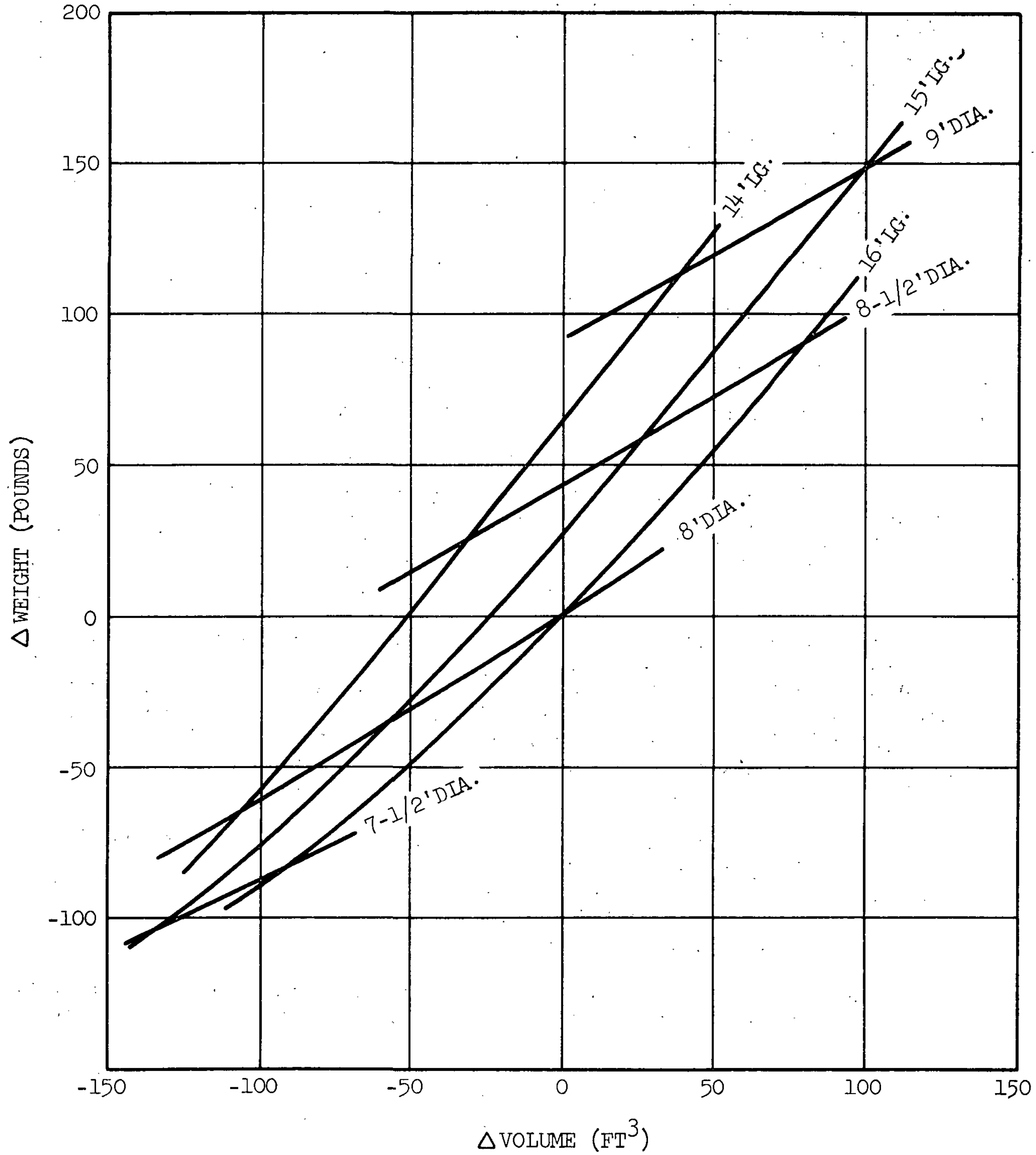

Figure 4-47. Final Version Configuration 3B
Δ Weight vs Δ Volume

The relationships shown are valid for volume variations of up to approximately ±150 cu ft relative to the nominal 750 cu ft volume of the shelter. The weight increments are based on the elements directly related to shelter geometry, e.g., pressure shell skin, micrometeoroid and thermal protection, numbers of stiffeners and their lengths convenience floor etc. The weights of external supporting structures and tie downs were assumed constant over the ±150 cu ft variation.

Fabrication - Assembly

The fabrication - assembly flow schematic for the final version of the recommended shelter configuration is shown in Figure 4-48.

The shelter would be constructed as three major assemblies:

Airlock end dome, cylindrical pressure wall, and inner dome

Center cylindrical pressure wall and docking tunnel

Aft end dome and cylindrical pressure wall

The spherical sector domes would be fabricated from circular blanks which are free formed to the 84 in. radius of curvature by hydraulic pressure applied through a holding ring. Chemical milling would be used to reduce the shell thickness and provide the necessary welding lands around the periphery and airlock door cutouts. The edge compression ring and door opening reinforcing elements would be rolled to the required radii and welded to the domes.

All single curvature pressure shells would be machined to provide the longitudinal and circumferential integral skin stiffereners and welding lands. A filler material would be used to support the machined panels during the subsequent rolling operations. After rolling and sizing the airlock cylindrical section, the closing joint would be automatically fusion welded. The two airlock spherical sector dome subassemblies would then be automatically fusion welded to the cylindrical section.

To facilitate the subassembly of the docking tunnel to the center pressure walls, a splice section consisting of approximately 60 deg arc of the pressure wall would be used. The docking tunnel splice and the remaining partial cylindrical section would be rolled, sized, and automatically fusion welded together to form a complete cylindrical center section.

The aft section of the shelter would be fabricated and assembled in the same manner as the airlock section but without the inner spherical sector dome.

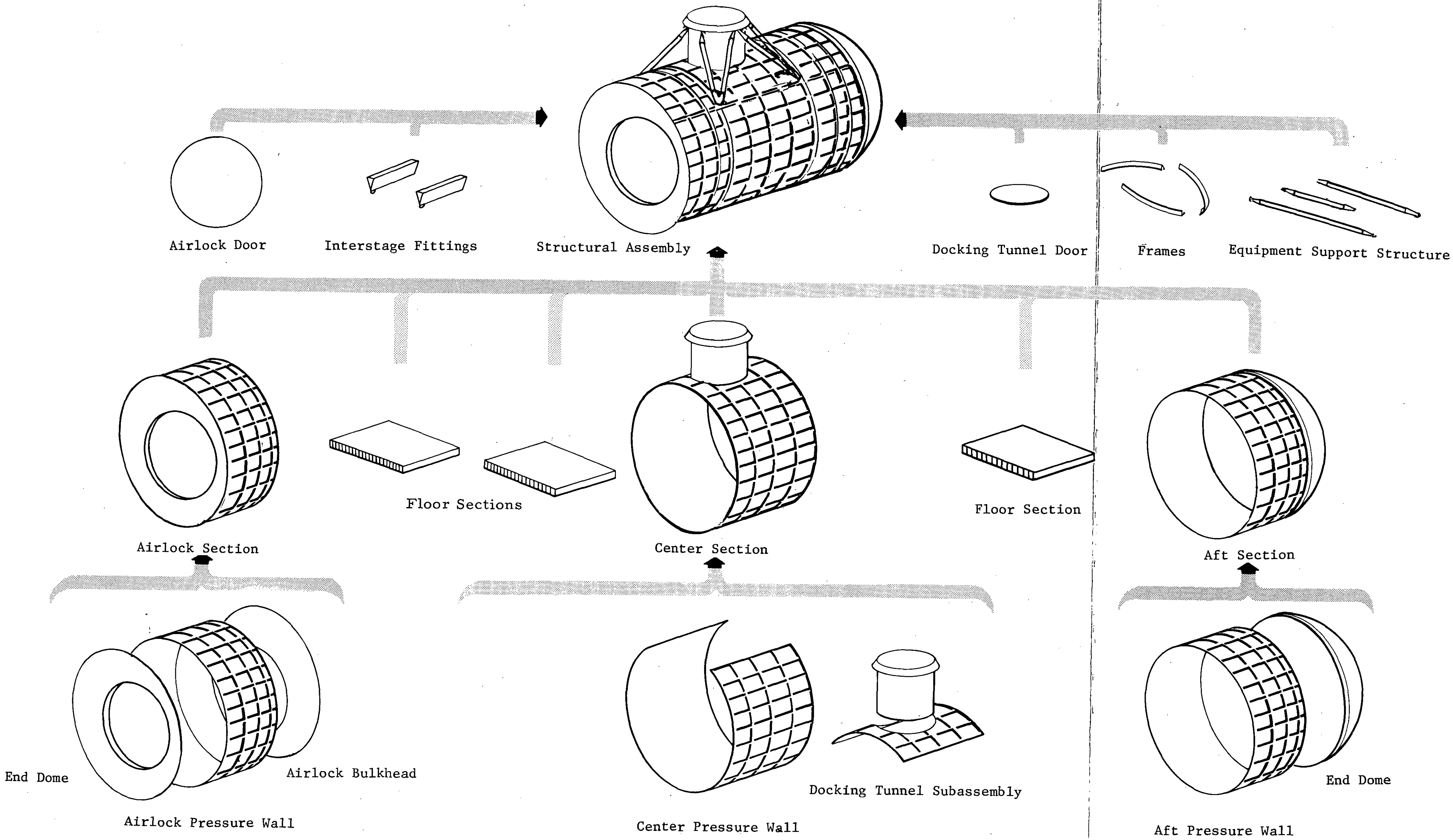

Figure 4-48. Shelter Fabrication Assembly Schematic

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The final fabrication - assembly operation consists of sizing/aligning the three sections and automatically fusion welding the two interfaces. The operation would be followed by welding/mechanically fastening external frames, longerons, structural support fittings, internal and external bracketry, floor supports, and floor panels.

Airlock doors and mechanisms, docking tunnel hatch and viewing ports, etc., would be installed after the final fabrication - assembly operation is completed.

SECTION 5

RELIABILITY

Reliability evaluations were made of the mechanism used in payload deployment and air lock door operations. Excluding the probability of puncture by a micrometeoroid, the shelter structure/pressure shell was considered to have a failure rate approaching zero.

The evaluations were based on the assumption of exponential failure rates and the following considerations:

Phase	Hours
Boost	0.559
Nonboost	79.228
Quiescent storage	4320.000
Staytime	1200.000

- Operational/Nonoperational "K" factors

	Operational	Nonoperational
Boost	10.0	0.01
Nonboost (thru staytime)	1.0	0.001

- Failure rates for mechanism components were obtained from the Honeywell Reliability Survey Report on Part Failure Rates, U-ED 23008 November 1962.

- For nonrepetitive operations, e.g., leveling the shelter or unloading the LSSM, an operational period of 1 hr was used in the calculations, although the actual operation might require less time.

  The results of the evaluation are shown in Table 5-1.

TABLE 5-I

RELIABILITY EVALUATION

Mechanism	2×10^6 (1/hours)	Σ Kt (hours)	Reliability	Assumptions
Airlock Doors and Seals	218.42 inboard doors 221.26 outboard doors	12.2714	.99731 .99728	4 door cycles/day during 50 day staytime and allowed 2 minutes/cycle
Shelter leveling	699.15	5.4298	.9962	leveled before 24 hours of staytime have elapsed
LSSM unloading	442.325	5.4538	.99759	unloaded before 48 hours of staytime have elapsed
Equipment unloading	293.30	15.5237	.99545	total use time of 10 hours throughout staytime
Docking Tunnel Hatch and Seal	30.7	6.60481	.999797	used once for in-flight checkout, available for emergency use throughout staytime

SECTION 6

DERIVATIVE SHELTERS

The recommended shelter configuration is readily adaptable to modifications which provide increased habitable volume and allow moving the shelter from the landed site.

INCREASED VOLUME

Increased volume can be obtained by in-situ extension of a structurally rigid inner section of the shelter which is in a retracted or telescoped position within the fixed, or outer, section of the shelter for delivery to the lunar surface; this concept is illustrated in Figure 6-1.

The effects of the extensible section on the outboard profile and arrangement of the supporting structure for the outboard equipment would be negligible. For this concept of providing additional volume, initial entry and use of the air lock is not impeded by the extensible section. However, in-flight checkout of the shelter via the docking tunnel hatch is precluded unless a hatch is provided in the extensible section adjacent to the docking tunnel.

In general, the structural arrangement of the fixed section of the shelter as previously described would be the same except at the aft end of the section. At this location, the end dome compression ring would be replaced by a member which provides the sealing surface for the extended shelter section and carries the flight and landing loads as well as the torsion loads on the sealing surface when the shelter is pressurized.

The arrangement of guide rails and mechanism for moving the extensible section and the in-situ placement of the convenience floor and equipment in the fixed section, after extension the inner section, require detailed rearrangement of internal fittings to the frames and longerons but impose no major structural modifications.

The extensible section structural arrangement would be similar to that of the fixed section but with frames and longerons of much lower section modulii since this section does not support external equipment and does not transfer docking ring loads.

Its permanent internal arrangement would be similar to the work/living and sleep-rest/radiation refuge areas as described for the recommended configuration. In the delivery mode, it would also house the convenience floor and equipment for outfitting the fixed section.

Based on a preliminary investigation, a motor-driven wire rope and pulley arrangement is suitable for extending the inner section of the shelter, using guide-rails to limit the eccentricity between the inner and outer sections. Shelter environmental pressure would load the seal; sealing surface configurations and a peripheral clamp similar in concept to that used for the air lock

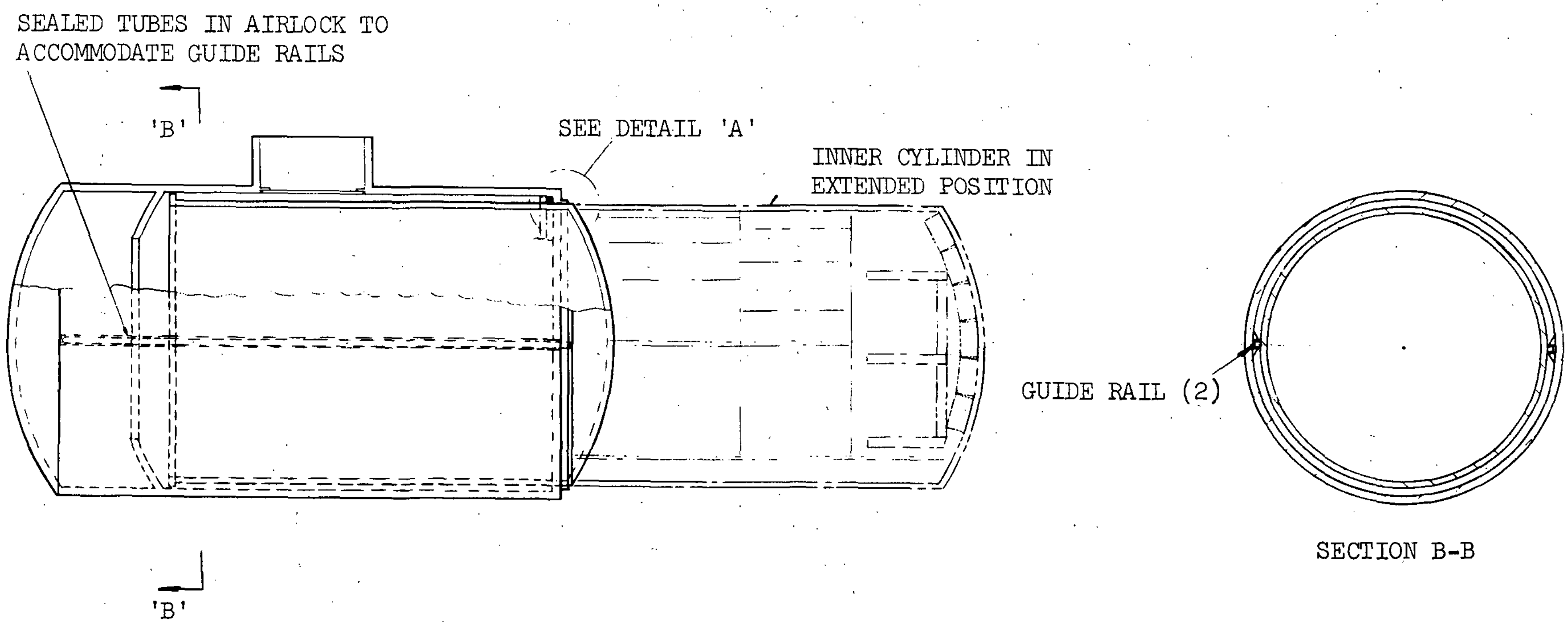

Figure 6-1. Extensible Volume Version of Configuration 3B

doors would be used to provide a positive mechanical connection between the two sections. The surfaces to be clamped would be accessible from inside the shelter, and since the installation of the clamp is nonrepetitive, a single bolt/toggle mechanism located on the clamp periphery would be used to tension it.

The extension of the inner section of the shelter provides approximately 500 cu ft of additional volume for a weight increase of about 400 lb. This relatively high volume-to-weight ratio is attained since the extensible section is not required to carry flight and landing loads from external equipment or docking ring loads.

TRANSPORTABILITY

The shelter can be transported on the lunar surface by attaching powered wheels to it and using the LSSM as a driving station as illustrated in Figure 6-2.

The powered wheels would be stored inside the shelter for the delivery phase and manually connected to the shelter during the shelter unloading sequence, previously described in Section 4, Radiation Analysis, when the shelter is in close proximity to the lunar surface. For the wheel size considered, i.e., 66 in. dia x 15 in. rim width, the periphery of each wheel would be deflected by strapping to allow its passage through the 56 in. dia air lock door openings.

The configuration and structural arrangement of the recommended shelter can accommodate the external attachment of the wheels without any major change; the wheel mounting fittings are supported by the end dome compression rings and lower longerons. Typically, the attachment of the wheel to the fitting utilizes splined flanges, or shaft and housing, with a peripheral locking collar to react loads transverse to the plane of the wheel. Except for the shelter operational equipment, other externally located equipment would be removed to provide the clearance envelope for the mounted wheels.

The LSSM is connected to the shelter with a guide bar which provides the controlling inputs for shelter wheel speed, braking, and skid steering as a function of LSSM maneuvers; it is not used to tow the shelter.

The shelter transportation power vs slope for the ELMS upland profile is shown in Figure 6-3.

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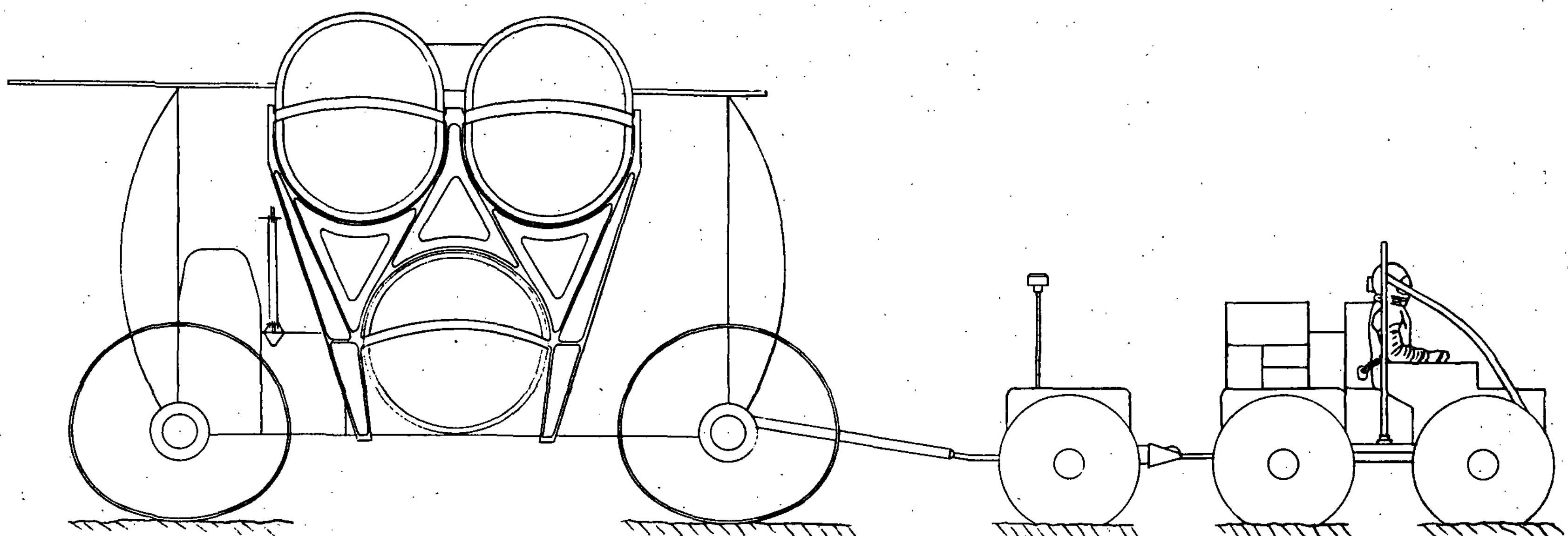

Figure 6-2. Transportation Version of Configuration 3B

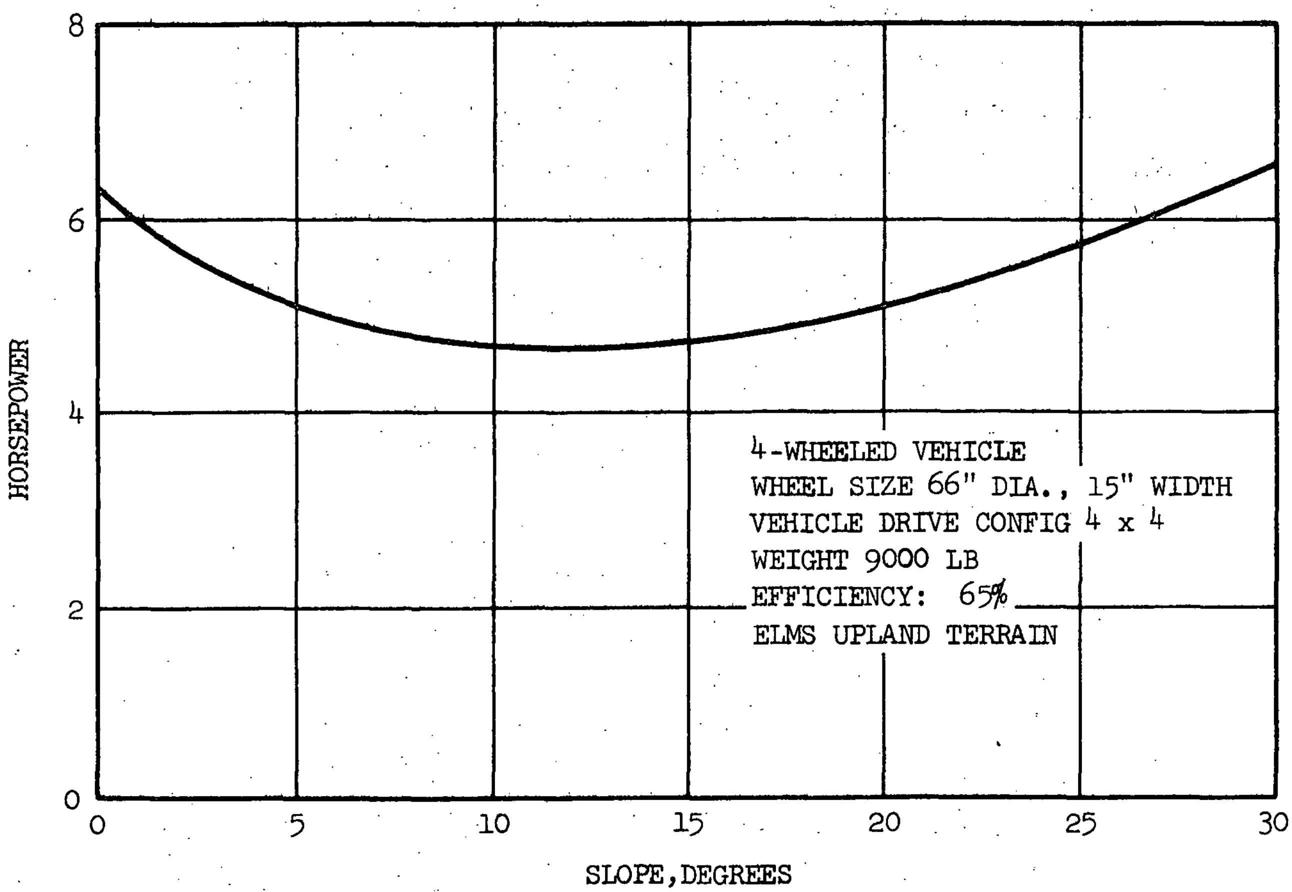

Figure 6-3. Shelter Transportation Power vs Slope

The weight penality to provide the shelter with transportability is summarized below:

Item		Weight, lb
Transportability		795
Wheels (4)	400	
Wheel drives (4)	240	
Structural Suspension	100	
Steering/Mobility controller	30	
Guide bar and cabling	35	
Shelter unloading (see Section 4, Radiation Analysis)		355
Total		1100

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BOOK 2
REVIEW OF SCIENTIFIC MISSION REQUIREMENTS

CONTENTS

ILLUSTRATIONS

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SECTION I

INTRODUCTION AND SUMMARY

INTRODUCTION

Four lunar scientific missions are described in the study guidelines based upon a 2-man, 14-day lunar staytime capability. Since the Early Lunar Shelter (ELS) will provide a considerably greater mission capability, the following steps were needed to establish the subsystem design requirements:

- Extrapolate the 2-man, 14-day missions to the ELS capability
- Determine the impact of ELS extended mission time on scientific equipment complement, expendables, and performance

The mission timelines and requirements studies reported in Volume 2 were primarily concerned with defining the following for a "baseline" mission:

Crew timelines and activities

Scientific mission support equipment lists and interface requirements

Power and material consumption profiles

The baseline mission was defined to contain sufficient equipment and operational capability to perform the experiments given for all four study guideline missions.

The studies reported in this volume investigated the following:

Utilization of the third crewman

Alternative scientific missions applicable to the ELS concept

Detailed definition of scientific mission timelines

Implications of alternatives upon crew safety and mission success

SUMMARY

Since each mission will be carried out through sorties to various points on the lunar surface, the number of crew members available to perform these sorties is critical in mission planning. A 2-man crew has been the basis for planning lunar missions to date (References 1 through 5). A basic problem in the subject study was to determine the impact of a 3-man crew on current baseline missions.

With additional manpower, alternate missions may be considered. A second problem for this study was to define alternate scientific missions applicable to the ELS concept and made possible with a 3-man rather than a 2-man crew.

To obtain pertinent data, experimental studies were performed and the literature searched. Proposed scientific missions were analyzed to determine crew assignments, and crew task timelines were developed. Wherever applicable, experimental data from other recent studies have been used.

With the data accumulated, baseline scientific missions were more closely defined or elaborated upon. Flexible timelines for 3-man crews were developed, including sortie task timelines, 24-hr mission timelines, and 14-day mission-sortie schedules. The timelines reflect crew activities involved in the following facilities: Local Scientific Survey Module, Lunar Flying Vehicle, Emplaced Scientific Station, and the ELS itself.

A further consideration involving the third crewman was his effect upon mission success and surface activity safety. Problems raised by operations during the lunar night also were considered.

Eighteen alternate missions were ranked according to relevance, scientific importance, and feasibility as determined by time available and equipment requirements. This report contains detailed descriptions of the first three alternate missions and the equipment and crew tasks involved, together with their impact upon the baseline missions.

Basic findings of the third-crew-member extrapolations are that he

- Increases the time available for surface activity and shelter tasks by about 60 percent
- Makes feasible 6-hr LSSM sorties
- Greatly enhances crew safety

These advantages may be obtained with a 50-percent increase in expendables and a 25-percent increase in living space and power requirements.

SECTION 2

THE SCIENTIFIC MISSIONS AND THEIR REQUIREMENTS

The successful execution of scientific missions by a 2- or 3-man crew is to a large extent dependent on the capabilities of life support systems, appropriate crew procedures, the definition of crew tasks, and the characteristics of the equipment housing and transporting of the crew. Within this framework, baseline scientific missions (as defined in Reference 5) and potential alternate scientific missions will be performed. The efficiency and safety of the crew will be a primary consideration, requiring adequate life support, avoidance of or protection against hazardous operations, and the scheduling of task assignments so that productive mission time is maximized within the limits of reasonable work/rest cycles and the known or expected man-machine performance capabilities of the LEM/T Shelter systems.

Mission guidelines and assumptions were obtained principally from recognized sources (References 1, 2, and 5) with changes made where necessary to accommodate a 3-man crew. These guidelines and assumptions are given in the Appendix.

APPLICATIONS OF EXPERIMENTAL RESULTS TO EARLY LUNAR SHELTER CONCEPTS

Honeywell has recently conducted a series of simulations for NASA to establish preliminary cabin free-volume design criteria for lunar surface vehicles. Performance and physiological measures were used in evaluating vehicle interior volumes during a series of 3-hr, 10-hr, and 72-hr simulations (Reference 16) culminating in an 18-day simulation referred to as the Lunex II simulation (Reference 7). Two-man crews were used for each of these simulations. An integral part of these simulations was a crew task analysis to determine representative timeline summaries of crew activities. Timeline analyses were performed to identify crew tasks, provide logical sequencing of tasks, and identify instances of potential conflict in task scheduling.

Upon completion of the short simulation phases of the study (3-hr through 72-hr), the analytic timelines were revised to incorporate the task schedules and task completion times empirically determined during the simulations. During the 18-day simulation, a task schedule based on the short-duration simulations and timelines generated by other investigators (References 17 and 18) was used. New task times were empirically determined, resulting in the evolution of a functional timeline permitting successful completion of daily task assignments for the remainder of the simulation.

Since these simulations were designed principally to evaluate cabin interiors, the applicability of crew task times to more extensive simulations or real missions involving crew activities outside a shelter is restricted to those tasks common to all missions. These tasks are sleeping, eating, housekeeping, hygiene, and pressure suit donning and doffing. The scientific tasks simulated, though categorically similar to tasks to be performed in a lunar surface shelter, were not realistic enough to provide actual mission performance time information. They did provide order-of-magnitude time estimates, however, in that they were designed to duplicate the type of physical activity required by crew members to complete the tasks.

Certain geophysical tasks designed by the University of Minnesota Geophysics Department were of particular value in this regard. The straightforward application of these results, however, must be considered preliminary, pending further simulations using more realistic systems and hardware. With these limitations in mind, the following experimental results are applicable to developing a task timeline for early lunar shelters.

Sleeping. For small-volume shelters requiring space allotted for sleeping to be shared with interior workspace, crew members should sleep concurrently, permitting minimum disturbance to sleeping crew members. Eight uninterrupted hours are allotted for this purpose.

Eating. To increase the time available for scientific tasks, no more than three meals a day should be required. The rehydration, mixing, and consuming of food prepared for space flights requires a significant time period. During 72-hr simulations, two subjects could prepare and consume an average 700-cal meal in a mean time of 33 min. The time to prepare and consume the same quantity of food increases to an average of approximately 43 min per meal for two subjects during extended simulations, as was evident in the 18-day study (see Figure 2-1). At times, meal preparation and consumption required as much as 50 min per meal. For three meals a day, 2 to 2-1/2 hr per day may be required of two men time-sharing this task. This is due to the subject's tendency to take more time per task during prolonged simulations and to be more concerned about cleanup and associated oral hygiene following each meal. The exact number of calories consumed does not appear to be as important a time factor as the time to set up, rehydrate, and mix the food. (The diet used is considered to be equivalent to that planned for the Apollo missions.) For this reason, it is desirable to have all major meals involving the rehydration of dehydrated food to be a time-shared task permitting crew members to assist each other in the preparation of meals; i.e., eating should be a parallel task, not a series task, if time is to be conserved.

Housekeeping, Hygiene and Personal Time. The time required to perform these activities has been frequently disregarded or underestimated. Short-duration simulations require less time for these activities than long-duration simulations. During the 18-day Lunex II simulation, the subjects were initially required to minimize personal time and housekeeping tasks. After four days, more time for relaxation and housekeeping was requested due to excessive fatigue and stress on the subjects. As a result, the time per day spent on personal time, hygiene, and housekeeping was increased from 1 hr 5 min to 4 hr 5 min, where it remained for the rest of the simulation

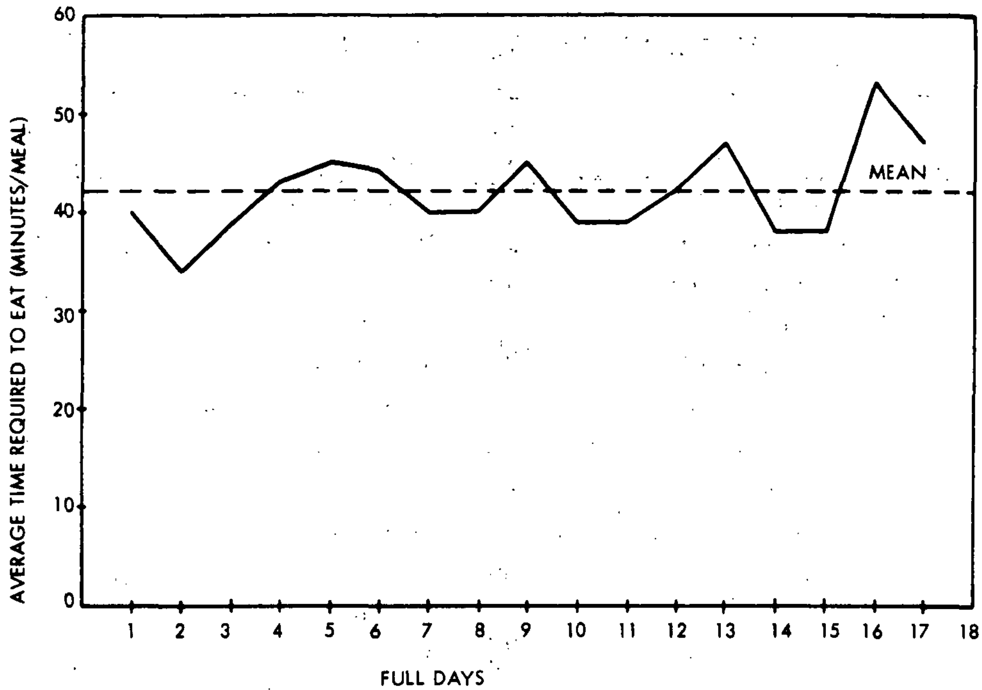

Figure 2-1. Meal Consumption Times vs Days in Simulator

Pressure Suit Donning and Doffing. The time to don and doff pressure suits is a sensitive function of subject training, the type of suit, and the amount and quality of associated support equipment. Mark IV pressure suits can be donned and pressurized simultaneously by two experienced subjects in a 48-cu-ft airlock in 20 min and doffed in 15 min. This includes one subject's donning and doffing of a PLSS mockup (Reference 16). During the 18-day simulation using Apollo state-of-the-art suits, 25 min were required by the two crew members to don the suits and backpack. Doffing the suit, hanging up for drying, and the associated personal cleanup required 45 min. The additional donning and doffing of a protective outer suit garment, or the donning and doffing of a hard suit for extravehicular activity can be expected to require more time. A NASA estimate (Reference 4, p. 5-23) of the time involved for the whole egress-ingress procedure for the LEM shelter requires 54 min for egress and 55 min for ingress. Verification of these times can be obtained only by simulated (or real) missions where all state-of-the-art components are used. These estimates are, at present, the best available.

The scientific tasks simulated were likewise limited in value in the absence of complete systems and equipment realism. The first four days and the finally evolved task times for the Lunex II simulation are shown in Tables 2-1 and 2-2. The times required to complete various groups of tasks for the 3-day and 18-day simulations are shown in Table 2-3. The times listed for driving would normally be included in the extravehicular surface activity during the LEM/shelter mission.

TABLE 2-1

EARLY LUNEX II TASK TIMELINE

Time of Day	Sequence A	Sequence B	Approximate Task Time (hr:min)
0600	Take down beds	Take down beds	:20
0620	Electrode checkout	Electrode checkout	:25
0645	Personal hygiene	Personal hygiene	:15
0720	Eat and clean up	Eat and clean up	:45
0750	Scientific tasks	Scientific tasks	:30
	Audio balancing	Sample measurement	
	Suit checkout	Audio balancing	
0820	Don suit	Don suit	:55
0915	Outside tasks	Inside tasks	:30
0945	Doff suit	Doff suit	:55
1040	Drive	Monitor	1:00
1140	Chart (if required)	Navigate	:30
1210	Eat and hygiene	Eat and hygiene	:45
1255	Scientific task	Scientific task	1:00
	Audio balancing	Geophysical tasks (or suit checkout)	
	Sample measurement		
	(G P I set)	Audio balancing	
	Geophysical tasks	Sample measurements	
1355	Don suit	Don suit	:55
1450	Inside tasks (e.g. G P I set)	Outside task	:30
1520	Doff suit	Doff suit	:55
1615	Eat and hygiene	Eat and hygiene	:45
1700	Monitor	Drive	1:00
1800	Navigate	Chart (if required)	:30
1830	Scientific tasks	Scientific tasks	1:00
	Sample measurement	Audio balancing	
	Audio balancing	Geophysical tasks	
	Geophysical tasks	Geophysical tasks	
1930	Buffer time period	Buffer time period	:30
2000	Eat and hygiene	Eat and hygiene	:40
2040	Scientific tasks	Scientific tasks	:50
	Sample measurement	Geophysical tasks	
	Geophysical tasks	Sample measurement	
2130	Remove electrodes	Remove electrodes	:05
2135	Hygiene	Hygiene	:15
2150	Set up beds	Set up beds	:10
2200	Retire	Retire	

TABLE 2-2

FINAL LUNEX II TASK TIMELINE

Time		Task Sequence	Approximate Task Time (hr:min)
0600	1	Take down beds	:20
0620	2	Electrode checkout	:15
0635	3	Eat (Meal 1) and clean up	:45
0720	4	Hygiene	:20
0740	5	Drive/Monitor	1:00
0840	6	Chart (if required)/Navigate	:20
0900	7	Don suit and pump down airlock	:30
0930	8	Outside task and airlock pump up/inside tasks	:35
1005	9	Crew exchange and airlock pump down	:20
1025	10	Inside tasks/Outside tasks, airlock pump up	:35
1100	11	Doff, suit drying, cleanup	:45
1145	12	Eat (Meal 2) and cleanup	:45
1230	13	Rest period	1:00
1330	14	Sample measurements	:20
1350	15	Audio balancing	:20
1410	16	GPI/Suit checkout	:20
1430	17	Suit checkout/GPI	:20
1450	18	Monitor/Drive	1:00
1550	19	Navigate/Chart (if required)	:20
1610	20	Eat (Meal 3) and cleanup	:45
1655	21	Audio balancing	:20
1715	22	Sample measurements	:20
1735	23	Geophysical tasks	1:00
1835	24	Buffer period	:30
1905	25	Maintenance, repair, and housekeeping	1:00
2005	26	Eat (Meal 4) and cleanup	:45
2050	27	Report writing, hygiene, and personal activity	1:00
2150	28	Remove electrodes and set up beds	:10
2200	29	Retire	

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TABLE 2-3

AVERAGE TIME TO COMPLETE TASKS (HR:MIN)

Task Group	Three-Day Simulations	First 4 days of 18-Day Simulation	Remainder of 18-Day Simulation
Personal time, hygiene and housekeeping tasks	1:05	1:30	4:05
Eating and associated cleanup	2:12	2:55	3:00
Driving task	2:15	2:00	2:00
Extravehicular tasks	1:00	1:00	1:10
Inside scientific tasks	7:55	4:25	3:40
Suit donning and doffing (plus egress-ingress and PLSS and suit checkout)	1:33	3:40	1:35
Buffer time period	—	:30	:30
Sleeping	8:00	8:00	8:00
Totals	24:00	24:00	24:00

The University of Minnesota Geophysics Department provided a variety of tasks designed to represent the type of geological activity expected on early lunar missions. These tasks were not intended to imitate actual lunar mission tasks but to represent simple yet realistic geological activities. The tasks required the collection of as many different rock and mineral categories as possible, retaining only one sample of each category. The tasks further required that the traverse of the lunar mission be accurately mapped with respect to prominent known terrain features and that new terrain features be mapped as they are observed.

The microscopic analysis of rock samples began with the subject in the inflated suit making judicious rock sample collections during his extravehicular activity. Nearly 100 rock samples, representative of the types geologists expect to find on the moon, were located in the area outside the Lunex II simulator. The subject's task was to visually sort the samples and select 20 rocks appearing to represent discrete categories. These 20 samples were returned to the Lunex II, where analysis of the samples was performed. In each of the 20 samples, there were no more than eight categories. The subject's task was to determine which eight should be returned to earth. Microscopic analysis of mineral samples required the analysis of mineral grains by use of a binocular microscope and a polarizing microscope. Mineral crystals requiring sorting by category and by properties were provided. These crystals had to be identified by sampling and microscopic counting. The minerals mounted on petrographic slides required analysis by the determination of anisotropic, isotropic, and opaque light transferring properties using the polarizing microscope. The subject's task was to sort crystals and to distinguish distinct mineral samples mounted on petrographic slides.

In association with the navigation tasks, specific terrain features were revealed at irregular times, and had to be located on the subject's map. For example, a particular mountain was showing during one navigation period. The angle to the mountain was noted and a ray drawn from the Lunex location through the mountain location. After several driving periods, the same mountain was again shown and a ray drawn. The intersection of the rays located the new terrain feature on the subject's map. In this way, single-dimension plotting of simulated lunar terrain features was possible.

The petrographic slide analyses, rock sample analyses, and terrain charting tasks were successfully completed within the simulation timeline constraints. The microscopic sorting and classification of mineral grains proved to be a painstaking, time-consuming task. The subjects did not have time to complete this task during the 18 days. Both subjects considered tasks of this variety too time-consuming for actual missions.

These simulations were, in accordance with their objective of evaluating cabin volumes, largely restricted to the performance of inside shelter tasks. It became obvious, however, that the performance by 2-man crews of routine tasks within the shelter leaves little time for daily outside activity.

If more time is to be spent outside the vehicle, this could be accomplished by devoting whole days to extravehicular tasks (assuming the pressure suits and support systems are adequate). On these days, few, if any, inside scientific tasks would be performed. Likewise, to accomplish inside tasks, whole days with no extravehicular activities may be required. This suggests that by alternating inside and outside tasks by days, a realistic timeline could be generated. It should be noted that housekeeping and hygiene require a considerable time allotment to avoid undue stress on the crew.

Suit donning and doffing time can be reduced by performing a "crew exchange" for extravehicular tasks. The crew exchange requires each subject's extravehicular activity to take place at a single location on the simulated traverse, one subject egressing from the vehicle immediately after the first subject had ingressed from his outside activity. This procedure requires each subject to don and doff his suit only once a day, instead of twice a day, with a total time saving of about 2 hr.

The application of these results to actual missions suggests that 2-man crews would be seriously curtailed with regard to the amount of scientific work they would be able to perform on the lunar surface.

Estimates of the relative energy expenditures required to perform simulation tasks were determined by measuring the subject's maximum aerobic oxygen consumption prior to and immediately after the 18-day simulation. The methods of indirect, open-calorimetry, permitting the continuous analysis of expired gases during treadmill runs, were used (Reference 7). Heart rates and oxygen consumption during submaximal and maximal work were measured as a function of time on the treadmill. From these data, plots of heart rate vs oxygen consumption were determined for each subject. A representative plot is shown in Figure 2-2.

These relationships essentially "calibrate" each subject, providing a means whereby relative oxygen consumption during various tasks performed in the simulation can be obtained directly from the heart rates measured during performance of those tasks. In addition, heart and respiratory rates obtained during a variety of task performances can be treated as a ratio of the measured value P, to the value Pc, achieved during maximal work. This permits the comparison of each subject's physical effort as a percentage of his own steady-state maximum. Figure 2-3 shows P/Pc value for heart rates averaged over the simulation tasks for each subject. It is apparent that tasks requiring large-muscle-group activity can be distinguished from those tasks which are basically sedentary. A comparison of P/Pc values shows that both subjects worked at similar levels of their maximum work capacity for any given task. No trends in heart or respiratory rates for any task were observed during the simulation. For this simulation, only tasks involving the active use of the pressure suit required high work outputs as measured by heart and respiratory rates.

Though the time allotted for extravehicular activities was unrealistic, it was a design goal to make the energy expenditure during outside activities approach or exceed the present Portable Life Support Systems (PLSS) rated capacities. For this purpose, treadmill walking in the pressurized suit was

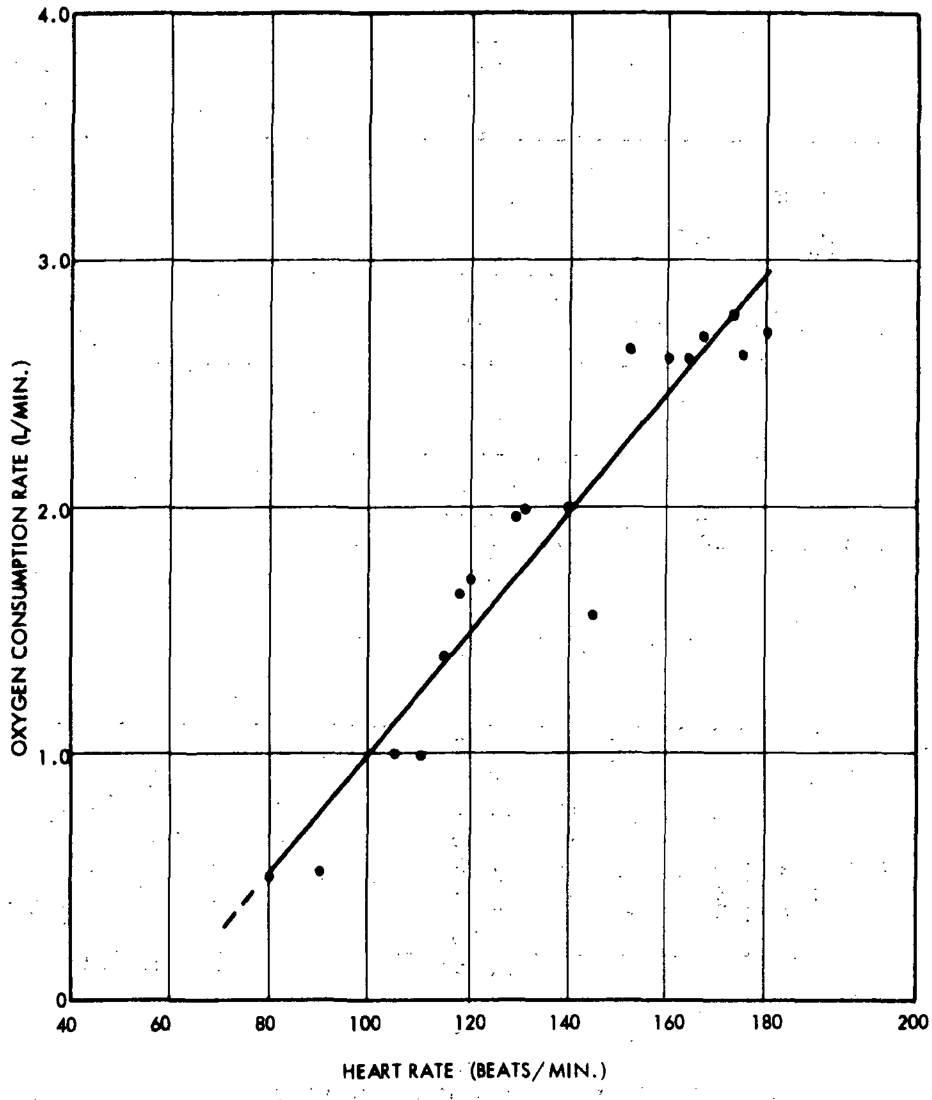

Figure 2-2. Relationship of Oxygen Consumption and Heart Rate - Operator I

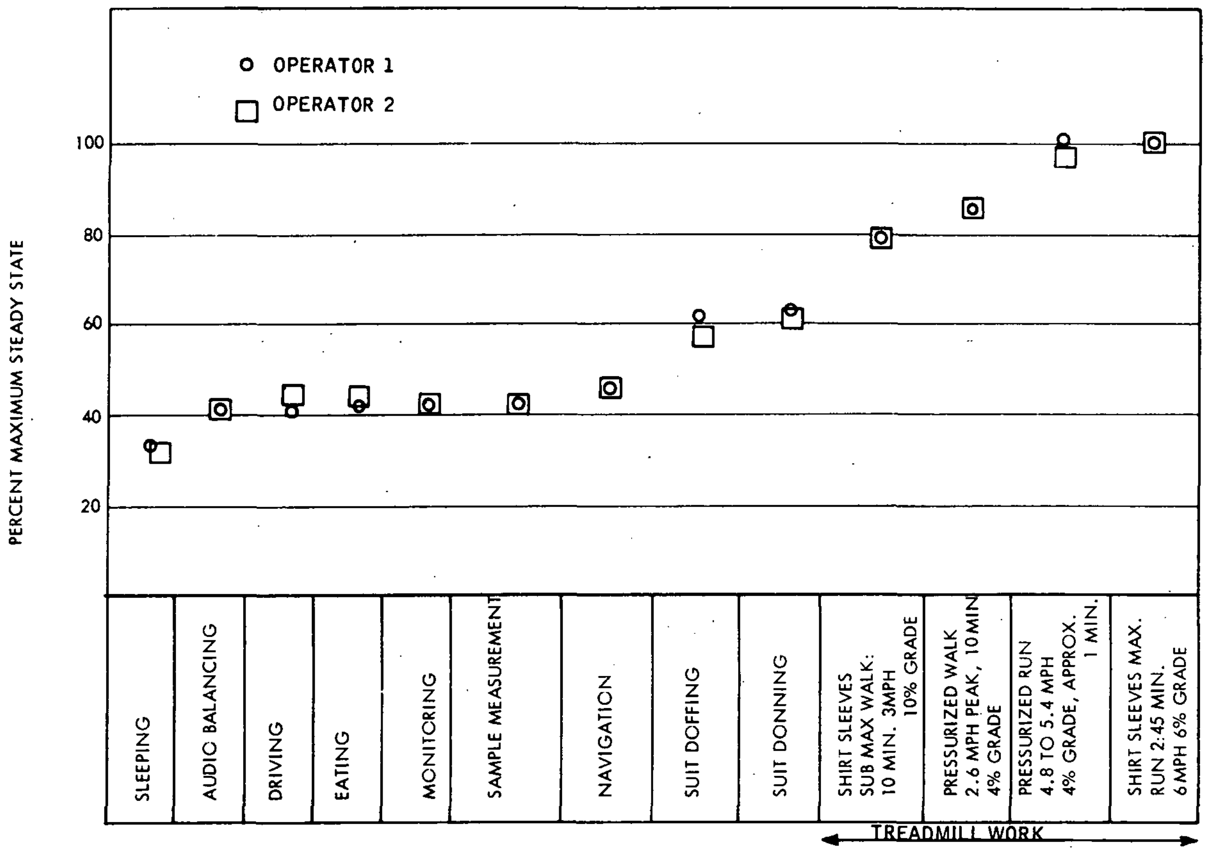

Figure 2-3. Mean Heart Rate Task Profiles as a Percent of Maximum Work - (P/P_C) 100

required during outside activities. Based on the heart rates observed during these activities and those obtained during the measurement of oxygen consumption, estimates were made of the oxygen consumption during inflated suit treadmill activity*. The Portable Life Support System (PLSS) currently considered allows energy expenditures of 5.04 kcal/min (1200 Btu/hr) for 4 hr; 6.73 kcal/min (1600 Btu/hr) for 3 hr; and 8.40 kcal/min (2400 Btu/hr) for short periods of 5 to 10 min (Reference 4). The estimated oxygen consumption data obtained during treadmill exercises, including walks up to 2.6 mph, showed that the rate of energy expenditure was in excess of these maximum allowable PLSS rates. Approximately 8 to 12 kcal/min were expended during 10-minute walking intervals. Figure 2-4 shows a typical treadmill profile where oxygen was consumed at an estimated average rate of 2.6 liters per min. Averaged over 17 full simulation days, it was estimated that the two subjects consumed 630 and 670 liters of oxygen per day, respectively.

During the simulation, selected emergency situations were evaluated. The simulated emergency rescue of a crew member injured on the lunar surface indicated that power assistance is mandatory for a single crew member to get a disabled crew member into the airlock. Even with power assistance, the single crew member performing the rescue must adhere strictly to pre-established procedures in order to get both himself and the injured crew member into the airlock. The problems associated with manually returning an injured crew member some distance from the shelter (e.g., several hundred yards) are believed to be nearly insurmountable by a single crew member. (This type of rescue was not simulated, all rescue being performed within 20 ft of the shelter.) This belief is based primarily on the excessive cumulative energy expenditure expected of the highly motivated crew member performing the rescue to get to the injured crew member rapidly, secure him, transport him to the shelter, and get both himself and the injured astronaut into the airlock. The effects of one-sixth gravity on emergency rescues are not known.

The presence of a third crew member would greatly alleviate this situation, even if his only contribution were to assist in backpack donning and in getting the injured crew member into the shelter.

BASELINE SCIENTIFIC MISSIONS

Four baseline scientific missions have been described by NASA (References 4 and 5). These missions and the scientific tasks to be accomplished are shown in Table 2-4. As has been noted before (Reference 2), baseline missions differ principally according to the location at which they are performed. Table 2-5 presents the approximate times required per scientific measurement as listed by the Bendix study (Reference 1). On the basis of task times in the Lunex II simulation and further unpublished simulations of scientific

*These estimates were made by summing the oxygen consumption per minute values corresponding to the heart rate observed each minute of the inflated suit treadmill activity.

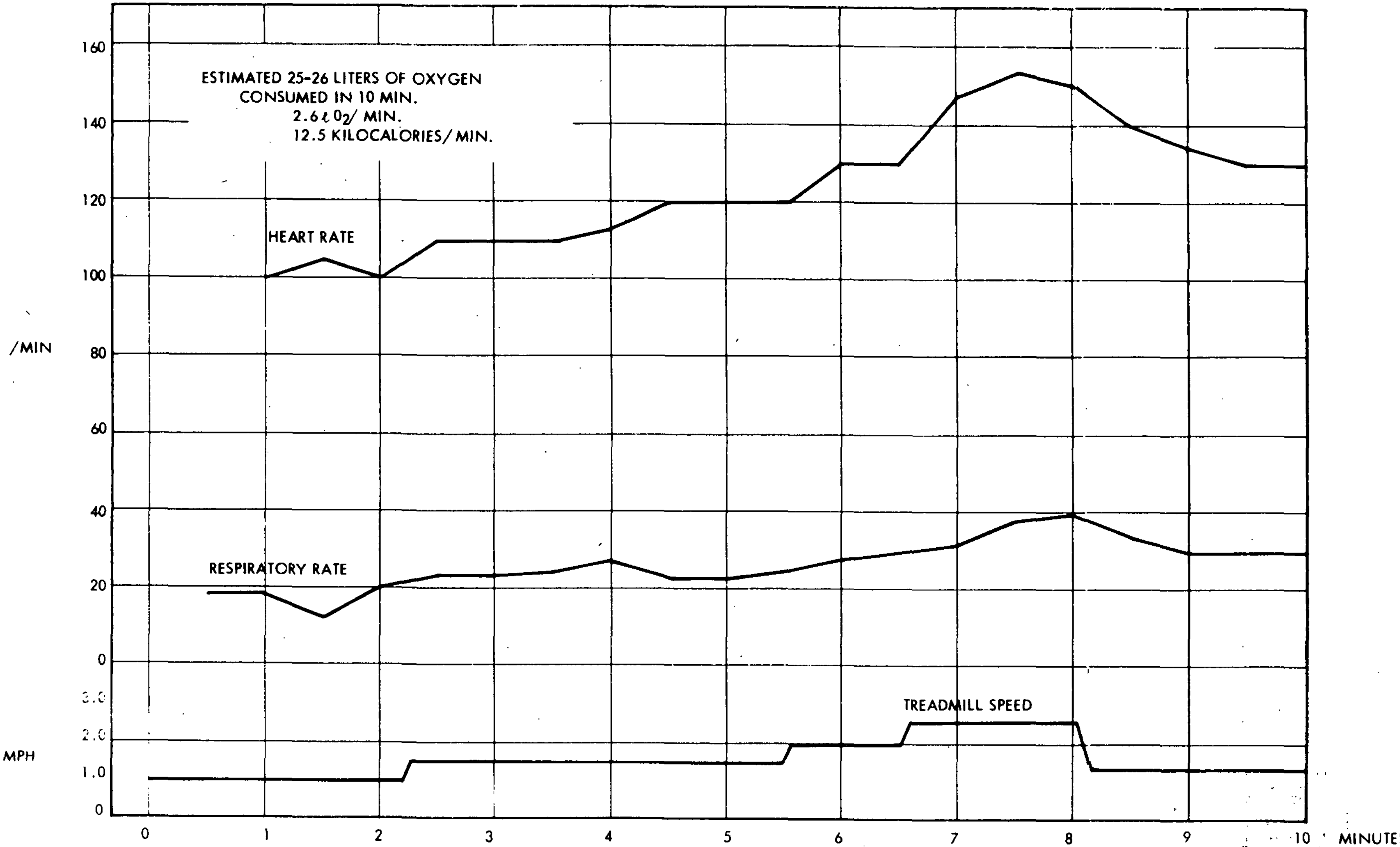

Figure 2-4. Treadmill Profiles at 4-percent Grade - Operator 2; 9 Full Days in Simulator

TABLE 2-4

NASA SUMMARY OF MEASUREMENTS MADE FOR BASELINE MISSIONS

Task	Expanded ESS (LSSM)	Hyginus* Rille (LSSM)	Alphonsus* (LSSM)	Alphonsus (LSSM/LFV)
Topographical Surveying	X	X	X	X
Surface Geology	X	X	X	X
100-ft Drill		X	X	
10-ft Drill	X		X	X
LEM/Shelter Laboratory Geology	X	X	X	X
Gravity	X	X	X	X
Magnetic	X	X	X	X
Seismic	X	X	X	X
Telluric Currents	X	X	X	
In Situ	X	X	X	X
Core-Hole Logging	X	X	X	X
Nuclear	X	X	X	X
Gas Analysis	X	X	X	X
ESS	X	X	X	
X-ray, Optical, and Radio Astronomy, Phase I	X	X	X	X

*Also included in Bendix document (Ref. 1)

TABLE 2-5

TASK COMPLETION TIMES PER MEASUREMENT FOR ONE MAN (BENDIX AND HONEYWELL ESTIMATES)

Basic LSSM Sortie Tasks at Each Stop		
Measurement	Completion Time as Listed In Bendix Report	As Determined For This Report
Topographical surveying	5 min per survey and 5 min extra if survey marker erected	5 min and 1 min extra for survey marker
Multiband photography and radiometry	1 min per reading	4 min per reading (8 cameras used)
Sample collection	1 min per sample (minimum)	3 min per sample collection series
Mapping	1 min per plot	3 min per plot
Gravity measurements	5 min at 1 km intervals	Time shared with above three measurements at each stop
Magnetic fields measurement	Not applicable (continuous measurement)	2 min per activation, LSSM moving
Nuclear measurements	10 min for discrete interval measurements some continuous measurements	10 min at each stop, no continuous measurements possible
Total Time Per Stop:	28 minutes (5 min alloted in LSSM timelines)	26 minutes

Alternate LSSM Sortie Tasks		
Measurement	Completion Time as Listed in Bendix Report	As Determined For This Report
Seismic recording		Using two men,
deep refraction	150 min to lay geophone net, 30 min/shot	50 min to lay net, 15 min/shot
shallow refraction	45 min/shot	45 min/shot
reflection	30 min/shot	30 min/shot
Telluric currents measurement	150 minutes	150 minutes
In Situ measurements	30 min per series	20 min per series
Drill 3-m hole	50 min astronaut time	50 min
Drill 30-m hole	5 hours astronaut time	5 hrs
Log hole, nuclear electrical induction, and sonic velocity readings	150 min astronaut time	150 min
Gas analysis	10 min for each series of readings	10 min
ESS emplacement	50 min to drill 3-m hole, 3-6 hrs to emplace ESS	3 hr 15 min total time, using two men

activity during sortie stops which have been performed, some of the times required during sortie stops have been changed. For instance, the NASA guidelines specify that during each stop on a standard LSSM sortie, gravimetry and nuclear measurements must be made, samples photographed and collected, the height or depth of local surface irregularities measured, and the position of these irregularities noted on the LSSM map. In addition, the present location of the LSSM must be plotted and noted on the map, multiband photographs and spectrographs (eight cameras in all) made, a survey marker installed, and data radioed to the shelter. Operation of the nuclear measurements package alone involves removing it from the LSSM, carrying it 50 ft away, turning on the various sensors in sequence, noting readings, and then returning it. NASA specified 5 min for each stop, with one man assigned to do all these tasks. We have determined that one man would take about 25 min, and that two men would take 15 min.

All the timeline changes we have made apply to the LSSM sorties and are summarized in the last column of Table 2-5. These changes were used in drawing the three-man LSSM timelines, with the result that the amount of territory covered and stops made had to be somewhat curtailed. We believe that the sorties as specified in this report still conform to the scientific goals set forth for the early lunar missions. The missions themselves, the kinds of LSSM and local sorties to be made, and the data gathered remain the same in our considerations.

Baseline Mission Timelines

Four different sets of timelines have been prepared for 3-man, 14-day lunar missions. They are:

Detailed LSSM sortie times and tasks for each of the four basic sorties.

Summary times and workloads for the 11 local ESA's defined by NASA.

Twenty-four-hour crew activity timelines for two typical mission days.

Fourteen-day mission schedules, showing sortie sequences for all four baseline missions and the effect of sortie scheduling and using 3- rather than 2-man crews on scientific task times, airlock cycles, and PLSS recharges for the Alphonsus and Hyginus Rille missions.

All of these times and schedules have been changed from those originally proposed by Bendix and set forth in the NASA guidelines. As mentioned in the last subsection, these changes were due to longer LSSM sortie task times being used and to fewer hours per day being available to scientific tasks from the results of the Lunex II simulation.

As a start, it was found that LSSM sorties scheduled for 6 hours would take about 6-1/2 hr to complete. Then, using the results of Lunex II, we determined that only about 7 to 7-1/2 hr would be available per day for scientific tasks. These findings led to two major changes: First, only one sortie could be scheduled per day instead of one 6-hr LSSM sortie and one 3-hr local ESA as in the NASA guidelines. Second, sortie routes and goals had to be modified because fewer LSSM and local sorties are available on a 14-day mission.

In the following tables a number of abbreviations are used to conserve space. These are defined as follows:

C/O	Checkout
ELS	Early Lunar Shelter
ESS	Emplaced Scientific Station
ESA	Extra-Shelter Activity
LFV	Lunar Flying Vehicle
LSSM	Local Scientific Survey Module
NMP	Nuclear Measurements Package
PLSS	Portable Life Support System
RTG	Radioisotope Thermal Generator
MG	Muscle Group
VL, L, ML	Large group activity, e.g., walking, carrying objects - very large, large, or medium large
S	Small group activity, e.g., adjusting instruments, sitting

Tables 2-6, 2-7, and 2-8 show the sortie schedules worked out for the Alphonsus and Hyginus Rille, Expanded ESS, and Alphonsus LSSM/LFV missions. Each of these takes 14 days, with the first and last days devoted to shelter and LEM-taxi checkout. One local ESA is scheduled for the first day of each mission. Eleven local ESA's are scheduled instead of the 14 indicated in the NASA guidelines, and 8 instead of 3 LSSM sorties. Table 2-6 has been expanded to show the differences in time-on-surface, man-hours-on-surface, man-hours for scientific tasks inside, airlock cycles, and PLSS recharges for different mission plans. Similar expansions can be performed on Tables 2-7 and 2-8 with much the same results. The emergency findings of the Lunex II simulation showed that rescue of a disabled crewman would be much more likely if one man pushed and the other pulled the third man into the airlock. For this reason the differences between holding the two ESA's (scheduled for half the days)

TABLE 2-6

BASIC MISSION TIMELINE WITH SORTIES AND TASKS FOR EACH DAY
(LSSM TIMES BASED ON TWO-MAN LSSM CREW)

Three-Man Crew Possibilities

				Concept A - One or Two Men on Surface, Two per LSSM Sortie, One per Local ESA, ESA's Staggered						Concept B - Two Men on Surface, Two per LSSM Sortie, One per Local ESA, ESA's Run Concurrently When Two Occur on Same Day					
Day	Sortie	Description	Hours on Surface	Total Time	Airlock Cycles	PLSS Recharge	Man-Hours on Surface	Man-Hours Inside	Comments	Total Time	Airlock Cycles	PLSS Recharge	Man-Hours on Surface	Man-Hours Inside	Comments
1	ESA No. 1	Unload LSSM	2	2:00	1 1	3 3	4:00	14:15		2:00	1 1	3 3	4	14:15	
2	LSSM No. 1 ESA No. 2	C/o drive on LSSM; start 100-ft drill	3:20 2:00	5:20	1 2 3	2 1 3	8:40	8:15		5:20	1 1 2	2 2 4	10:40	5:00	No. 2 uses two men
3	LSSM No. 2 ESA No. 3	Emplace ESS; complete 100-ft drill hole	5:12 2:00	7:12	1 2 3	4 1 5	12:24	4:10		7:12	1 1 2	4 2 6	14:24	2:30	No. 3 uses two men
4	LSSM No. 3	Sample collection and geological measurements	6:28	6:28	1 1	4 4	12:56	3:00		6:28	1 1	4 4	12:56	3:00	
5	ESA No. 4 ESA No. 5	ESS activation; lay geophones	3 3	6:00	1.5 1.5 3	1 1 2	6:00	8:00		3:00	1 1	1 1 2	6:00	11:30	
6	LSSM No. 4	Deep seismic charge emplacement	6:30	6:30	1 1	4 4	13:00	3:00		6:30	1 1	4 4	13:00	3:00	
7	ESA No. 6 ESA No. 7	Log 100-ft hole; sonic velocity measurements on 100-ft hole	2 2	4:00	1.5 1.5 3	1 1 2	4:00	13:00		2:00	1 1	1 1 2	4:00	14:00	
8	LSSM No. 5	Same as LSSM 3	6:28	6:28	1 1	4 4	12:56	3:00		6:28	1 1	4 4	12:56	3:00	
9	ESA No. 8 ESA No. 9	Seismic charge detonations; Phase I Astronomy setup	2:30 2:30	5:00	1.5 1.5 3	1 1 2	5:00	11:30		2:30	1 1	1 1 2	5:00	12:00	
10	ESA No. 10 ESA No. 11	X-ray and optical astronomy; radio astronomy	3 3	6:00	1 2 3	3 3	9:00	6:00		5:00	1 1 2	2 2 4	10:00	5:00	No. 1 uses two men
11	LSSM No. 6	Same as LSSM 4	6:30	6:30	1 1	4 4	13:00	3:00		6:30	1 1	4 4	13:00	3:00	
12	LSSM No. 7	Same as LSSM 3	6:28	6:28	1 1	4 4	12:56	3:00		6:28	1 1	4 4	12:56	3:00	
13	LSSM No. 8	Same as LSSM 3	6:28	6:28	1 1	4 4	12:56	3:00		6:28	1 1	4 4	12:56	3:00	
		Totals		75:24	25	44	126:48	83:10		63:44	16	47	131:48	82:15	

Two-Man Crew Possibilities

		Concept C - One Man on Surface, Local ESA's Staggered						Concept D - Two Men on Surface for Local ESA's					
Day	Sortie	Total Time	Airlock Cycles	PLSS Recharge	Man-Hours on Surface	Man-Hours Inside	Comments	Total Time	Airlock Cycles	PLSS Recharge	Man-Hours on Surface	Man-Hours Inside	Comments
1	ESA No. 1	3:00	2 2	1 1	3:00	8:00		2:00	1 1	2 2	4:00	9:00	
2	LSSM No. 1 ESA No. 2	5:20	1 2 3	1 1 2	5:20	4:00		5:20	1 1 2	1 2 3	7:20	3:00	
3	LSSM No. 2 ESA No. 3	7:12	1 2 3	2 1 3	7:12	2:30		7:12	1 1 2	2 2 4	9:12	1:30	
4	LSSM No. 3	6:28	1 1	2 2	6:28	3:00		6:28	1 1	2 2	6:28	3:00	
5	ESA No. 4 ESA No. 5	6:00	1.5 1.5 3	1 1 2	6:00	3:00		3:00	1 1	1 1 2	6:00	6:00	
6	LSSM No. 4	6:30	1 1	2 2	6:30	3:00		6:30	1 1	2 2	6:30	3:00	
7	ESA No. 6 ESA No. 7	4:00	1.5 1.5 3	1 1 2	4:00	7:00		2:00	1 1	1 1 2	4:00	9:00	
8	LSSM No. 5	6:28	1 1	2 2	6:28	3:00		6:28	1 1	2 2	6:28	3:00	
9	ESA No. 8 ESA No. 9	5:00	1.5 1.5 3	1 1 2	5:00	5:30		2:30	1 1	1 1 2	5:00	8:00	
10	ESA No. 10 ESA No. 11	6:00	1.5 1.5 3	1 1 2	6:00	3:00		5:00	1 1 2	2 2 4	10:00	3:00	
11	LSSM No. 6	6:30	1 1	2 2	6:30	3:00		6:30	1 1	2 2	6:30	3:00	
12	LSSM No. 7	6:28	1 1	2 2	6:28	3:00		6:28	1 1	2 2	6:28	3:00	
13	LSSM No. 8	6:28	1 1	2 2	6:28	3:00		6:28	1 1	2 2	6:28	3:00	
	Totals	75:24	26	26	75:24	51:00		65:54	16	31	84:24	51:30	

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TABLE 2-7

EXPANDED ESS MISSION SORTIE SUMMARY

Day	Sortie	Description	Hours on Surface	Remarks
1	ESA No. 1	Unload LSSM	2:00	
2	LSSM No. 1 ESA No. 5	C/o drive on LSSM; lay geophones	3:20 3:00	No 30-m drill on this mission, so ESA's 2 and 3 omitted
3	LSSM No. 2 ESA No. 8	Emplace ESS; seismic charge detonations	5:12 2:00	
4	LSSM No. 3	Sample collection and geophysical measurements	6:28	
5	LSSM No. 9	Satellite ESS emplacement	6:32	
6	LSSM No. 10	Satellite ESS emplacement	6:32	
7	LSSM No. 11	Satellite ESS emplacement	6:32	ESA's 6 and 7 omitted because no 30-m hole
8	ESA No. 4 ESA No. 9	ESS activation; Phase I astronomy setup	3:00 2:30	
9	ESA No. 10 ESA No. 11	X-ray and optical astronomy; radio astronomy	3:00 3:00	
10	LSSM No. 4	Deep seismic charge emplacement	6:30	
11	LSSM No. 5	Same as LSSM 3	6:28	
12	LSSM No. 6	Same as LSSM 4	6:30	
13	LSSM No. 7	Same as LSSM 3	6:28	
14	Transfer to LEM taxi			

TABLE 2-8

ALPHONSUS LSSM - LVF MISSION SORTIE SUMMARY

Day	Sortie	Description	Hours on Surface	Remarks
1	ESA No. 1	Unload LSSM	2:00	
2	LSSM No. 1 ESA No. 5	C/o drive on LSSM; lay geophone net	3:20 3:00	No 30-m drill and no ESS emplacement so ESA's 2, 3, 4, 6, and 7 are omitted
3	LSSM No. 3	Sample collection and geophysical measurements	6:28	LSSM sortie No. 2 is also omitted
4	ESA No. 8 ESA No. 9	Seismic charge detonation; Phase I astronomy setup	2:00 2:30	
5	LSSM No. 4	Seismic charge detonation	6:30	
6	ESA No. 10 ESA No. 11	X-ray and optical astronomy; radio astronomy	3:00 3:00	
7	LSSM No. 5	Same as LSSM 3	6:28	
8	LSSM No. 6	Same as LSSM 4	6:30	
9	LSSM No. 7	Same as LSSM 3	6:28	
10	LFV No. 1	Photography and sample collection, selected areas	6:00	
11	LFV No. 2	Same as LFV 1	6:00	
12	LSSM No. 8	Same as LSSM 3	6:28	
13	LSSM No. 9	Same as LSSM 3	6:28	
14	Transfer to LEM taxi			

consecutively and concurrently were compared. The latter concept means that during local ESA's two men would be on the surface at the same time, doing different things. Results for four different plans, two with the 3-man crews and two with 2-man crews, are summarized in Table 2-9.

Concept B in Table 2-9 offers considerable advantages in man-hours on the surface and in crew safety during local ESA's. It was chosen as the basis for Tables 2-10 and 2-11, typical 24-hr timelines for LSSM and local ESA sortie days.

A definite problem exists on LSSM sortie days, for which no solution appears in the NASA guidelines. This is that, with 6-1/2-hr sorties and two additional hours for suit donning and doffing, almost 9 hr elapse between meals for the 2-man LSSM crew. Either some provision must be made for eating while in the suit, or the sortie must return to the shelter half way through the mission. Other than this one problem, the 24-hr timelines are realistic and conform very closely to the final times found to be necessary in the Lunex II simulation (see Table 2-2). These times are applicable to days 2 to 13 of all four missions. Normally the two schedules will alternate days to give enough inside scientific time to analyze samples collected on the previous LSSM sortie. In some cases, several long sorties occur on successive days, especially in the expanded ESS mission where sample collection is not common. Days 2 and 3 of the Alphonsus and Hyginus Rille missions are unusual in that the two external ESA's must be carried out consecutively since one of each of them takes a 2-man crew. The extra time required on day 3 of these missions must come from crew rest time and report-writing time on that day.

Strict adherence to a detailed timeline tends to build up stress in crew members, especially if equipment problems or other factors cause deletion of tasks which must be made up later. In the Lunex II simulation (Reference 7), the subjects stated that even a slight perturbation of a functional timeline tended to greatly effect over-all task completion. Based on 18 days of rigorous adherence to a task schedule, the Lunex II subjects requested that all tasks omitted for any reason should be permanently deleted and not re-inserted later in the mission.

Sortie Task Timelines

The baseline mission timelines assign blocks of time to the various sorties to be performed. In general, sorties of the same duration can be exchanged since the type of measurements made on many of the sorties are the same. Certain sorties must be performed at the sight called for, since *in situ* measurements are required at specified locations. The only severe constriction on sortie scheduling is that seismic shots must not be made after the astronomy experiment equipment has been set up. Setting up and performing Phase I astronomy studies takes two days of local ESA's.

Detailed LSSM sortie task timelines are shown in Tables 2-12 through 2-15. The sortie time increments are derived primarily from Bendix studies (Reference 1), modified as shown in Table 2-5. Notes on the differences in each sortie and a sortie summary are attached to each timeline. These four timelines handle most of the sorties which have been proposed for early lunar missions

TABLE 2-9

SUMMARY OF MISSION DIFFERENCES

	Crew Activity Alternatives	Total Time on Surface, hr/min	Total Man-Hours on Surface	Total Man-Hours for Inside Tasks	Airlock Cycles Required	PLSS Recharges Required	Crew Safety Probabilities During ESA*
3-Man Crews	A-Consecutive ESA's	75:24	126:48	83:10	25	44	Low on local ESA; high on LSSM sorties
	B-Concurrent ESA's	63:44	131:48	82:15	16	47	High on local ESA and on LSSM sorties
2-Man Crews	C-Consecutive ESA's	75:24	75:24	51:00	26	26	Low on local ESA; impossible on LSSM
	D-Concurrent ESA's	65:54	84:24	57:30	16	31	Fair on local ESA; impossible on LSSM

*Where crew safety is defined as the probability of rescuing a disabled crewman on the surface, including getting him into the airlock and/or applying a patch to a torn suit in time.

TABLE 2-10

THREE-MAN, 24-HR TIMELINES FOR LSSM SORTIE DAYS, ALPHONSUS OR HYGINUS RILLE MISSIONS (CONCEPT B, TWO MEN ON SURFACE)

Elapsed Time	Time per Task	Astronaut I	Astronaut II	Astronaut III	Remarks
0600	20	Take down beds	Take down beds	Take down beds	
	45	Eat meal I and clean up	Eat meal I and clean up	Eat meal I and clean up	
0700	20	Hygiene	Hygiene	Hygiene	
0800	55	Don suit, PLSS c/o	Don suit, PLSS c/o	Don vented suit - aid in PLSS c/o	No. III assists I and II
	10	Egress to surface	Egress to surface	Monitor airlock	
0900	6:30	LSSM sortie	LSSM sortie	Monitor sortie, inside geological tasks	
1000					
1100					
1200				Eat snack	Some method of feeding Astronauts I and II must be found while they are on the 6-hour sortie, otherwise 9 hours elapse between meals.
1300				Earth communications	
1400					
1500					
	55	Doff suit Recharge PLSS	Doff suit, Recharge PLSS	Doff suit	Scientific tasks are best scheduled on an "As-Time-Available" basis, rather than specific times for specific tasks; tasks not critical to mission success which cannot be completed on the day assigned to them should be dropped from the schedule.
1600	45	Eat meal II and clean up	Eat meal II and clean up	Eat meal II and clean up	
1700	1 hr	Rest	Rest	Rest	
1800	30	Scientific tasks inside	Scientific tasks inside	Scientific tasks inside	
	20	Suit c/o			
1900	1 hr	Maintenance, repair, and housekeeping			
			Suit c/o		
2000	45	Report writing, hygiene, and personal activity			
				Suit c/o	
2100	45	Eat meal III and clean up	Eat meal III and clean up	Eat meal III and clean up	
	30	Buffer period	Buffer period	Buffer period	
2200	10	Set up beds	Set up beds	Set up beds	
	8 hr	Rest	Rest	Rest	
0600					

TABLE 2-11

THREE-MAN, 24-HR TIMELINES FOR LOCAL ESA SORTIE DAYS, ALPHONSUS OR HYGINUS RILLE MISSIONS (CONCEPT B, TWO MEN ON SURFACE)

Elapsed Time	Time per Task	Astronaut I	Astronaut II	Astronaut III	Remarks
0600	20	Take down beds	Take down beds	Take down beds	See remarks in Table 10
0700	45	Eat meal I and clean up	Eat meal I and clean up	Eat meal I and clean up	
	20	Hygiene	Hygiene	Hygiene	
0800	55	Don suit, PLSS c/o	Don suit, PLSS c/o	Don vented suit; assist I and II	
	10	Egress to surface	Egress to surface	Monitor airlock	
0900 1000 1100	3 hr	Local ESA	Another local ESA in same vicinity as No. I	Monitor I and II; some reporting and earth data transmittal	
1200	55	Doff suit PLSS recharge	Doff suit PLSS recharge	Doff suit help I and II	
1300	45	Eat meal II and cleanup	Eat meal II and cleanup	Eat meal II and cleanup	
1400	1 hr	Rest	Rest	Rest	
1500 1600 1700 1800	4 hr	Scientific task time - geological samples sorting Suit c/o Also checkout any equipment emplaced on ESA's	Map completion, petrographic analysis Suit c/o (astronomy, ESS, geophone net)	Suit c/o	
1900	45	Eat meal III and cleanup	Eat meal III and cleanup	Eat meal III and cleanup	
2000	1 hr	Maintenance, repair, and housekeeping			
2100	1 hr	Report writing, hygiene, and personal activity			
2200	30	Buffer period	Buffer period	Buffer period	
0600	8 hr	Rest	Rest	Rest	

TABLE 2-12

THREE-MAN TIMELINES FOR FIRST LSSM SORTIE (APPLIES TO ALL MISSIONS)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG.	Comments
1	Outside shelter	10	Check out and load LSSM	Spare PLSS	29	Carried from shelter to LSSM	L	
2	LSSM	1	Climb to driver's seat of LSSM	---	---	---	L	Includes strapping into seat
3	LSSM	10	Drive on heading, 1 km	Control stick	---	---	S	
4	Surface	25	Set up, operate gravimeter, NMP; take surface samples; plot location of samples; make on-spot preliminary analysis of samples	Gravimeter NMP Geological samples kit, surveying staff	5.9 15.5 2.7 13.0	Set up on surface, turn on. Carry away from vehicle 25 m. Chip samples with hammer, collect. Hold in hand. Measure of height and depth of surface irregularities	L L L L	Several different measurements to make. Note good location for FSS emplacement.
5	LSSM	11	Drive 1 km	As in 2, 3	---	---	L-S	
6	Surface	25	Same as 4, except survey marker must be implanted beside LSSM	As in 4 Survey marker	0.9	Same as 4 Pound into lunar soil with mallet.	L	Marker must be set if last marker or shelter will be out of sight at next stop - unlikely for this short sortie
7	LSSM	11	Drive 1 km			Same as above	S	
8	Surface	25	Experiments			Same as above	L	
9	LSSM	11	Drive 1 km			Same as above	S	
10.	Surface	25	Experiments			Same as above	L	
11	LSSM	11	Drive final distance to ELS			Same as above	S	
12	Surface outside shelter	15	Unload geo. samples and used PLSS, transport to shelter	Geo. sample boxes Used PLSS	1.8 24	Carried to shelter from LSSM (5 m)	L	One astronaut must also hook up LSSM for recharge if batteries instead of RTG are used.
Buffer time 20 min.								

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside Shelter	10	Same as Astronaut I	2nd PLSS	29	Same as Astronaut I	L	Concurrent with No. 1 activity
2	LSSM	1	Climb to pass. seat	---	---	---	L	Includes strapping into seat.
3	LSSM	10	Turn on magnetometer	Magnetometer mounted on LSSM	4	Turn on, check	S	Does not require constant attention.
4	LSSM	25	Plot location, take photographic and radiographic pictures of surrounding area	Topo surveying gear Photometry and radiometry gear	23 30	Aim, note readings verbally to ELS, take about 8 different exposures of each object, field, or sky segment chosen; 8 different cameras involved.	S S	All used on LSSM from seated position. Some pencil work required on maps.
5	LSSM	11	As in 2, 3.	---	---	---	S	Turns on magnetometer as in 3.
6	LSSM	25	Same as 4	---	---	---	S	As in 4.
7	LSSM	11	As in 2, 3, some map work.	---	---	Same	---	Map work while moving, if possible. Also photographs from photography equipment while moving.
8	LSSM	25	As in 4.	---	---		---	
9	LSSM	11	As in 2, 3, some map work	---	---	---	---	
10.	LSSM	25	As in 4.	---	---	---	---	
11	LSSM	11	As in 2, 3.	---	---	---	---	
12	Surface outside shelter	15	Same as Astronaut I also returns photo and radiometry equipment.	Used PLSS Film packs	24 1.8	Same as Astronaut I.	L	Concurrent with Astronaut I activity

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Shelter	10	Monitor No. 1 and No. 2.	Visual, radio contact	---	---	S	Keep track of checkout, read checkout list.
2	Shelter	1	Some analysis equipment setup	Microscope, pestle, slides	2.3	By hand	S	
3	Shelter	20	Continue analysis equipment setup	Microscope, pestle, slides	2.3	By hand	ML	
4	Shelter	15	Locate LSSM with rangefinder. Monitor stop. Plot location, elevation of LSSM. Record data.	Visual, radio	---	From seated position.		Involves plotting on maps, switching data recording equipment to correct channel, independent ranging with laser theodolite.
5	Shelter	21	Analysis of samples	As in 3	---	From seated position.	S	Using equipment setup in 3.
6	Shelter	15	As in 4.	---	---	---	S	All from seated position.
7	Shelter	21	Analysis of samples	---	---	---	S	
8	Shelter	15	As in 4				S	
9	Shelter	21	Write-up of analysis of results				S	
10.	Shelter	15	As in 4	---	---	---	S	
11	Shelter	21	Write up, take down analysis equipment	---	---	---	ML	
12	Shelter	5	Monitor crew return, air lock functioning	Same as 1			ML, S	

NOTES ON THIS SORTIE

(1) All measurements are in kilograms and kilometers.

(2) This is the first sortie, on Lunar Maria with few distinguishing features. Its main purpose is training of the LSSM crew and procedures evaluation. This timeline applies to all lunar missions.

(3) The same measurements are made at all stops on this sortie. No scientific equipment is emplaced on the surface.

(4) The astronaut who dismounts at each stop sets up the gravimeter, walks 25 m away from the LSSM with the nuclear measurements package, sets it up, makes nuclear measurements, makes a 60 m reconnoiter around the NMP collecting samples, returns to the LSSM, and repacks the gravimeter and NMP. This sequence is the same for all LSSM sorties.

(5) Since total mission time with buffer period is 3:20, no PLSS exchange will be necessary. Extra PLSS's are carried as a safety measure only.

(6) PLSS's, if not used, can probably be left on LSSM for next mission.

SORTIE SUMMARY

Range . . . . 8 km
Radius . . . . 2 km
Time . . . . 3 hours
Buffer . . . . 20 min
Total time 3:20
Stops . . . . Four at 25 minutes each

MEASUREMENTS TAKEN

Continuous

(1) Magnetism
(2) Sample collection

At Each Stop

(1) Gravity gradient
(2) Nuclear measurements
(3) Range and bearing to ELS and geological formations
(4) Photography and radiometry
(5) Height - depth of local surface irregularities
(6) Plot significant features on map
(7) Sample photography and collection

ROUTE

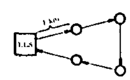

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TABLE 2-13

THREE-MAN TIMELINES FOR SECOND LSSM SORTIE (APPLIES TO ALL MISSIONS EXCEPT ALPHONSUS LSSM - LSV; EXPANDED SATELLITE ESS SORTIE IS FOR EXPANDED ESS MISSION)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	15	Check out and load LSSM	PLSS-power pkg. for ESS	29 34 102	Transported from TLS to LSSM	L L L	One man can carry ESS, two men carry to LSSM
2	LSSM	11	Drive 1 km	Control stick	---	By hand	S	Must scan for correct ESS area
3	Surface	20	Unload 3 m. drill - set up	3 m. drill	14	Lift off LSSM, set on ground	L	Must check area for suitable location
4	Surface	150	Drill 3 m. hole; help with setup of ESS	3 m. drill ESS	14 102	Feed bit through drill. Lift ESS from LSSM to ground near 3 m. drill. Main package unfolded, sensors checked and aligned, power plugged in.	L VL	Must spend 50 min. with 3 m. drill during 150-min. drilling time. Monitor drill progress at 10-minute intervals.
5	Surface	30	Replace PLSS	Spare PLSS	29	Strapped on from LSSM	L	Includes new PLSS checkout time
6	Surface	15	Pack up 3 m. drill, load on LSSM	3 m. drill	14	Loaded by hand	L	Leave drill corings for Astronaut II to tune
7	Surface	10	Final check of ESS system	Transceiver on shelter	--	--	S	Corrections may have to be *made to instruments and connections*
8	LSSM	11	Drive to shelter	Control stick	--	By hand	S	
9	Surface outside shelter	16	Unload used PLSS, 3 m. drill	PLSS, 3m. drill	24 14	Carried to shelter	L	Three trips, LSSM-shelter, shelter-LSSM, LSSM-shelter
	Buffer time	35 minutes						

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	15	Checkout	PLSS-3 m. drill ESS	129 14 102	Transported from shelter to LSSM	L	Included in Astronaut I's equipment list
2	LSSM	11	Prepare ESS for unloading	---	---	From seated position	S	Minor adjustments to ESS while riding on LSSM
3	Surface	20	Unload 34 kg. portion of ESS	Power pkg. for ESS	34	Set up 25 m. from drill	L	
4	Surface	150	Continue setup of ESS pkg. Unload main ESS with help of Astronaut I. Setup of ESS.	ESS All parts of ESS	102 135	Emplace, turn on power supply. Lift ESS from LSSM to ground. Carry two instruments away from main ESS and emplace on ground.	L VL L	Lifting ESS on or off LSSM takes 4 minutes of high effort
5	Surface	30	Aid Astronaut I in PLSS Checkout		39	Strap on from rack on LSSM	L	
6	Surface	15	Insert sensors from ESS in drill hole. Collect drill corings, place in sample bags	Sensors from main ESS	3.3 4.5	Pushed into hole by hand. Insert 75-cm lengths in tubes provided on LSSM	L L	
7	Surface	10	Same as Astronaut I	Same as Astronaut I	--	Same	S	
8	LSSM	11	Ride LSSM	---	---	---	S	
9	Surface outside shelter	15	Unload used PLSS	PLSS	24	Carried by hand	L	

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Shelter	15	Monitor outside activity	Visual, radio contact	---	---	S	Read check list to driver, check ESS radio operating correctly
2	Shelter	11	Earth data transmittal	Radio	---	By hand-seated	S	Also monitor LSSM
3	Shelter	10	Monitor LSSM	Laser range-finder	---	By hand-standing up behind rangefinder	ML	Determine position of 3 m. drill, plot
4	Shelter	120	Earth data transmittal. Perform some geological analysis. Spot monitoring of LSSM Crew.	Radio Mass Spectrometer Biotelemetry system	---	From seated position	S	Analysis of samples from Sortie No. 1. *Check on work rate during* high energy tasks.
5	Shelter	30 20	Begin check of ESS functions. Complete check, read off checklist	ESS transceiver ESS checklist	---	From seat From seat. May have to move about to check ESS functions	S	
6	Shelter	25	Complete scientific task.	Mass Spectrometer	---	Seated	S	
7	Shelter	10	Ok final check	Transceiver	---	Standing	S	
8	Shelter	11	Prepare PLSS recharge equipment	---	---	Sitting	S	
9		15	Monitor crew return, air-lock functioning					

NOTES ON THIS SORTIE

(1) Total sortie devoted to emplacing main ESS 1 km from shelter.

(2) Maximum time is 5 hours, 12 minutes. This means Sortie 1 is a poor candidate for the same day as Sortie 2. Local ESA could be performed on the same day, though.

(3) For emplacing satellite ESS's, activities 2 and 8 are: 81 min, drive 8 km; 4 and 8 are reduced to 5 min each. Buffer time is increased to 40 min. Total mission time is 8 hours 33 min.

SORTIE SUMMARY

Range	2 km	(12 km for satellite ESA emplacement)
Radius	1 km	(6 km for satellite ESA emplacement)
Time	4.42	(5.53 for satellite ESA emplacement)
Buffer	:35	(:40 for satellite ESA emplacement)
Total time - 5:12		(8:33 for satellite ESA emplacement)
Stops - 1 for 225 minutes		

MEASUREMENTS TAKEN

Continuously

Sample collection on return trip

At the Stop

(1) Drill core collection
(2) Plot of position of ESS on LSSM map

ROUTE

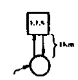

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TABLE 2-14

THREE-MAN TIMELINES FOR THIRD LSSM SORTIE (APPLIES TO ALL MISSIONS)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside near shelter	10	Checkout and load LSSM	Spare PLSS, Gas Analyzer	29 4.5	Carried from ELS to LSSM in two trips	VL	Gas Analyzer stowed on LSSM for removal during sortie stops.
2	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Include time to get on LSSM. Drives on heading to first stop.
3	Surface	15	Set up gravimeter, turn on, operate NMP Collect geo. samples, plot location of geo. samples, measure terrain irregularities, return gravimeter to LSSM	Gravimeter, NMP Geo. sample kit, Verbal report to ELS. Surveying Staff, Gravimeter	5.9 15 2.7 6 13 5.9	Set up on surface, turn on. Carry 25 m from LSSM, make measurements, bring back. Pick up samples, place in containers. Describe location over radio. Carry back to LSSM.	L S L VL	Measures height of surface, holes. Also can take pictures of sample location.
4	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Continue on heading
5	Surface	15	As in 3	---	---	---	L	---
6	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Continue on heading
7	Surface	35	As in 3, and gas analysis	Same Gas Analyzer (mass spectrometer)	4.5	Set up spectrometer near gas source or on ground. Then take down readings (AC waveform digitalized to 4 bits of information)	L ML S	Measurement takes 10 min, after regular measurements are made
8	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Turn onto far leg of sortie
9	Surface	25	As in 7	Same	---	By hand	VL, L	---
10	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Continue on far leg
11	LSSM	30	PLSS exchange	Spare PLSS	29	Put on from rack of LSSM	L, VL	Also help Astronaut II don PLSS
12	Surface	15	As in 3	Same	---	---	VL, L	No gas analysis planned
13	LSSM	21	Drive 2 km	---	---	---	S	Turn to shelter
14	Surface	15	As in 3	---	---	---	VL, L	
15	LSSM	21	Drive 2 km				S	Continue to shelter
16	Surface	15	As in 3				VL, L	
17	LSSM	21	Drive 2 km				S	Drive remaining distance to shelter
18	Outside shelter	15	Unload LSSM, transport gear to shelter	Used PLSS Gas Analyzer Geo. samples	24 4.5 4.5	Carry to ELS in 3 round trips	VL L	

Buffer period 40 minutes

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside near shelter	10	Load LSSM, assist Astronaut I in check-out.	Spare PLSS, Penetrometer, surface electrical and radiometry pkg	29 2.3 1.5 3.2	Carried from ELS to LSSM in 3 trips	VL L L	Instruments constitute In Situ measurements pkg. Stowed on LSSM near gas Analyzer.
2	LSSM	21	Sample collection Magnetometer activation	Sample scoop Magnetometer	0.2	Scoop samples by hand - turn on Magnetometer	S S	Samples collected if interesting ones appear enroute. Magnetometer performance monitored. Note readings verbally to ELS. Mark on map. Survey gear is lised to LSSM. Some cameras are hand-held, others are mounted on LSSM.
3	Surface	15	Plot location of LSSM Take photos and spectrographs Modify map Install survey marker	Laser rangefinder and theodolite Photography and radiometry gear Map and pen	23 39 0.8	Take a fix on last marker. About 6 different exposures of each object, area or sky segment. Plot location on map. Pounded into surface.	S ML S S L	
4	LSSM	21	As in 2	---	---	---	--	---
5	Surface	15	As in 3	---	---	---	--	---
6	LSSM	21	As in 2	---	---	---	--	---
7	Surface	35	As in 3, and In Situ measurements Surface electrical pkg.	Same Penetrometer Radiometry pkg.	2.7 1.5 3.2	Set on surface, trigger, take readings. Insert electrodes into surface, then take readings. Take reflectance readings.	ML ML	In Situ measurements are used to determine penetration distance, bulk density, reflectance properties, electrical conductivity and dielectric constant. Each series takes about 20 min as multi-band photo and radiometry task will be curtailed. Continue to collect samples.
8	LSSM	21	As in 2	---	---		S	
9	Surface	25	As in 7	Same	---	---	L, S	
10	LSSM	21	As in 2	Same	---	---	S	
11	LSSM	30	PLSS exchange	Spare PLSS	29	Put on from rack on LSSM	VL, L	Also help Astronaut I don PLSS
12	Surface	15	As in 3	---	---	---	ML, S	No In Situ measurements
13	LSSM	21	As in 2		---	---	S	
14	Surface	15	As in 3	---	---	---	ML, S	
15	LSSM	21	As in 2				S	
16	Surface	15	As in 3				ML, S	
17	LSSM	21	As in 3				S	
18	Outside shelter	15	Unload LSSM, transport gear to shelter	Used PLSS-In Situ pkg, film pkg.	24 39 1.8	Carry to ELS in 2 round trips	VL VL	

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Shelter	10	Monitor egress, read LSSM checklist	Visual, Radio	---	Check communications system and data transmittal equipment	S S	Also notify earth that sortie has begun
2	Shelter	25	Set up geological equipment	Petrographic analyses kit, microscope, Beckmann, oil baths	4.8	Set up on shelter work table	ML S	
3	Shelter	10	Monitor and record comments by Astronauts I and II; plot LSSM location	Radio Laser rangefinder and theodolite	--- 23	From seat at worktable. Must get up and aim through window	ML	
4	Shelter	25	Continue geological analysis	---	---	---	--	---
5	Shelter	10	As in 3	---	---	---	--	---
6	Shelter	25	Put away geo. analysis gear. Conduct ESS checkout.	Gas equipment	4.8	---	--	ESS checkout - involves testing data channels, sensor performance, power
7	Shelter	20	Monitor LSSM, record gas analysis and In Situ results. Plot LSSM position	Radio communication channels. Laser rangefinder-theodolite	23	From seat. From window if LSSM still visible, otherwise use LSSM reported position	S ML	
8	Shelter	25	Earth report - systems checkout	Radio	---	From seated position	S	Check life support systems
9	Shelter	20	As in 7 and begin sample packaging		---	Sort samples and package them	S	
10	Shelter	25	Complete sample packaging	Sample bag	---	From seat - I motion	S	
11	Shelter	30	Checkout personal PLSS, exchange	Radio, biotelemetry system	---	From seat	S	Check comm., read PLSS checklist
12	Shelter	10	As in 3	---	---	---	ML, S	
13	Shelter	25	Begin film analysis from previous sortie	---	---	Seated-analyze and package film	S	
14	Shelter	10	As in 3	---	---		S	
15	Shelter	25	Film analysis				S	
16	Shelter	10	As in 3				S	
17	Shelter	21	Store equipment, ready PLSS recharge equipment				ML	
18	Shelter	15	Monitor airlock LSSM activity					

NOTES ON THIS SORTIE

(1) This is the standard 6-hour scientific measurements and sample collection sortie which was scheduled for 8 out of 12 LSSM sorties on the four baseline missions.

(2) Twenty extra minutes have been added to the timeline to make gas analysis and in situ measurements. These occur on 2 or 3 of the 8 sorties. Other sorties would be 20 minutes shorter.

(3) The revised timeline of this sortie, based on workload estimates and task times reported in the NASA Guidelines, makes allowance for 7 15-minute stops enroute instead of 11 5-minute and 5 10-minute stops as specified by existing sortie schedules.

(4) Stops will be at points of geological interest, such as in Dark Plain material, crater wall-floor contact areas, red-blue contact lines, Fra Mauro formations, or fumaroles. The 2-km distance between stops used in this timeline is intended only as an average distance.

(5) PLSS exchange will occur when about 45 minutes of life-support expendables are left in the PLSS in use. This can happen anywhere from 2 to 4 hours into the sortie.

(6) Driving times are based on an average speed of 6 kmh, with 1 minute to mount, buckle in and start.

SORTIE SUMMARY

Range 16 km
Radius 4 km
Time 5.46
Buffer 0.40
Total time 6.28
Stops: Five at 15 min each
Two at 25 min each

MEASUREMENTS TAKEN

Continuously

(1) Magnetism
(2) Sample collection

At Each Stop

(1) Gravity gradient
(2) Nuclear measurements
(3) Range and bearing to ELS and geological formations
(4) Photography and radiometry
(5) Height or depth of local surface irregularities
(6) Plot significant features on map
(7) Sample photographs and collection

At Two of the Stops

(1) Gas analysis (mass spectrometry)
(2) In situ measurements (see chart for description)

ROUTE

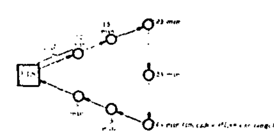

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TABLE 2-15

THREE-MAN TIMELINES FOR FOURTH LSSM SORTIE (APPLIES TO ALL MISSIONS)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	10	Checkout, load LSSM	Spare PLSS, deep seismic equipment package	20 80	Carried to LSSM Carried to back of LSSM	VL VL	Shared activity with Astronaut II
2	LSSM	21	Drive 2 km	Control stick	--	By hand	S	Drive 2 km on course away from shelter
3	Surface	15	Implant charge Some sample collection	Charge detonator wire Sample bags Scoops	0.25 0.25 0.45 0.45	Gets charge and detonator from equipment pkg. Pokes holes in ground, places detonator in charge, secures wire to ground	L	Nuclear measurements and gravimetry omitted. Sample collection as time permits.
4	LSSM	11	Drive 1 km	Control stick	--	---	S	On same heading
5	LSSM	1	Monitor II	---	--	From seat	S	
6	LSSM	10	Drive 1 km	Control stick	--	By hand	S	On same heading
7	Surface	15	Same as 3	---	--	---	L	
8	LSSM	11	Drive 1 km	Control stick	--	---	S	On same heading
9	LSSM	1	Monitor II				S	
10	LSSM	10	Drive 1 km				S	On same heading
11	Surface	15	Same as 3				L	
12	LSSM	11	Drive 1 km	Control stick	--	---	S	Same heading
13	LSSM	1	Monitor II				S	
14	LSSM	10	Drive 1 km				S	Same heading
15	Surface	15	Same as 3				L	
16	LSSM	11	Drive 1 km	Control stick			S	Head back to shelter
17	Surface	15	Same as 3				L	
18	Surface	30	PLSS exchange	Spare PLSS	20	Put on from rack	VL	Also aid Astronaut II don PLSS
19	LSSM	11	Drive 1 km	Control stick			S	Same heading
20	LSSM	1	Monitor II				S	
21	LSSM	10	Drive 1 km				S	Same heading
22	Surface	15	Same as 3				L	Same heading
23	LSSM	22	Drive 2 km	Includes stop to set off charge			S	Same heading
24	Surface	15	Same as 3				L	
25	LSSM	22	Drive 2 km	Control stick			S	Same heading
26	Surface	15	Same as 3				L	
27	LSSM	11	Drive to ELS	Control stick			S	Same heading
28	Outside shelter	15	Unload LSSM	Used PLSS-geo. samples	24 4.5		S VL	Same heading
Buffer 60 minutes								

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	10	Load LSSM	Spare PLSS, deep seismic equipment package	20 80	Carry to back of LSSM	VL VL	Shared activity with Astronaut I; package is 3' x 3' x 4'.
2	LSSM	21	Continuous sample collection, magnetometer activation	---	--	Seated on LSSM	S	
3	Surface	15	Plot location Photography and radiometry Modify map	Laser rangefinder and theodolite Camera package Map table	13 20 --	From seat. Take bearing on last site and relay to ELS	ML	Must also monitor Astronaut I during emplacement of charge
4	LSSM	11	Lay out wire	Wire reel	8.9	From seat	S	Wire is automatically unwound from reel. Astronaut II must monitor operation to prevent snags.
5	LSSM	1	Set off charge	Terminal posts	---	From seat	S	Connect wires, monitor explosion
6	LSSM	10	Sample collection while moving		--	From seat	S	
7	Surface	15	Same as 3				ML	
8	LSSM	11	Lay out wire				S	
9	LSSM	1	Set off charge				S	
10	LSSM	10	Sample collection				S	
11	Surface	15	Same as 3				ML	
12	LSSM	11	Lay out wire				S	
13	LSSM	1	Set off charge				S	
14	LSSM	10	Sample collection				S	
15	Surface	15	Same as 3				ML	
16	LSSM	11	Lay out wire				S	
17	Surface	15	Same as 3, but set off charge first				ML	
18	Surface	30	PLSS exchange	Spare PLSS	20	Put on from rack	VL	
19	LSSM	11	Layout wire				S	
20	LSSM	1	Set off charge				S	
21	LSSM	10	Sample collection				S	
22	Surface	15	Same as 3				ML	
23	LSSM	22	Same as 4, 5, 6 - includes stop to set off charge				S	
24	Surface	15	Same as 3				ML	
25	LSSM	22	Same as 23				S	
26	Surface	15	Same as 3				ML	
27	LSSM	11	Lay out wire				S	
28	Outside Shelter	15	Unload LSSM	Used PLSS Seismic pkg.	24 80		S VL	Set off final charge from inside shelter

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Shelter	10	Monitor egress Read LSSM checklist	Radio	--	Seated	S	
2	Shelter	10	Turn on geophone recording apparatus, check each phone (at LSSM position)	Recorders, phone Map	Not lifted	Must stand up to activate geophones	S ML	
3	Shelter	37	Report, log keeping, earth data transmittal	Radio, logs, tape decks	Not lifted	Seated	ML S	With laser theodolite
4	Shelter	5	Final check on geophone set			Seated	S	
5	Shelter	11	Monitor shot results			Standing	S	Communicate results to crew for modification of charge placement
6	Shelter	8 20	Plot LSSM Location Set up geological analysis equipment			Seated	S	
9		11	Monitor shot results			Standing	S	
10		8 20 11	Same as 7 Conduct cursory examination of samples returned so far Monitor shot results				S	
14	Shelter	8 30 56	Same as 7 Further analysis of interesting samples. Monitor shot results, then data transmittal. Complete geological examination			Seated	S	
18	Shelter	11	Monitor shot results			Seated	S	
21		20 11	Plot LSSM location Stow geological equipment Monitor shot results			Seated	S	
24		20 11	Checklist LSSM location - Plot location check geophone set Monitor shot				S	
28	Shelter	41	Monitor return to ELS				S	

NOTES ON THIS SORTIE

(1) Main purpose of this sortie is to emplace seismic charges at 1-km intervals from shelter and detonate them. Readings from the previously emplaced geophone set (Local ESA 5) are taken by the third astronaut, in the shelter.

(2) Since much of Astronaut III's time is taken up with recording the seismic shots, there is only 1 hour, 47 minutes available for other scientific tasks during the mission.

(3) Gravimetry and nuclear measurements are deleted from the mission since Astronaut I's time is used to emplace the explosive charges at each stop. Some sample collection could still be done.

(4) PLSS exchange occurs when about 45 minutes of life support expendables remain in the PLSS being worn. This will probably occur sooner for Astronaut I since his level of activity is higher. The 30 minutes allowed can be used in two 15-minute segments.

(5) This sortie was planned using the NASA guideline range of 8 km. If a 8 km sortie limit is acceptable or if LSSM speed can be raised to 12 km/h, then it would not be necessary to follow the same course out and back, and more samples could be collected. Using the *present speeds, desired range, ad PLSS duration times, a retracing of the outbound route* is necessary.

(6) A safety hazard exists during this mission if material from each seismic charge is thrown by the explosion. In the light lunar gravity, rocks could travel the 1 km to the LSSM, causing damage when they land. No analysis of this hazard has been performed. The 1 km range for setting off each charge has been arbitrarily chosen. Longer ranges impose wire weight penalties.

SORTIE SUMMARY

Range	14 km
Radius	8 km
Time	5:50
+	
Buffer	:60
Total	6:30
Stops	8, 15 min each 7, 1 min each to detonate explosives

MEASUREMENTS TAKEN

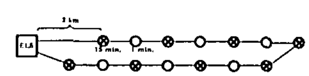
Continuous

(1) Magnetometer readings
(2) Sample collection

At Each Stop

(1) Multiband photography and radiometry
(2) Range and bearing to ELS and geological formations
(3) Plot significant features on map
(4) Sample collection
(5) Some nuclear measurements by Astronaut II
(6) Deep seismic reflection readings at shelter

ROUTE



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involving an LSSM. In some cases, such as ESS emplacement, further sorties of the same type can be easily generated simply by increasing the travel times. (See notes for sortie 2.) Others, such as the basic measurements sortie, have the same timeline but different directions on different days. Routes will vary from the simple triangular tracks shown, depending on the kind of material which is being traversed. Representative sortie routes based on lunar contour maps are published in the basic Bendix study (Reference 1). The MG column in the timelines is included as a rough measure of workload. It indicates the approximate levels of effort involved in each task as a function of the muscle group involved. These measures were used to ensure that the workload of each man did not get so high that he would use the capacity of two PLSS's before the end of the 6-1/2-hr sorties.

Table 2-16 is a condensed summary of the 11 local ESA's which were considered for this report. The sortie mission, crew required, and time required were drawn from Bendix and NASA data. Effort estimates were made in the same way as in the LSSM timelines, again to ensure that one PLSS would be enough for each sortie. Two of the sorties, 5 and 8, use the LSSM to transport one man about 2 km out and back. These were classified as local ESA's instead of LSSM sorties because only one crewman is used and because of their short duration. Some of the sortie times have been shortened because the workload rate was too high to allow one PLSS to supply 3 hr of surface time. Most ESA's are performed in pairs under concept B, the one chosen for the 24-hr timelines. This would entail two men on the surface at the same time, working on different projects but in the same vicinity.

Contribution of a Third Crew Member to Crew Safety and Mission Success

Crew safety and mission success are significantly enhanced by the addition of a third crew member. The contributions to crew safety are particularly evident in the following areas:

Emergency rescue of a disabled crew member.

Reduction of task work loads by time-sharing activities.

Increasing the range of visual contact on the lunar surface. This has the secondary implication that a communication failure between one crew member performing an ESA and the shelter need not terminate activity providing communication and visual contact between at least two of the crew members exists.

An emergency rescue of a disabled astronaut by one crew member is generally not feasible unless some form of power assistance is provided (Reference 7). Two crew members may be able to effectively retrieve a disabled crew member by manual means. Emergency rescue simulations using 3-man crews are recommended for further study.

TABLE 2-16

SUMMARY OF LOCAL SURFACE SORTIES (LOCAL ESA's)

No.	Description	Number of Crew	Total Time (hrs:min)	Muscle Group Involved	Range (km)	Missions Used on
1	Unload and set up LSSM; check external gear; lay out erosion samples	2	2:00	VL (0:20) L (1:00) S (0:40)	0.5	All
2	Begin 30-m hole drilling	1	2:00	VL (0:40) L (1:00) S (0:20)	0.0	Alphonsus, Hyginus Rille
3	Complete 30-m hole	1	2:00	VL (0:10) L (1:00) S (0:50)	0.0	Alphonsus, Hyginus Rille
4	ESS activation	1	3:00	VL (0:00) L (1:00 S (2:00	2.5	All but LSSM/LFV mission
5	Lay out geophone net; set off one charge	1	3:00	VL (0:00) L (1:00) S (2:00)	4.0	All
6	Nuclear and electrical logging of 30-m hole	1	2:00	VL (0:00) L (1:30) S (0:30)	0.0	Alphonsus, Hyginus Rille
7	Sonic velocity measurements on 30-m hole	1	2:00	VL (0:10) L (1:20) S (0:30)	0.0	Alphonsus, Hyginus Rille
8	Seismic charge emplace and ESS checkout	1	2:00	VL (0:10) L (0:40) S (1:10)	4.0	All
9	Phase I astronomy experiments setup	1	2:30	VL (0:30) L (0:30) S (1:30)	1.0	All
10	Optical and x-ray astronomy experiments and observations	2	3:00	VL (0:00) L (0:30) S (2:30)	1.0	All
11	Radio astronomy observations	2	3:00	VL (0:00) L (0:30) S (2:30)	1.0	All

For safety reasons, 2-man LSSM sorties are considerably more reliable than 1-man sorties. If a surface operator is disabled during an LSSM sortie, a second crew member is immediately available to provide assistance. If the LSSM is also disabled, the additional crew member could radio the base shelter for an LFV rescue. (The present LFV concept, however, allows room for only two crew members. The remaining astronaut would have to either await the return of the LFV or walk back to the base shelter.)

The safety of the 1-man LSSM sortie with two men remaining in the shelter is not as greatly improved by the addition of a third crew member since time-critical assistance to the extravehicular crew member is no better than that provided by a 2-man crew. If a single crew member on an LSSM sortie is disabled, one of the two mem in the shelter will perform the LFV rescue while the other will operate any automated rescue equipment in the vicinity of the shelter upon the return of the LFV and assist the disabled crew member inside the shelter.

As in the LSSM sorties, the prime advantage of the third crew member during emergency conditions occurring during close ESA's is that one of the two crew members is immediately available to assist the other crew member should he become disabled on the lunar surface. For a 1-man close ESA, the third crew member's activities are limited to monitoring the rescue operation, operating any automated rescue equipment associated with the shelter, and assisting the disabled crew member inside the shelter.

From the standpoint of mission success, 3-man crews have definite advantages over 2-man crews, in that:

Eating times would not be increased since, for major meals involving rehydration of food, food preparation time would be the same and eating would remain a time-shared activity. Preliminary studies which we have made (unpublished) indicate little difference in the time required for one man versus that required for two men to prepare and eat a 700-cal meal.

More man-hours could be spent on the lunar surface by having crew members work in pairs during local ESA's. This is a difference of 5 hours in the 3-man missions, and a difference of 56 hours over the 2-man missions we have considered. This is an increase of 61 percent over the 2-man missions.

The time required for three crew members to don and doff their pressure suits should be about the same as that required for 2-man crews if their tasks are time-shared.

More uninterrupted time would be available for a single crew member to perform scientific tasks inside the shelter during paired crewmember ESA's. This assumes that the monitoring time and stress level of the crew member remaining in the shelter is reduced by the presence of a second man on ESA. Also, during nearby single-member ESA's, one crew member is completely free to perform inside scientific tasks while the other man monitors the condition of the surface crew member. This method of ESA performance yields some extra scientific time but was rejected because of the lowered safety factor in case the outside man was disabled. (See Table 2-6.)

It was pointed out earlier in this report that during the Lunex II simulation the 2-man crew felt that geological analysis inside the shelter was too time-consuming and should not be considered for lunar missions. Since a prime goal of such missions is to return samples to the earth and since the weight of samples is limited, some analysis must take place on the moon. The presence of a third man increases the inside scientific time available by 31 hr or 60 percent. This should provide enough time to complete geological tasks.

With a 2-man LSSM crew, the workload of a single man could be alleviated by alternating the high-workload tasks. Gravity measurements and other automated measuring devices could be read by the crew member remaining on the LSSM during stops. The man who leaves the LSSM would then be concerned with sample collection, marker development, and local terrain surveying. In either case, with one <u>or</u> two men, meaningful measurements probably cannot be made during 5-min stops. Such stops could be made with two men and some data gathered. The value of samples collected during short periods may depend on chance rather than careful selection. Six-hour sorties are further complicated by the time and effort required to exchange PLSS's, a situation which is alleviated in the 2-man sortie.

Experimental data are needed concerning the interaction of crew members with the LSSM before any firm answers can be given to the sortie length and workload problems. In particular, the time it takes to disembark, remount, and exchange PLSS's for 1- or 2-man crews should be known, and the degree of automated data collection, transmittal, and recording which will be available during these sorties should be specified.

Lunar Night Effects on Missions

During the middle of the lunar night, when the earth is full, the level of illumination is estimated to be about 10 times that of a full-moon night on earth.

Present lunar missions are programmed only for the first five days of the 2-wk night period, and the evening and morning of the lunar night are the darkest times. Just after local sunset near the center of the near-side the earth is seen only as a thin crescent, and its light does not become appreciable until about two days after sunset.

The effect of these conditions on shelter operations would be negligible, and it would be profitable to schedule as many inside tasks as possible for the last five days of the mission. During the last two of these days, earth-light would be quite bright, and ESA's without extensive artificial illumination would again be practical. Several safety factors are apparent during the first period of darkness. First is that any LSSM sorties would have to be provided with bright headlights to avoid hazardous obstructions. It is not likely that driving speed would have to be reduced over the 6 km/hr now planned for daylight sorties. Beacons would be necessary on the shelter, the LSSM, and the individual surface suits to prevent outside operators becoming lost. Results of the current Gemini flights indicate that point sources of light such as are used as beacons on earth may not be easily visible in a vacuum, since there is no scattering of the light. This is a problem which will have to be settled by experimentation. Bright illumination should also be provided in the vicinity of the shelter, and this may have to be used during the daylight hours as well, if scattering from nearby material is not enough to illuminate the shadow cast by the shelter. At no time should one man be allowed on the surface alone when it is very dark, since the probability of a fall which would damage the suit or the man is much higher in the dark. Flares should be carried to aid in emergency location if visual contact is lost.

ALTERNATE SCIENTIFIC MISSION DEFINITION

General

A lunar shelter program should be capable of revision to meet changing scientific needs between the time of initial planning and the actual delivery to the moon. A search of current lunar scientific missions literature was conducted to reveal the kinds of alternate missions which might become important during this period. The selection of these was based on the possibility of extra time and equipment becoming available, the likelihood of basic scientific tasks being completed on earlier missions requiring expansion of the goals of the ELS program, and improved technology making possible more sophisticated missions.

About 500 documents related to lunar activities were examined during the first phase of the literature search; 50 of these had some bearing on scientific missions. The most important and comprehensive of these are cited in the list of references at the end of this report. The final step in the literature search was to define about 20 promising missions which would be compatible with ELS weight and time allotments. This was done by compiling data from all the references listed. The names and descriptions of the 18 missions finally compiled are listed in the subsection below. They were originally listed under three general science headings but have been regrouped in this report by relevance, importance, and completeness of data available.

The first three missions were expanded, and timelines were prepared for them. This information is presented in a subsequent portion of this subsection. Each of these three missions is described, additional requirements in equipment and astronaut time are listed, and general changes from basic mission timelines given. Representative timelines for each mission are also included. For the first two alternate missions, Resources Investigations and Near-Side Radio Astronomy, 3-man operation is proposed, and the timelines are for three men.

The third alternate mission, General Observations with the 40-in. telescope, is now planned as a 2-man mission. The reasons for this are detailed in the requirements section of that mission description.

Alternate Scientific Missions List

This subsection describes the 18 scientific missions originally specified by Honeywell. They have been ranked for relevance to general lunar missions goals, scientific importance, and most importantly, availability of timelines and equipment specifications. The first three missions are listed as candidates for alternate mission definitions.

1. Mission 1

This mission involves resources investigations, using basic geological experiments to gain information on water sources, subsurface cavities for storage and shelter, suitable shielding materials, geothermal energy available, gases and liquids present in rocks, solar energy utilization, and mineral deposits. These studies require addition to the timelines on analysis of geological experiments and some extra time during experiments themselves. The exact amount of additional time required is not known, but approximate data are available.

Resources investigations can be integrated with current geological and geophysical timelines. These tasks involve additional measurements and sample collection of LSSM traverses and longer missions close to the ELS. Little extra equipment is required. It is felt that resources specifications will be necessary for further mission planning and that this task has high priority for early missions.

2. Mission 2

This mission involves radio astronomy from the nearside. Three programs have been defined for small-antenna equipment: nondirectional radio observations, directional observations on the 20 major discrete sources of extrasolar system radio noise, and submillimeter radio observations. Very complete timelines and equipment guides are available in this mission.

The radio astronomy experiments recommended in this task are not included in Phase I, II, or III astronomy studies now being considered. Data gained from this task will be of substantial importance in outlining future near- and far-side radio missions. Equipment can be included in any of the current astronomy missions.

3. Mission 3

This mission involves the use of a 40-in. telescope for general observation programs in astronomy. Seven observation programs have been defined for near-side missions applications. They are: 1 through 3 from Mission 12, three additional spectrography programs, and a laser, range-finder-augmented, sea-surface, height measurement study using a laser that is not yet a state-of-the-art instrument. The 40-in. telescope is a later lunar mission instrument with only 2-man operation now planned. Major modifications to a shelter are necessary with this instrument unless it is mounted on a separate LEM descent stage.

The next 15 missions have also been ranked. They are candidates for alternate missions, but is was felt that less data existed on these, and that the first three missions, listed above, were more critical for early lunar missions.

4. Mission 4

This is a series of nine experiments to determine the effects of lunar environment on human performance and capabilities. These include the effects of breathing various gas mixtures under reduced gravity conditions, bone demineralization studies, cardiovascular performance, psychological studies, vision studies, work capability determination, metabolic costs in reduced gravity, clinical monitoring, and bioassays of body fluids. Hourly timelines are available, and the equipment required is state-of-the-art except for some biotelemetry systems.

5. Mission 5

This mission consists of alternate particle and field experiments to supplement those specified in the NASA guidelines. Included in this series of experiments are three studies dealing with solar wind interaction with geo-magnetosphere and solar particle scattering and reactions. Detailed equipment lists and timelines to 10-min levels are available.

6. Mission 6

This mission includes a series of experiments to extend the basic geo-chemistry investigations using neutron activation methods to determine the composition of the lunar surface material. Some timeline information and initial equipment requirements are known.

7. Mission 7

This mission consists of additional geophysical experiments not considered in the NASA guidelines. Four experiments are defined on surface magnetic susceptibility, subsurface electrical sensitivity, surface electrical survey, and vertical temperature change lagging. Equipment and timeline guides are available. All equipment is state-of-the-art.

8. Mission 8

This mission includes additional geology experiments to determine the extent of differentiation and segregation of lunar materials. The four experiments proposed are chemical analysis of materials using X-ray fluorescence, density measurements by flotation, chemical analysis of solids by mass spectrometer, and *in situ* infrared reflectance and emissivity measurements to correlate with orbital measurements. Basic equipment specifications and general or hourly timelines are available.

9. Mission 9

This mission consists of a series of geomorphology experiments to determine the relative importance of internal and external forces in shaping lunar topography. These studies involve the use of a quadruple mass spectrometer to analyze lunar gases, both general and near sources of emission. Hourly level timelines are available for early experiments.

10. Mission 10

This mission is designed to determine the biological effects of the lunar environment and includes six experiments dealing with somatic, genetic, and sterilizing effects of low-g, 2-week daylight periods, radiation, and temperature found on lunar surface. Information is available for hourly 2- or 3-man timelines, as are approximate equipment weights and volumes.

11. Mission 11

This mission involves radioactive safety and levels measurement, involves experiments in shielding for time and thickness variables, biological samples exposure during EVA, comparison of surface dust removal techniques for suits and equipment, and radiological monitoring. Ten-minute timelines are available.

12. Mission 12

This mission includes representative observation programs using a 12-in. optical telescope. Six programs are as follows: (1) trial observations to test suitability of lunar surface location for an optical observatory; (2) general astronomical high-resolution photographs of solar system and stellar objects in the 1000-A to 3000-A range; (3) photoelectric observation of peculiar stellar objects on wavelengths not received on earth; (4) low-dispersion spectroscopy of stars; (5) wide field (using different optical system) photographic survey of visible sky; and (6) wide-photometric survey of light or intensity distribution of sources. Because of uncertainty of observation times, only hourly timelines are available for some of these programs.

13. Mission 13

This mission consists of planned observations of Earth from the lunar landing site using a 6-in. cassegrainian telescope. The planned observations include atmosphere heat balance, reflectivity and albedo, auroral and airglow emission, ultraviolet scattering by atmosphere, atmosphere sounding by infrared scanning, ocean heat balance (two experiments), and multiband ocean photography.

14. Mission 14

This mission calls for the determination of engineering properties of the lunar surface and environment in regard to lunar surface construction capabilities. The experiments proposed are: corrosive action of surface material; rate of dust collection on equipment; effects of leakages from vehicles, shelter, and suits; gas requirements for lunar case drilling; explosive energy coupling in lunar materials; elastomer and polymer degradation; and metal joining techniques comparisons. Since there is uncertainty on equipment required, timelines are not available.

15. Mission 15

This mission entails a study of local lunar magnetoionic medium and surface electromagnetic properties. Six different types of observations have been planned: lunar plasma properties near surface, lunar wave propagation at 10-km ranges on the surface, ambient vector magnetic filed measurements, charged dust spectral analysis, and solar plasma detection.

16. Mission 16

This mission involves research on special astronomical and astrophysical problems. About 15 special research projects have been proposed, but the four highest ranking on the NAA study (Reference 8) to MSFC are Einstein-effect eclipse photography, X-ray observation of interstellar medium distribution, detection of high-energy gamma rays, and high- and low-resolution studies of X-ray sources. Timelines exist for most of these problems only at approximate levels.

17. Mission 17

This mission consists of 40-in. telescope applications in geophysics and meteorology. Five observational programs are now proposed: earth atmosphere circulation measurement in conjunction with other meteorological experiments; earth atmosphere density above 30 km measured by stellar refraction; earth atmosphere study during eclipse of sun; non-terrestrial planetary atmosphere circulations; and determination of planetary albedoes and spectral reflectances.

18. Mission 18

This mission involves 40-in. telescope applications in the particles and fields area. Six observational programs are now defined on sunspot formation and development, prominence of fine structure vs wavelength, flare ejection of material, moderate dispersion scan in ultraviolet region, high scan in the same region, and ultraviolet flare spectra.

Alternate Missions Definitions

1. Resources Investigations

a. Description of the Mission--Successful manned occupation of the moon is directly related to the degree man develops lunar resources to serve his needs. While orbiters and probes will provide fundamental information on these resources, the astronauts in an ELS program can utilize the array of equipment provided for basic geological missions to get specific information on the availability of resources. The main interests in this mission are:

Sources of water

Subsurface voids for shelter

Suitability of available materials for shielding against

- Thermal exposure
- Radiation
- Meteorite impact

Geothermal energy available

Mineral deposits

Methods of mining and processing, mode of utilizing resources

Opportunities peculiar to lunar conditions

- Low vacuum
- Slowly shifting temperature and light extremes
- Reduced gravity

Gases and/or liquids in rock pores

Solar energy available

The investigation of these areas will be concurrent with many other activities in the ESA sorties, particularly geological mapping and sample collection of LSSM traverses. Equipment required will be provided by geochemical, geodesic, geophysical missions, and analytic equipment in the vehicle and on earth bases.

b. Additional Requirements of the Mission--Since sorties already planned call for extra activity, the sorties must be either longer or more numerous to accommodate the desired activity. This means that three men would be required. Two men could perform this mission but with marginal chances of successful sampling and analysis and with activity in other missions curtailed. There is no extra equipment to emplace or a specific series of extra measurements to make on this mission. Extra astronaut time requirements would be continuous over the 14-day staytime on LSSM sorties, local ESA and in-shelter analysis of samples. Extra laboratory equipment in the shelter is required for more complete petrographic analysis and for trace-mineral identification. Training of at least one of the astronauts must include a thorough grounding in the kinds of minerals and liquids which may occur, interpretation of magnetometer, gravimeter and seismic recording traces for detection of low-subsurface caves, and a general resources-oriented prime mission responsibility.

c. Timelines

General changes from basic mission timelines

Additional time required at 1-km intervals on each LSSM sortie for additional sample collection and further on-foot reconnoitering of the stop: 5 to 10 min extra per stop.

Extra tasks for local ESA consist of radiation and thermal sensors emplaced under soil at varying depths, workload determination for moving rocks and soil, and solar panel emplacement and monitoring: One hour extra local ESA per day.

Extra time inside the shelter: Two hours extra sample analysis and classification per day required.

Specific timeline - (see Table 2-17)

2. Radioastronomy on the Near-Side

a. Description of the Mission--Radioastronomy observations will be most suitable for far-side missions where the moon acts as a shield for radio noise from the earth. This experiment consists of two series of observations which are appropriate for near-side missions and which provide data that cannot be obtained from the earth. The first of these is a nondirectional study of solar system noise sources, mainly in the decameter wavelengths blocked by earth's atmosphere. This uses small, simple antennas and radiometers for continuous scanning from 300 kHz to 20 MHz. The second experiment uses two large, in-place antennas to do directional studies on the 20 major sources of noise on the 1-MHz band. The two series of observations are described below.

Nondirectional Radiometery. Monitoring the intensity and changes over time of solar meter-length radiation and Jupiter decameter bursts which cannot be observed from the earth's surface are the prime goals of this experiment. Searches will also be made for sources of low-frequency emission from other solar-system objects,

TABLE 2-17

TWENTY-FOUR-HOUR TIMELINES FOR RESOURCES INVESTIGATION MISSION

TIME (hrs)	ASTRONAUT I Activity	ASTRONAUT II Activity	ASTRONAUT III Activity	TIME (hrs)	REMARKS
	Eat and Hygiene	Eat and Hygiene	Eat and Hygiene		15 man hours for outside tasks 16 hours for inside scientific tasks 3 airlock cycles Sorties: Two different sorties, each on alternate days. Even days have longer stops (15 min instead of 5 min.) and half the range of baseline missions. Odd days are sorties with one long (1 hr) stop at a selected point of resources interest, with 10-ft. drill hole and extensive sample collection and processing
-1-	Don suit Egress	Don suit Egress	Don suit	-1-	
-2-	Sortie	Sortie	Monitor Report	-2-	
-3-	Basic Traverse Mission on	Basic Resources investigation		-3-	
-4-	LSSM	Mission with I on LSSM	Lab experiment	-4-	
-5-			Petrographic Analysis and	-5-	
-6-			Mass Spectrometry	-6-	
-7-				-7-	
-8-	Ingress PLSS Recharge	Ingress Doff suit		-8-	
-9-	Eat and Hygiene	Eat and Hygiene PLSS Recharge	Eat and Hygiene Egress	-9-	
-10-	Monitor Lab experiment	Lab experiment Sample checking	Local ESA Samp. collection	-10-	
-11-	Charting and plotting site	Chromatic Gas Analysis	Drill Compaction	-11-	
-12-	locations. Report	and Spectrographic	Study	-12-	
-13-		Analysis	Ingress Doff suit	-13-	
-14-	Doff suit Eat and Hygiene	Eat and Hygiene	PLSS Recharge Eat and Hygiene	-14-	
-15-				-15-	
-16-				-16-	
-17-	Rest	Rest	Rest	-17-	
-18-				-18-	
-19-				-19-	
-20-				-20-	
-21-				-21-	
-22-				-22-	
-23-				-23-	

especially the terrestrial planets. This is a 2-week experiment, concentrating on the sun during the lunar day and on the planets after sunset, about day 9.

Directional Radioastronomy and Radiometry. This experiment uses an interferometer, erected on the moon's surface early in the mission, at a specific wavelength of 300 m. Source flux density is measured continuously. This record reveals the spatial distribution in right ascension and intensity of the 20 sources to be studied. Data transmission and recording to the shelter is automated. This experiment also takes the full two weeks of mission time, with the major astronaut effort during the first three days.

b. Additional Requirements of the Mission--Instrumentation needed for the nondirectional radiometry experiment includes:

(1) Antennas. Two loop antennas and one whip antenna mounted on the shelter. These are deployed by an astronaut on the second day.

(2) Multichannel Stop-frequency Ryle-Vomberg Radiometer. This instrument is used for noise measurements over the frequency range 300 kHz to 20 MHz. It is a conventional Dicke-type receiver with an all-solid-state noise source. The frequency range is covered in 10 to 20 steps with a 20-kHz bandwidth. The receiver noise figure is less than 8 db, dynamic range greater than 70 db, and a relative measurement accuracy of plus or minus 0.5 db is maintained. Items (2), (3), and (4) are mounted in the shelter.

(3) Rapid-burst Radiometer. The fast-burst radiometer used in conjunction with one of the loop antennas is designed to measure the characteristics of impulsive noise bursts such as solar type III bursts. It will consist of four fixed-frequency receivers, all of which will be open to reception at the same time until a burst is detected. The presence of a burst will be established by the detection of a signal above some preset threshold, in which case the receiver will store the detected signal and shut itself off. The telemetry system will sample the receivers serially, and each receiver will be reactivated upon reading out its measured data. Upon reactivation, the cycle will repeat. The time between readings on any one channel will be about 150 ms and will require about 20 ms to perform a reading. By locking a channel after a signal is detected and measuring its time of occurrence and amplitude, it is possible to measure the intensity, duration, and frequency drift of a burst.

(4) Phase Detector. This instrument provides a relative comparison of the phase of the signal incident on the loop antenna with respect to that received by the whip. Two phase detectors are required, one for each loop antenna. The output from each is sampled in synchronism with the step-frequency control provided in the Ryle-Vomberg radiometer.

Total equipment weight is 20 lb, volume 0.5 cu ft; total energy required is 140 kwh.

Instrumentation required for the directional radioastronomy and radiometry experiment is:

(1) Remote Dipole Array Antenna. Twelve half-wave and one MHz dipoles and associated reflectors arranged in an east-west line to form one 1800-m-long element of an interferometer. The effective area of the element at 1 MHz is 250,000 square meters. The element is located 5 km from the main base.

(2) Central Diople Array Antenna. This element is located at the main base and is the same type as the remote antenna.

(3) Radiometer. This instrument is a Ryle-Vomberg radiometer capable of operating at five frequencies logarithmically spaced over the range 100 kHz to 1 MHz. The output is proportional to the signal strength incident on the antenna. This is included in the first study.

(4) PF Transmitter. This instrument is a small microwave transmitter. The 0.5-w power output is sufficient for the purpose for which it is employed, namely to link the remotely deployed interferometer element with the element located at the main base.

(5) RF Receiver. This instrument is a microwave receiver located at the main base. Receiving signals from the nicrowave transmitter located at the remote site, it completes the necessary link tying the remote antenna element with the element located at the main base to form an interferometer.

Total equipment weight is 1000 lb for the antenna array and 5 lb for instrumentation. Total volume is 50 cu ft; total power required is 150 kwh.

c. Timelines--General changes from basic mission times are discussed below. For the first experiment, additional crew time on ESA will be required to erect and position the three antennas on day 2. Thereafter, extra internal scientific time by one man will be needed to monitor the equipment (1 hr/day in 10-min intervals) and to reduce and interpret the data gathered (2 hr/day in 30-min intervals). Total man hours, ESA and inside activity, is 38 hr. The second study involves emplacing 3600 m of dipoles in two linear arrays 5 km apart. The first element is near the shelter and is emplaced on day 3 by the third astronaut. The remote antenna, 5 km distant on a maria or other flat plain, is emplaced on one 6-hr sortie on day 4. Because of the extra time involved in these two studies, three men are necessary if other scientific tasks are to be carried out. There is no requirement for more than one man on ESA at a time, however. After day 4, monitoring of the remote antenna receiver and the radiometer takes 1 hr/day in 10-min intervals. Reduction and analysis takes 2 hr/day in 30-min intervals. Total time required is 45 hr. Final analysis of data from both experiments takes place on day 13. This will take two men working together for 4 hours or 8 man hours. The total time required to set up antennas, monitor equipment, reduce data, and conduct the final analysis is 91 hours. Only one man at a time is required until day 13, when two are necessary, both working inside the shelter.

For data on the specific timeline, see Table 2-18.

3. Forty-Inch Telescope - Basic Astronomical Observations Mission

a. Description of the Mission--The use of a 40-in. telescope in an early lunar shelter program supposes a heavy commitment to astronomy for the whole mission. An instrument of this size on the lunar surface has a greater resolving power than the 200-in. telescope at Mt. Palomar and can receive wavelengths in the ultraviolet which are absorbed by earth atmosphere

It would be able to make observations impossible with the smaller instruments of the Phase I, II, and III Optical Astronomy Programs in the basic ELS mission plans. The use of a telescope this large would result in significant advances in almost every phase of optical astronomy, as well as providing data for the design of a permanent lunar observatory with 100 to 200-in. telescopes. Because of the extra weight and additional man hour requirements of the 40-in. mission, it is not recommended as a replacement for Phase I, II, and III astronomy programs. It would be a logical choice for the second or third ELS missions, when the early astronomy programs have been completed.

The 40-in. telescope is mounted on top of the shelter. It is operated from inside, and all observations and sensor changes are made from inside. Observations would be made on a continuous basis from the time the telescope is erected until the end of the mission. Provision has been made in the design of the telescope for automatic operation, after the mission is over, for a period of up to one year.

Three basic observation programs make up the manned part of the mission:

Investigation of distribution patterns and densities of interstellar gas through emission line spectrometry and investigation of rotational periods of nearby stars.

Survey, by photoelectric methods, selected stars in sky fields to test the brightness-size-distance relationship leading to a further classification of selected stars. In addition, within the capabilities of the aperture, a certain amount of surface mapping and astrometry of astronomical bodies will be commenced; in particular, investigation of high-resolution characteristics of very faint stars and galaxies, up to the limit of the tracking and recording capability of the sensors. This will be mostly in the UV portion of the spectrum, but will also include the visual and near infrared.

Mapping the areas of galactic visual noise sources can be done, guided by radio astronomy results from on earth, in orbit and eventually on the far side of the moon.

TABLE 2-18

TWENTY-FOUR-HOUR TIMELINES FOR RADIOASTRONOMY ALTERNATE MISSION

TIME (hrs)	ASTRONAUT I Activity	ASTRONAUT II Activity	ASTRONAUT III Activity	TIME (hrs)	REMARKS
	Eat and Hygiene	Eat and Hygiene	Eat and Hygiene		9 hours ESA available
-1-	Don suit Egress	Don suit		-1-	15 hours for inside scientific tasks on time shared basis
-2-	Sortie Basic Traverse Mission on LSSM	Monitor Report		-2-	9 hours radio astronomy time available
-3-		Chk Radiometer Plot Results		-3-	Astronaut II is a professional astronomer
-4-		Monitor Report	Rest	-4-	Sorties and Local ESA are the same as for the baseline mission, except that Days 2, 3 and 4 are spent erecting antennas during ESA.
-5-				-5-	
-6-				-6-	
-7-		Chk Radiometer Plot Results		-7-	
-8-	Ingress PLSS Recharge	Doff suit		-8-	
-9-	Eat and Hygiene	Eat and Hygiene		-9-	
-10-	Monitor Report Lab Time		Eat and Hygiene Don suit	-10-	
-11-			Egress	-11-	
-12-	Chk Radiometer Plot Results	Rest	Local ESA	-12-	
-13-	Lab experiment			-13-	
-14-	Eat and Hygiene			-14-	
-15-			Ingress Doff suit	-15-	
-16-			Monitor Radiometer	-16-	
-17-			PLSS Recharge Lab experiment time	-17-	
-18-	Rest			-18-	
-19-		Eat and Hygiene	Eat and Hygiene	-19-	
-20-		Monitor Radiometer, Review radio experiment Progress, Plot results, Store Data	Lab experiment Time	-20-	
-21-				-21-	
-22-				-22-	
-23-				-23-	

Investigation of the high-resolution characteristics of the spectra of distant stars and galaxies to reveal the red shift of very faint objects and help to determine the reason for the shift; whether through absorption, photon half-life phenomena, or a Doppler shift due to increasing velocity with increasing distance from the observer.

Several series of observations at different wavelengths using direct photography, spectroscopy, photoelectric photometry, and spectral scans will be made in each observation program. Photographs, spectrograms, and numerical data will be transferred back to earth at the end of the mission.

The 40-in. telescope has a number of other proposed observation programs. These include meteorological studies of earth, Mars, and Venus, atmosphere observations for the terrestrial planets, Jupiter and Saturn, meteorite impact counts on other planets, ocean surface height measurements, and some high-resolution solar photography. A 2-week mission does not permit all these to be done, but the surface height measurement series has been included to give an example of nonastronomical use of the telescope.

The experiment profile below is from the Kollsman Instrument Feasibility Study for the 40-in. telescope, with additions from the North American Scientific Mission support study for LESA.

(1) Acquire in any order and track the following or similar stars: Capella, Gamma Velorum, Zet Puppis, Antares, Aldebaran, Beta Centauri, Spica, Achernar, Rigel, Sirius, Deneb, Canopus, Procyon, Arcturus. Perform the following experiments on each of the stars:

UV photon counting (fine, medium, and coarse modes)

UV spectral photography (fast and slow film)

Visual photon counting (fine, medium, and coarse modes)

Visual spectral photography (fast and slow film)

Image photography on starfield camera or electron camera.

Additional recording on the above stars:

Mount angles at periodic intervals

Tracking error (fine guidance) signals at periodic intervals

The data reduction requirements are:

From recorded photon count plot spectral characteristics of at least two of the above stars for correlation with data obtained on earth and OAO-GEP spectroscopic experiments.

From the true astrometric data on two of the above stars, determine accurate OAP coordinates and orientation.

From determined OAP coordinates and orientation, calibrate coordinate converter. Determine accuracy of programmed tracking by monitoring open loop fine guidance error signals on two of the above stars.

(2) Acquire in any order and using the program track mode, track the following or similar extended sources: nebulae in Orion, Spica, Eta Carinae, Magellanic cloud galaxy, Milky Way galaxy, and Milky Way dark clouds.

Perform the following experiments with the narrow (5 ft x 2 A) entrance slot:

UV photon counting (medium and selected fine modes)

UV spectral photography (fast film)

Visual photon counting (medium and selected fine modes)

Visual spectral photography (fast film)

(3) Acquire in any order and track at least three short-term bright spectroscopic variable stars (such as Alpha Pavonis and at least six bright radio astronomy sources (quasars).

Perform the following experiments on each of the stars in the existing OAP spectral configuration:

Photon counting (fine mode)

Spectral photography (fast film)

Repeat the above experiments for each variable star at specified time intervals for the duration of the manned experiment phase.

(4) Acquire in any order and using the program track mode, track stars in galactic clusters, such as Pleiades, 47 Tulanae, Omega Centauri, Perseus (2).

Perform the following experiments:

UV photon counting (coarse mode)

Visual photon counting (coarse mode)

Electron camera photography (six photographs)

UV photography of central core of these clusters

The data reduction requirements are:

From photon count and magnitude, plot and determine peak photon count versus magnitude. Extrapolate to system limit.

Correlated data with calibration stars for fine and medium photon count modes. Check correlation by obtaining photon count peak for two additional magnitudes.

(5) Acquire in any order and using the time program track mode (equatorial conversion to alt-azimuth) track the planets: Mars, Mercury, Venus, earth, Saturn and Jupiter and zodiacal light.

Perform the following experiments:

Wide band image photography using starfield camera.

Narrow band (100 A) image photography (4 filters) using starfield camera.

Polarimetry (4 narrow bands, voice recorded) percent and relative direction using relay optic.

Total field image magnitude using photometric adjunct to the starfield camera.

Additional recording:

Visual spectral photography.

(6) Manually scan and view through relay optics. Photograph with or without UV sensitive photocathode, on an electrostatic image intensifier, various portions of the Milky Way galaxy, Mayall's object and other objects of interest.

Photograph images of interest on starfield camera.

Record astronaut impression data on voice recorder for correlation with film data.

(7) From various recorded data determine tracking precision versus star magnitude. Extrapolate data to the star limit. Acquire and track a star .5M less than star limit and determine tracking precision. Record a starfield image using the electron camera at the longest feasible exposure.

(8) Perform high-resolution photographic studies at a variety of specific wavelengths on the stellar objects tracked in No. 1, 2, 4, and 5.

(9) Using a laser rangefinder, find and track targets on earth oceans for 2-hr periods, with continuous range recording. Also track land-based calibration sites and record range.

b. Extra Requirements of the Mission--Instrumentation requirements for this mission are discussed below. The 40-in. telescope, mount, additional optics and support instrumentation come installed on the shelter. The telescope is a diffraction-limited, 38-in.-aperature, modified Ritchey Chretien type with 190-in. focal length. It has a spectral range of from 900 A in the ultraviolet region to 10,000 A in the infrared. Support instrumentation includes photometers, both photographic and photoelectric; low- and high-resolution spectrographs; spectral scanners; film holders; laser range-finder; a film-processing package; and electronic and television starfield cameras. Total weight of this package is 2370 lb.

The telescope tube is mounted on top of the shelter. One leg of its supporting yoke serves as an optical relay to bring all the focal points inside the shelter. All sensing and data interpreting equipment can be attached to the optical system from inside, so normal operation of the telescope is entirely in shirtsleeve condition.

Because of the 2300-lb weight of the package, there is little allowance for other equipment to be landed with the shelter. The ESS, LSSM, LFV, 10- and 100-ft drills, and internal geological analysis equipment would have to be delivered separately, used from previous missions, or deleted from the mission profile. Since this equipment is necessary for almost all the tasks outlined in the basic mission plan, deleting it would make the 40-in. telescope mission primarily astronomical. Some sample collection, photography, and mapping could be done on local ESA.

Crew requirements for the mission are as described below. The mission outlined by Kollsman and by North American uses only two crew members. Both of these are occupied full-time on astronomical experiments. If it proves feasible to man an exclusively astronomical mission to the lunar surface, then a 2-man crew is feasible. If utilization of previous equipment or the landing of another vehicle with extra equipment is allowable, then three men should be considered a minimum. For the 2-man crew the commander is an astronaut trained as an astronomer, while the other man is a professional astronomer with astronaut training. These two are supplemented by another astronaut trained in geology for the 3-man crew.

c. Timelines--General changes from basic mission timelines are described below. The 2-man timeline for this mission is completely changed from the basic mission. Of the 332 hr available to each man during the mission, 112 hr or one-third of each day are devoted to astronomical experiments on the 40-in. instrument. The three-man configuration allows the third man to perform basic mission ESA, although the number of sorties will be reduced from 13 to 11. This is because the first two days of the mission will be devoted to erecting the telescope, which arrives on the side of the shelter. This requires two men working two 3-hr sorties each.

For data on specific timelines see Table 2-19.

TABLE 2-19

THREE-MAN TIMELINES FOR 40-IN. TELESCOPE ALTERNATE MISSION

TIME (hrs)	ASTRONAUT I Activity	ASTRONAUT II Activity	ASTRONAUT III Activity	TIME (hrs)	REMARKS
	Eat and Hygiene	Eat and Hygiene	Eat and Hygiene		1) 9 hours per day available for sortie and local ESA 2) 6 hours per day available for scientific tasks aside from astronomy 3) 15 hours per day available for astronomy. This allows completion of basic 40" telescope program. 4) Days 1, 2, amd 3 are different from this schedule in that 3 local ESA sorties per day are made to erect the telescope and mount. 5) Two-man time lines for this mission eliminate Astronaut III. Astronaut II still makes one local ESA per day. Astronaut I then must don suit while No. II is on the surface. 3 hours of local ESA, 2 hours of internal scientific tasks and 15 hours of Astronomical observation and Data analysis are then available. Astronaut I is a professional astronomer, No. II and III are astronauts with astronomical training.
-1-	Rest	Don suit	Don suit Egress	-1-	
-2-		Monitor and Report Time shared with Astronomical Experiment and Scientific tasks	LSSM Sortie - Baseline Mission Traverse	-2-	
-3-				-3-	
-4-				-4-	
-5-				-5-	
-6-				-6-	
-7-				-7-	
-8-			Ingress PLSS Recharge	-8-	
-9-		Eat and Hygiene Egress	Eat and Hygiene	-9-	
-10-	Eat and Hygiene	Local ESA	Monitor and Report, Astronomical Experiment	-10-	
-11-	Astronomical Experiment			-11-	
-12-				-12-	
-13-		Ingress Doff suit		-13-	
-14-		PLSS Recharge Eat and Hygiene	Doff suit Eat and Hygiene	-14-	
-15-	Lab experiment Time	Rest	Rest	-15-	
-16-				-16-	
-17-	Eat and Hygiene			-17-	
-18-	Astronomical Experiment Time			-18-	
-19-				-19-	
-20-				-20-	
-21-				-21-	
-22-				-22-	
-23-	Report			-23-	

SECTION 3

CONCLUSIONS

The principal results of this analysis are as summarized below.

- Flexible 24-hr crew task timelines are more realistic than detailed crew task allocations.

- On the basis of published equipment operating times, available time on the LSSM sorties, and data from the extravehicular tasks in the Lunex II study, workloads on the 1-man LSSM sorties may be too high to allow effective completion of the scientific tasks allotted to these sorties.

- The addition of a third crew member frees more man hours for lunar surface and shelter scientific activities while reducing the effective workload per man.

- The primary advantages of a 3-man over a 2-man crew are:

    Increased crew safety, especially on LSSM sorties

    Decreased workload per man per day

    Enhanced scientific mission success, since the probability of completing all scientific objectives within the allocated time periods is increased. This is also furthered by the greater range of scientific skills provided by three men.

- The primary disadvantages of a 3-man as opposed to a 2-man crew are:

    Extra life support equipment, requiring additional PLSS's and larger shelter environmental control and power systems.

    Increased weight due to the additional crew member, his support equipment, and the food, water and oxygen he requires.

    Increased shelter volume. An additional hard suit and an additional bunk may be required.

    Increased carrying capacity of the LSSM with its corresponding increase in weight, volume, and power requirements.

Further study is recommended in the following areas:

Visual capabilities of man during simulated lunar night.

Simulations requiring the use of geophysical and astronomical equipment in a simulated lunar environment. Experimental timelines and workloads would be determined for each man/equipment interface.

Three-man shelter simulations to evaluate the effect of the third man on emergency rescue, crew workloads and environmental support requirements.

One- vs two-man donning of state-of-the-art PLSS's. This should *include PLSS exchange on simulated 6-hr LSSM sorties.*

The capabilities of 1- vs 2-man operations of a simulated LSSM to determine the shortest effective stop time, optimal utilization of equipment, and metabolic workloads.

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APPENDIX

GUIDELINES AND ASSUMPTIONS FOR EARLY LUNAR SURFACE MISSIONS

CREW ACTIVITY GUIDELINES

Surface Excursions

For crew safety reasons at least one astronaut will remain in the shelter. This astronaut may divide his time between monitoring or assisting the surface astronauts and scientific tasks. The astronaut remaining inside the shelter will wear the soft suit in the vented condition. The astronaut performing the ESA will wear a hard suit. For a 3-man crew with two crew members remaining in the shelter, one of the two should wear a hard suit to increase safety and reliability if an emergency rescue of the outside crew member is necessary. If two crew members are on the lunar surface, hard suits will be worn by each.

A surface operator, or astronaut outside the LEM/T Shelter, may spend a maximum of 6 hr on the surface (if two backpacks are used) in any one excursion. No more than 6 hr per day on the lunar surface should be permitted for any one astronaut. Two successive days of 6-hr excursions for a single astronaut should be avoided if possible. Rest periods appropriate to the Apollo hard suit limitations and normal endurance limits of a 75 percentile astronaut should be included when performance time is calculated for extended walks on the surface.*

Major Surface Operation Constraints

The maximum distances that an astronaut can walk under normal and emergency conditions are:

- Normal

Distance	1.5 statutory miles (sm.)	(2.4 km)
Average Rate	0.5 mph	(0.8 km/hr)
Duration	3 hr	(3 hr)

- Emergency

Distance	2.0 sm	(3.2 km)
Average Rate	0.5 mph	(0.8 km/hr)
Duration	4 hr	(4 hr)

Slopes, hills, and rough country will reduce the surface operator's walking capability.

*Based on 1-g simulations and the work required for men performing tasks in current pressure suits, 6-hr excursions may be excessive.

The portable life support system (PLSS) has been developed to provide a 3-hr operating period of 1600 Btu per hr plus a 1-hr emergency operating period. The maximum operating time for the PLSS is 4 hours including the emergency operation time. Peak loads of 2000 Btu per hr can be sustained by the PLSS for short durations of the order of 5 minutes. A recent simulation has indicated that it is desirable to have a PLSS capable of supporting higher peak loads (Reference 7) since sustained walking rates considerably higher than 0.5 mph (e.g., 2.6 mph) can result in oxygen consumption rates in excess of the assumed PLSS system capabilities.

Operation of equipment on the lunar surface should be conducted, whenever possible, in the standing position. Work while kneeling should be kept to a minimum.

Location of LEM/T Shelter

The shelter will be located approximately 0.5 km from the LEM/TAXI. The mode of astronaut transfer will be walking from the LEM/TAXI to the shelter at mission start, and by riding the LSSM from the shelter to the LEM/TAXI at mission end. For a 3-man crew, this requires either increased LSSM carrying capacity, two LSSM trips, or walk back by one crew member.

Training

All crew members should be trained in the deployment and use of all equipment critical to mission success and crew survival. This does not include scientific equipment where crew specialization may be expected.

Egress/Ingress

Although the acts of ingress and egress require relatively little time, the preparations for egress and the normal recharge and storage routine following ingress require considerable time. Taking these factors into account approximately 60 min should be allowed for each ingress and each egress. (A more detailed discussion of ingress/egress time requirements is given in Section 5.0, Volume I of the NASA guideline documents.)

Sleeping

When sleeping periods are staggered, provisions should be made to keep disturbances at a minimum while crewmen are asleep.

First Sortie

The first LSSM and/or LFV sortie should be limited to 3 hr or less in the visual vicinity of the shelter to permit engineering checkout and familiarization.

ESS Deployment

The Emplaced Scientific Station (ESS), if required by the mission, will be deployed early in the mission in case an abort occurs.

Contingency Time

Sufficient contingency time should be included throughout the mission to allow for unexpected events or task difficulties.

Mission Duration

The minimum lunar stay time shall be 14 days, unless an abort is necessary.

Monitoring

Monitoring facilities should be designed so that visual monitoring of surface activities can take place by one crewman when the other is operating in the vicinity of the shelter. The viewing facilities should also allow remote control and observation of a surface vehicle operating in the vicinity of the shelter.

LOCAL SCIENTIFIC SURVEY MODULE (LSSM) CHARACTERISTICS

A preliminary description of the LSSM parameters follows:

Capable of being operated by a single astronaut (no cabin and of transporting a cargo up to 600 lb of scientific equipment. A second astronaut is able to ride in the cargo space if required.

Speed of at least 5 km/hr in soft soils and 8 km/hr on level, compacted soild.

Capable of operating within a circular area of at least 8-km radius from the LEM/Shelter. Range per sortie is 30 km based on an average speed of 5 km/hr and 6 hours of continuous travel.

Capable of operating at any time during the lunar cycle.

Capable of being replenished for additional sorties after its return to the LEM/Shelter. The vehicle will be capable of at least one 6-hr sortie per 24 hr throughout the 14-day mission without undue penalties to the overall system.

A central onboard electrical power source for all vehicle loads. Average power available will be approximately 1 kw for the 6-hr sorties.

A vehicle navigation system with the capability of indicating headings, distance traversed, local, vertical, and angles.

Mobility over as wide a range of lunar surface conditions as possible.

In the remote (unmanned) mode, capable of transporting 900 lb of scientific payload.

LUNAR FLYING VEHICLE (LFV) CHARACTERISTICS

The primary mission of the LFV is to return to the LEM from a disabled surface vehicle. A secondary mission is to supplement the surface vehicle by permitting access to areas not obtainable by surface means. The following summarizes the characteristics of such a vehicle:

An open-cockpit, manually controlled vehicle which can carry two pressure-suited astronauts.

Capable of transporting two astronauts with their PLSS or one astronaut and 300 lb of scientific equipment at least 15 mi (24 km) radial distance and return without refueling.

Approximately 22 min required for LFV preflight preparations.

The Apollo EVA backpack communications set is used. This equipment operates in the VHF band and operations are restricted to line-of-sight except at very short ranges. For exploration mission operations, additional equipment comprises part of the scientific payload on the LFV, and it includes an S-band transmitter which communicates directly with the Apollo deep space stations.

The communication system includes its own self-contained power source, and power required by the scientific payload is supplied by a source included as part of the payload.

TIME MANAGEMENT

Sleep Schedules

A minimum time period of 7.5 hr average per 24 hr should be allowed for sleep. Any lesser amount can result in a decrement in personnel. The recommended minimum unit of sleep is 3.5 hr. On the final day of the lunar surface mission, the day of lift-off, a greater rather than lesser amount of sleep should be allowed for insofar as this is possible.

In determining the particular time during which sleep periods are scheduled, serious considerations should be given to diurnal cycles and the possible detrimental effects on human performance of modifying the 24-hr period to which the crewman is normally adapted.

Eating and Personal Time

Some functions (monitoring activities, briefings, verbal reports) may be performed simultaneously with personal activities, but in any case allowances should be made and times specified for such activities. Approximately 29 percent of a 24-hr day may be required for eating, personal time, hygiene and housekeeping (Reference 7).

BOOK 3
HASSLE ANALYSIS OF PROPOSED SCHEDULE

CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

ILLUSTRATIONS (Continued)

ILLUSTRATIONS (Continued)

TABLES

SECTION I

INTRODUCTION AND SUMMARY

INTRODUCTION

One plan for lunar exploration proposes the initial delivery of an unmanned Early Lunar Shelter (ELS) with Drill and Local Scientific Survey Module (LSSM) and a later landing by two men to operate the equipment. A recent estimate of the hardware cost of the initial two-flight operation indicates an expenditure of $570 million dollars (Reference 1). Subsequent landing site explorations using the same concept are estimated to cost $520 million dollars. The potential contribution of this expenditure of resources is related to total lunar exploration program plan. The national objective of landing a man on the moon and returning him to earth with lunar material will have already been accomplished along with the emplacement of a 200-lb lunar surface experiments package (ALSEP). It is likely that several lunar landings at varied locations will have been accomplished along with extensive lunar orbit surveys by manned and unmanned systems. The objectives of the ELS/LSSM lunar exploration are, therefore, the accomplishment of scientific results which are beyond the need to duplicate these achievements.

The achievement of scientific objectives for each mission is the primary result which must be planned and used to evaluate the various proposed systems of lunar exploration. This report is aimed at exploring one method of planning in the context of an ELS/LSSM mission.

SUMMARY

The preferred ELS/LSSM schedule reported in AiResearch report number 67-1964-6, Book 2, has been analyzed with the HASSLE (Honeywell's Automated Schedule Simulator and Load Evaluator) computer program. Parametric variations in astronaut speed or capability, LSSM speed, and schedule interrupts have been employed. The results of this analysis are summarized as follows:

1. The proposed schedule is feasible under perfect (no interrupt) nominal conditions. A 4% variation in scientific achievement is predicted due to human variability alone.

2. The proposed exploration system schedule performance is very sensitive to reductions in vehicle or astronaut capabilities as well as to minor interrupts due to contingencies.

3. The proposed schedule is most sensitive to astronaut capabilities. Since information exists which indicates the astronauts may perform well in the 1/6-g environment, this may require major revisions in the planned schedule to make better use of astronaut capability.

4. Schedule interrupts and reduced outside capability tend to create spare time in the ELS. Some consideration should be given to providing for use of this time as well as to the added operational hours which may be required of the ELS.

5. Increasing the speed capability of the LSSM beyond the design point is not an effective way of improving the output of the proposed schedule when faced with interrupt problems.

6. No major astronaut stress or safety problems appear to limit the proposed schedule or endanger the astronauts.

7. The HASSLE program provides an effective tool for studying the schedule-vehicle-man interaction. It should be further developed as suggested in Section 4 and further applied to lunar exploration schemes.

SECTION 2

HASSLE PROGRAM EVALUATION OF LSSM/ELS SCIENTIFIC MISSION

GENERAL

This study makes use of the digital computer program HASSLE (Honeywell's Automated Schedule Simulator and Load Evaluator) to evaluate the schedule reported in AiResearch Report 67-1964-6, Book 2, "Early Lunar Shelter Design and Comparison Study, Review of Scientific Mission Requirements". The nature of the HASSLE program is discussed in Reference 2. Generally HASSLE is a Fortran language mathematical model used to simulate complete missions of operators performing scheduled and unscheduled activities over long periods of time. Crew characteristics and expected variance are dynamically simulated and continually modified to reflect the setting for each task. A Monte Carlo technique is used to simulate schedule uncertainties and variance in stochastic variables. The schedule evaluation made in this analysis include both the expected mean values and their variance due to the stochastic nature of a manned operation. The behavior of the crew is predicted from the best models available from experimental data and theoretical considerations. The system simulation is subjected to a "driving function" or disturbance in the form of time delays or schedule disturbances representative of realistic operations.

In this study the speed of the crew's performance and the vehicle mode of travel are treated as parametric variables which correspond to variations in equipment and/or speed permitted by such variables as lighting conditions. A previous application of HASSLE evaluated 2-man crews, so it was necessary to modify the program to allow evaluation of the recommended schedule. The approach taken consisted of defining joint tasks for the crew members on the lunar surface during the scientific task times.

The principal product of the ELS/LSSM mission is the scientific accomplishment of the astronauts. Since no measure of discovery or "science" achievement can be defined "a priori", it is assumed that the useful application of astronaut time is a criterion related to the ultimate objectives. Available astronaut scientific "time" for essential tasks and observation is, therefore, considered the primary product to evaluate schedules and system capabilities.

In order to measure schedule achievement and capability better, a HASSLE program modification was introduced into the input schedule. An unspecified "science" activity was introduced into every LSSM and ESA activity. This activity fits into the exploration schedule as a "nonpriority zero % essential" task which requires more time than would be normally available in the schedule. It serves the function of providing a scientific task which will be done on the lunar surface whenever time is available. Since the science activity is "zero %" essential, the computer program will work at this task only until the astronaut must ingress to the ELS due to a PLSS supply problem. Being nonpriority, the primary mission elements will always take precedence over this science task. This program improvement, therefore, allows the astronaut simulation to take advantage of his valuable exploration opportunities to the maximum. The measure is also most sensitive to schedule variations since it will be affected by all performance variations which affect the schedule.

INPUT SCHEDULE EVALUATED

The HASSLE schedule analysis reported herein is based upon the recommended 14-day missions which involved 11 local ESA's, as shown in Table 2-1, and eight LSSM sorties for the Alphonsus and Hyginus Rille missions. Concept "B," or the two men on the surface, is employed in this analysis since it is the preferred and best specified schedule available. Tables 2-2 and 2-3 are the typical time lines for LSSM and Local ESA Sortie days. The details of the LSSM sorties are to be found in Tables 2-12 through 2-15 of AiResearch Report 67-1964-6, Book 2.

Table 2-4 is the input schedule into the analysis. This base schedule is a sequential statement of 11 ESA's and 8 LSSM sorties involving a 3-man crew in Concept B. The input schedule includes:

- o A time sequence of activities constituting the planned schedule
- o A priority task list of tasks which will be rescheduled if not completed or attempted for various reasons
- o The average time, expected deviation, task type, safety level, travel required, and percent essential of each task
- o Description of:

  crew members speed and initial proficiency

  vehicle travel rates

  interrupt distribution and probabilities

  relative importance of tasks

Table 2-4 can be understood by noting its relationship to the basic information found in AiResearch Report 67-1964-6, Book 2. The design point vehicle speeds and distances are of special interest.

INTERRUPTS

Several types of unscheduled "interrupts" can occur in HASSLE during the planned task execution sequence. The interrupts may represent repair time (both scheduled and emergency) due to equipment failure, time lost due to equipment malfunction, or any other event which might cause a delay in the desired schedule.

The interrupts are divided into four categories and are generated from exponential distributions based on an average time input for each category. The four types are:

1. Inside — time delay

2. Outside — time delay

TABLE 2-1

SUMMARY OF LOCAL SURFACE SORTIES (LOCAL ESA's)

No.	Description	Number of Crew	Total Time, hr:min	Muscle Group Involved	Range, km	Missions Used on
1	Unload and set up LSSM; check external gear; lay out erosion samples	2	2:00	VL (0:20) L (1:00) S (0:40)	0.5	All
2	Begin 30-m hole drilling	1	2:00	VL (0:40) L (1:00) S (0:20)	0.0	Alphonsus, Hyginus Rille
3	Complete 30-m hole	1	2:00	VL (0:10) L (1:00) S (0:50)	0.0	Alphonsus, Hyginus Rille
4	ESS activation	1	3:00	VL (0:00) L (1:00 S (2:00	2.5	All but LSSM/LFV mission
5	Lay out geophone net; set off one charge	1	3:00	VL (0:00) L (1:00) S (2:00)	4.0	All
6	Nuclear and electrical logging of 30-m hole	1	2:00	VL (0:00) L (1:30) S (0:30)	0.0	Alphonsus, Hyginus Rille
7	Sonic velocity measurements on 30-m hole	1	2:00	VL (0:10) L (1:20) S (0:30)	0.0	Alphonsus, Hyginus Rille
8	Seismic charge emplace and ESS checkout	1	2:00	VL (0:10) L (0:40) S (1:10)	4.0	All
9	Phase I astronomy experiments setup	1	2:30	VL (0:30) L (0:30) S (1:30)	1.0	All
10	Optical and x-ray astronomy experiments and observations	2	3:00	VL (0:00) L (0:30) S (2:30)	1.0	All
11	Radio astronomy observations	2	3:00	VL (0:00) L (0:30) S (2:30)	1.0	All

TABLE 2-2

THREE-MAN, 24-HR TIMELINESS FOR LSSM SORTIE DAYS, ALPHONSUS OR HYGINUS RILLE MISSIONS (CONCEPT B, TWO MEN ON SURFACE)

Elapsed Time	Time per Task	Astronaut I	Astronaut II	Astronaut III	Remarks
0600	20	Take down beds	Take down beds	Take down beds	
	45	Eat meal I and clean up	Eat meal I and clean up	Eat meal I and clean up	
0700	20	Hygiene	Hygiene	Hygiene	
0800	55	Suit don, PLSS c/o	Suit don, PLSS c/o	Don vented suit - aid in PLSS c/o	No. III assists I and II
	10	Egress to surface	Egress to surface	Monitor airlock	
0900	6:30	LSSM sortie	LSSM sortie	Monitor sortie, inside geological tasks	
1000					
1100					
1200				Eat snack	Some method of feeding Astronauts I and II must be found while they are on the 6-hour sortie, otherwise 9 hours elapse between meals.
1300				Earth communications	
1400					
1500	55	Suit doff Recharge PLSS	Suit doff Recharge PLSS	Suit doff	Scientific tasks are best scheduled on an "As-Time-Available" basis, rather than specific times for specific tasks; tasks not critical to mission success which cannot be completed on the day assigned to them should be dropped from the schedule.
1600	45	Eat meal II and clean up	Eat meal II and clean up	Eat meal II and clean up	
1700	1 hr	Rest	Rest	Rest	
1800	30	Scientific tasks inside	Scientific tasks inside	Scientific tasks inside	
	20	Suit c/o			
1900	1 hr	Maintenance, repair, and housekeeping	Suit c/o		
2000	45	Report writing, hygiene, and personal activity		Suit c/o	
2100	45	Eat meal III and clean up	Eat meal III and clean up	Eat meal III and clean up	
	30	Buffer period	Buffer period	Buffer period	
2200	10	Set up beds	Set up beds	Set up beds	
	8 hrs	Rest	Rest	Rest	
0600					

TABLE 2-3

THREE-MAN, 24-HR TIMELINESS FOR LOCAL ESA SORTIE DAYS, ALPHONSUS OR HYGINUS RILLE MISSIONS (CONCEPT B, TWO MEN ON SURFACE)

Elapsed Time	Time per Task	Astronaut I	Astronaut II	Astronaut III	Remarks
0600	20	Take down beds	Take down beds	Take down beds	See remarks in Table 10
0700	45	Eat meal I and clean up	Eat meal I and clean up	Eat meal I and clean up	
	20	Hygiene	Hygiene	Hygiene	
0800	55	Suit don and PLSS c/o	Suit don and PLSS c/o	Don vented suit; assist I and II	
0900	10	Egress to surface	Egress to surface	Monitor airlock	
1000 1100	3 hrs	Local ESA	Another local ESA in same vicinity as No. I	Monitor I and II; some reporting and earth data transmittal	
1200	55	Suit doff PLSS recharge	Suit doff PLSS recharge	Suit doff help I and II	
1300	45	Eat meal II and cleanup	Eat meal II and cleanup	Eat meal II and cleanup	
1400	1 hr	Rest	Rest	Rest	
1500 1600 1700 1800	4 hrs	Scientific task time - geological samples sorting Suit c/o Also checkout any equipment emplaced on ESA's	Map completion, petrographic analysis Suit c/o (astronomy, ESS, geophone net)	Suit c/o	
1900	45	Eat meal III and cleanup	Eat meal III and cleanup	Eat meal III and cleanup	
2000	1 hr	Maintenance, repair, and housekeeping			
2100	1 hr	Report writing, hygiene, and personal activity			
2200	30	Buffer period	Buffer period	Buffer period	
0600	8 hrs	Rest	Rest	Rest	

TABLE 2-4

BASE SCHEDULE

```
/HEADING                                                                                              CARD NO.  0001
X                                       GARY ERALEY                                                   CARD NO.  0002
X                                       VERA STUMPRIS                                                 CARD NO.  0003
/BASE SCHEDULE                                                                                        CARD NO.  0004
X                    S   S S T P                                        DIST                          CARD NO.  0005
X                    P C U A R L J                           MILE       FROM OTHER                    CARD NO.  0006
X TASK               E A I F A   N AVG  TIME T-UP PCNT       POST TASK  LAST OPER      OXGN           CARD NO.  0007
X NAME     OP NUM    C T Y E V = T TIME DEV  TIME ESS        TIME DIST  TASK TASK      SUPP           CARD NO.  0008
X                                                                                                     CARD NO.  0009
X                                                                                                     CARD NO.  0010
MISC        1   1    2 3 N 4     J 11.0  .0  10.  100.            0.0   0.0   S                       CARD NO.  0011
MISC        2   1    2 3 N 4     J 11.0  .0  10.  100.            0.0   0.0   S                       CARD NO.  0012
EAT 2       1   2    2 3 N 1     J  .75 .17  10.   70.                        S                       CARD NO.  0013
EAT 2       2   2    2 3 N 1     J  .75 .17  10.   70.                        S                       CARD NO.  0014
REST        1   3    2 2 N 1     J  .90  .0   0.0  30.       12.75            S                       CARD NO.  0015
REST        2   3    2 2 N 1     J  .90  .0   0.0  30.       12.75            S                       CARD NO.  0016
SUIT UP     1   4    2 3   1     J  .92 .10  10.  100.                        S                       CARD NO.  0017
SUIT UP     2   4    2 3   1     J  .92 .10  10.  100.                        S                       CARD NO.  0018
EGRESS      1   5    2 9   2     J  .17 .05  15.  100.                        S           8.          CARD NO.  0019
EGRESS      2   5    2 9   2     J  .17 .05  15.  100.                        S           8.          CARD NO.  0020
ESA1        1   6    2 7   3 1 1    1.0 .15  75.  100.             .5    .5      21                   CARD NO.  0021
SCIENCE     1  6A    1 8   3        3.0  .1   0.    0.                           22                   CARD NO.  0022
SCIENCE     2  6A    1 8   3        3.0  .1   0.    0.                           23                   CARD NO.  0023
INGRESS     1   7    2 9   2     J  .17 .05  15.  100.       19.40       .5   S                       CARD NO.  0024
INGRESS     2   7    2 9   2     J  .17 .05  15.  100.       19.40       .5   S                       CARD NO.  0025
UNSUIT      1   8    2 3   1     J  .92 .10  10.  100.       19.3                                     CARD NO.  0026
UNSUIT      2   8    2 3   1     J  .92 .10  10.  100.       19.3                                     CARD NO.  0027
EAT 3       1   9    2 3 N 1     J  .75 .17  10.   70.                                                CARD NO.  0028
EAT 3       2   9    2 3 N 1     J  .75 .17  10.   70.                                                CARD NO.  0029
M.R.H       1  10    2 10 N 1    J 1.0   .2  10.   50.                                                CARD NO.  0030
M.R.H       2  10    2 10 N 1    J 1.0   .2  10.   50.                                                CARD NO.  0031
R.H.P       1  11    2 3 N 1     J 1.0   .2   5.   50.       22.00                                    CARD NO.  0032
R.H.P       2  11    2 3 N 1     J 1.0   .2   5.   50.       22.00                                    CARD NO.  0033
SLEEP       1  12    2 1   1     J 8.0   .0   0.0  90.       30.00                                    CARD NO.  0034
SLEEP       2  12    2 1   1     J 8.0   .0   0.0  90.       30.00                                    CARD NO.  0035
RISE        1  13    2 3 N 1     J  .33 .05   0.0  20.       30.33            S                       CARD NO.  0036
RISE        2  13    2 3 N 1     J  .33 .05   0.0  20.                        S                       CARD NO.  0037
EAT 1       1  14    2 3 N 1     J  .75 .17  10.0  70.                                                CARD NO.  0038
EAT 1       2  14    2 3 N 1     J  .75 .17  10.0  70.                                                CARD NO.  0039
HYGIENE     1  15    2 3 N 1     J  .33  .1   0.0  30.                                                CARD NO.  0040
HYGIENE     2  15    2 3 N 1     J  .33  .1   0.0  30.                                                CARD NO.  0041
SUIT UP     1  16    2 3   1     J  .92  .1  10.0 100.                                                CARD NO.  0042
SUIT UP     2  16    2 3   1     J  .92  .1  10.0 100.                                                CARD NO.  0043
EGRESS      1  17    2 9   2     J  .17 .05  15.0 100.       32.50                        8.          CARD NO.  0044
EGRESS      2  17    2 9   2     J  .17 .05  15.0 100.       32.50                        8.          CARD NO.  0045
LSSHI       1  18    1 8   4 2      2.5  .7  20.   50.            2.    2.5      46                   CARD NO.  0046
PLSS CHG    1  19    2 3   2     J  .1  .01  13.0 100.                                    4.          CARD NO.  0047
PLSS CHG    2  19    2 3   2     J  .1  .01  13.0 100.                                    4.          CARD NO.  0048
ESA2        1  20    1 7   3 1 2    2.0  .5  20.   90.            0.    0.       49                   CARD NO.  0049
SCIENCE     1 20A    1 8   3        3.6  .2   0.    0.                           49                   CARD NO.  0050
SCIENCE     2 20B    1 8   3        4.6  .2   0.    0.                           49                   CARD NO.  0051
INGRESS     1  21    2 9   2     J  .17 .05  15.0 100.       38.17                                    CARD NO.  0052
INGRESS     2  21    2 9   2     J  .17 .05  15.0 100.       38.17                                    CARD NO.  0053
UNSUIT      1  22    2 3   1     J  .92  .1  10.0 100.       39.00                                    CARD NO.  0054
UNSUIT      2  22    2 3   1     J  .92  .1  10.0 100.       39.00                                    CARD NO.  0055
EAT 2       1  23    2 3 N 1     J  .75 .17  10.0  90.       39.75                                    CARD NO.  0056
EAT 2       2  23    2 3 N 1     J  .75 .17  10.0  90.       39.75                                    CARD NO.  0057
REST        1  24    2 3 N 1     J 1.0   .0   0.0  50.       40.75                                    CARD NO.  0058
REST        2  24    2 3 N 1     J 1.0   .0   0.0  50.       40.75                                    CARD NO.  0059
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AIRESEARCH MANUFACTURING DIVISION
Los Angeles, California

TABLE 2-4 (Continued)

SCIENCE	1	25	2	3	N	1			J	1.5	.2	5.0	50.						CARD NO. 0060
SCIENCE	2	25	2	3	N	1			J	1.5	.2	5.0	50.						CARD NO. 0061
SUIT C/O	1	26	2	10	N	1			J	.33	.05	1.0	30.						CARD NO. 0062
SUIT C/O	2	26	2	10	N	1			J	.33	.05	[illegible]	50.						CARD NO. 0063
M.R.H	1	27	2	10	N	1			J	1.0	.2	10.0	30.						CARD NO. 0064
M.R.H	2	27	2	10	N	1			J	1.0	.2	10.0	50.						CARD NO. 0065
R.H.P	1	28	2	3	N	1			J	1.0	.2	10.0	50.						CARD NO. 0066
R.H.P	2	28	2	3	N	1			J	1.0	.2	10.0	50.						CARD NO. 0067
EAT 3	1	29	2	3	N	1			J	.75	.17	10.0	70.						CARD NO. 0068
EAT 3	2	29	2	3	N	1			J	.75	.17	10.0	70.						CARD NO. 0069
RETIRE	1	30	2	3	N	1			J	.17	.05	0.0	50.	46.00					CARD NO. 0070
RETIRE	2	30	2	3	N	1			J	.17	.05	0.0	50.	46.00					CARD NO. 0071
SLEEP	1	31	2	1	N	1			J	8.0	0.0	0.0	80.	54.0					CARD NO. 0072
SLEEP	2	31	2	1	N	1			J	8.0	0.0	0.0	80.	54.00					CARD NO. 0073
RISE	1	32	2	3	N	1			J	.33	.05	0.0	20.	54.33					CARD NO. 0074
RISE	2	32	2	3	N	1			J	.33	.05	0.0	20.	54.33					CARD NO. 0075
EAT 1	1	33	2	3	N	1			J	.75	.17	10.0	70.						CARD NO. 0076
EAT 1	2	33	2	3	N	1			J	.75	.17	10.0	70.						CARD NO. 0077
HYGIENE	1	34	2	3	N	1			J	.33	.1	0.0	30.						CARD NO. 0078
HYGIENE	2	34	2	3	N	1			J	.33	.1	0.0	30.						CARD NO. 0079
SUIT UP	1	35	2	3		1			J	.92	.1	10.0	100.						CARD NO. 0080
SUIT UP	2	35	2	3		1			J	.92	.1	10.0	100.						CARD NO. 0081
EGRESS	1	36	2	9		2			J	.17	.05	15.0	100.	56.50				8.	CARD NO. 0082
EGRESS	2	36	2	9		2			J	.17	.05	15.0	100.	56.50				8.	CARD NO. 0083
LSSM2	1	37	1	7		4	2	3		4.0	.5	10.	80.		1.	2.	82		CARD NO. 0084
ESA 3	2	38	1	8		3	1			2.0	.25	10.	50.				83		CARD NO. 0085
SCIENCE	1	38A	1	8		3				7.2	.5	0.	0.				83		CARD NO. 0086
SCIENCE	2	38B	1	8		3				7.2	.5	0.	0.				83		CARD NO. 0087
INGRESS	1	39	2	9		2			J	.17	.05	15.0	100.	63.87				1.	CARD NO. 0088
INGRESS	2	39	2	9		2			J	.17	.05	15.0	100.	63.87				1.	CARD NO. 0089
UNSUIT	1	40	2	3		1			J	.92	.10	10.0	100.	64.33					CARD NO. 0090
UNSUIT	2	40	2	3		1			J	.92	.10	10.0	100.	64.33					CARD NO. 0091
EAT 2	1	41	2	3	N	1			J	.75	.17	10.0	90.	65.59					CARD NO. 0092
EAT 2	2	41	2	3	N	1			J	.75	.17	10.0	90.	65.59					CARD NO. 0093
REST	1	42	2	2	N	1			J	.33	.1	0.0	50.						CARD NO. 0094
REST	2	42	2	2	N	1			J	.33	.1	0.0	50.						CARD NO. 0095
SUIT C/O	1	43	2	10	N	1			J	.33	.05	10.0	80.	66.25					CARD NO. 0096
SUIT C/O	2	43	2	10	N	1			J	.33	.05	10.0	80.	66.25					CARD NO. 0097
M.R.H	1	44	2	10	N	1			J	1.0	.2	10.0	50.	67.25					CARD NO. 0098
M.R.H	2	44	2	10	N	1			J	1.0	.2	10.0	50.	67.25					CARD NO. 0099
R.H.P	1	45	2	3	N	1			J	1.0	.2	50.0	50.	68.25					CARD NO. 0100
R.H.P	2	45	1	3	N	1			J	1.0	.2	50.0	50.	68.25					CARD NO. 0101
EAT 3	1	46	2	3	N	1			J	.75	.17	10.0	70.	69.25					CARD NO. 0102
EAT 3	2	46	2	3	N	1			J	.75	.17	10.0	70.	69.25					CARD NO. 0103
RETIRE	1	47	2	3	N	1			J	.17	.05	0.0	50.	70.00					CARD NO. 0104
RETIRE	2	47	2	3	N	1			J	.17	.05	0.0	50.	70.00					CARD NO. 0105
SLEEP	1	48	2	1	N	1			J	8.0	0.0	0.0	80.	78.00					CARD NO. 0106
SLEEP	2	48	2	1	N	1			J	8.0	0.0	0.0	80.	78.00					CARD NO. 0107
RISE	1	49	2	3	N	1			J	.33	.05	0.0	20.						CARD NO. 0108
RISE	2	49	2	3	N	1			J	.33	.05	0.0	20.						CARD NO. 0109
EAT 1	1	50	2	3	N	1			J	.75	0.17	10.0	70.						CARD NO. 0110
EAT 1	2	50	2	3	N	1			J	.75	0.17	10.0	70.						CARD NO. 0111
HYGIENE	1	51	2	3	N	1			J	.33	0.10	0.0	30.						CARD NO. 0112
HYGIENE	2	51	2	3	N	1			J	.33	0.10	0.0	30.						CARD NO. 0113
SUIT UP	1	52	2	3		1			J	.92	0.10	10.0	100.						CARD NO. 0114
SUIT UP	2	52	2	3		1			J	.92	0.10	10.0	100.						CARD NO. 0115
EGRESS	1	53	2	9		2			J	.17	0.05	15.0	100.	80.50				8.	CARD NO. 0116
EGRESS	2	53	2	9		2			J	.17	0.05	15.0	100.	80.50				8.	CARD NO. 0117
LOOK	1		1	7		3		4									113		CARD NO. 0118
LOOK	2		1	7		3		4									113		CARD NO. 0119

TABLE 2-4 (Continued)

LS543	1	54	1	8		4	2		J	3.9	.5	20.	30.		6.	2.	114		CARD NO.	0120
LS543	2	54A	1	8		4	2		J	3.9	.5	20.	30.		6.	6.	114		CARD NO.	0121
SCIENCE	1	54A	1	8		3				6.5	.5	0.	0.				114		CARD NO.	0122
SCIENCE	2	54B	1	8		3				6.5	.5	0.	0.				114		CARD NO.	0123
INGRESS	1	55	1	9		2			J	.17	0.05	15.0	100.	87.17				2.	CARD NO.	0124
INGRESS	2	55	2	9		2			J	.17	0.03	15.0	100.	87.17				2.	CARD NO.	0125
UNSUIT	1	56	2	3		1			J	.92	0.10	10.0	100.						CARD NO.	0126
UNSUIT	2	56	2	3		1			J	.92	0.10	10.0	100.						CARD NO.	0127
EAT 2	1	57	2	3		1			J	.75	0.17	10.0	70.						CARD NO.	0128
EAT 2	2	57	2	3		1			J	.75	0.17	10.0	70.						CARD NO.	0129
SCIENCE	1	A58	1	3	N	1			J	.5	0.2	0.0	25.						CARD NO.	0130
SCIENCE	2	A58	1	3	N	1			J	.5	0.2	0.0	25.						CARD NO.	0131
REST	1	58	2	2	N	1			J	1.0	0.1	0.0	50.						CARD NO.	0132
REST	2	58	2	2	N	1			J	1.0	0.1	0.0	50.						CARD NO.	0133
SUIT C/O	1	59	210		N	1			J	.33	0.05	10.0	90.	91.00					CARD NO.	0134
SUIT C/O	2	59	210		N	1			J	.33	0.05	10.0	90.	91.00					CARD NO.	0135
M.R.H	1	60	210		N	1			J	1.0	0.2	10.0	50.						CARD NO.	0136
M.R.H	2	60	210		N	1			J	1.0	0.2	10.0	50.						CARD NO.	0137
R.H.P	1	61	1	3	N	1			J	1.0	0.2	50.0	50.						CARD NO.	0138
R.H.P	2	61	2	3	N	1			J	1.0	0.2	50.0	50.						CARD NO.	0139
EAT 3	1	62	2	3	N	1			J	.75	0.17	10.0	70.						CARD NO.	0140
EAT 3	2	62	2	3	N	1			J	.75	0.17	10.0	70.						CARD NO.	0141
RETIRE	1	63	2	3	N	1			J	.17	0.03	9.0	50.	94.00					CARD NO.	0142
RETIRE	2	63	2	3	N	1			J	.17	0.05	9.0	50.	94.00					CARD NO.	0143
SLEEP	1	64	2	1	N	1			J	8.0	0.0	0.0	90.	102.0					CARD NO.	0144
SLEEP	2	64	2	1	N	1			J	8.0	0.0	0.0	90.	102.0					CARD NO.	0145
RISE	1	65	2	3	N	1			J	.33	0.05	0.0	20.						CARD NO.	0146
RISE	2	65	2	3	N	1			J	.33	0.05	0.0	20.						CARD NO.	0147
EAT 1	1	66	2	3	N	1			J	.75	0.17	10.0	70.						CARD NO.	0148
EAT 1	2	66	2	3	N	1			J	.75	0.17	10.0	70.						CARD NO.	0149
HYGIENE	1	67	2	3	N	1			J	.33	0.1	1.0	30.						CARD NO.	0150
HYGIENE	2	67	2	3	N	1			J	.33	.1	1.0	30.						CARD NO.	0151
SUIT UP	1	68	2	3		1			J	.92	.1	10.0	100.						CARD NO.	0152
SUIT UP	2	68	2	3		1			J	.92	.1	10.0	100.						CARD NO.	0153
EGRESS	1	69	2	9		2			J	.17	.05	13.0	100.	104.5					CARD NO.	0154
EGRESS	2	69	2	9		2			J	.17	.05	13.0	100.	104.5					CARD NO.	0155
ESA 4	1	70	1	7		3	2	4		2.6	.5	20.	80.		1.25	1.25	147		CARD NO.	0156
ESA 5	2	71	1	7		3	2	5		2.4	.5	20.	80.		2.0	2.0	148		CARD NO.	0157
SCIENCE	1	71A	1	8		3				3.2	.3	0.	0.				148		CARD NO.	0158
SCIENCE	2	71B	1	8		3				3.2	.3	0.	0.				148		CARD NO.	0159
INGRESS	1	72	2	9		2			J	.17	.05	15.0	100.	107.7					CARD NO.	0160
INGRESS	2	72	2	9		2			J	.17	.05	15.0	100.	107.7					CARD NO.	0161
UNSUIT	1	73	2	3		1			J	.92	.1	10.0	100.						CARD NO.	0162
UNSUIT	2	73	2	3		1			J	.92	.1	10.0	100.						CARD NO.	0163
EAT 2	1	74	2	3	N	1			J	.75	.17	10.0	70.	109.5					CARD NO.	0164
EAT 2	2	74	2	3	N	1			J	.75	.17	10.0	70.	109.5					CARD NO.	0165
REST	1	75	2	2	N	1			J	1.0	.1	0.0	50.						CARD NO.	0166
REST	2	75	2	2	N	1			J	1.0	.1	0.0	50.						CARD NO.	0167
SCIENCE	1	76	1	3	N	1			J	4.0	.4	0.0	70.						CARD NO.	0168
SCIENCE	2	76	1	3	N	1			J	4.0	.4	0.0	70.						CARD NO.	0169
SUIT C/O	1	77	210		N	1			J	.33	.05	10.0	80.						CARD NO.	0170
SUIT C/O	2	77	210		N	1			J	.33	.05	10.0	80.						CARD NO.	0171
EAT 3	1	78	2	3	N	1			J	.75	.17	10.0	70.	115.5					CARD NO.	0172
EAT 3	2	78	2	3	N	1			J	.75	.17	10.0	70.	115.5					CARD NO.	0173
M.R.H	1	79	2	3	N	1			J	1.0	.2	10.0	50.						CARD NO.	0174
M.R.H	2	79	2	3	N	1			J	1.0	.2	10.0	50.						CARD NO.	0175
R.H.P	1	80	2	3	N	1			J	1.0	.2	50.0	50.						CARD NO.	0176
R.H.P	2	80	1	3	N	1			J	1.0	.2	50.0	50.						CARD NO.	0177
RETIRE	1	81	2	3	N	1			J	.17	.05	0.0	50.	118.0					CARD NO.	0178
RETIRE	2	81	2	3	N	1			J	.17	.05	0.0	50.	118.0					CARD NO.	0179

TABLE 2-4 (Continued)

SLEEP	1	82	2	1	N	1			J	8.0	0.0	0.0	80.	126.0					CARD NO.	0180
SLEEP	2	82	2	1	N	1			J	8.0	0.0	0.0	80.	126.0					CARD NO.	0181
RISE	1	83	2	3	N	1			J	.33	.05	0.0	20.						CARD NO.	0182
RISE	2	83	2	3	N	1			J	.33	.05	0.0	20.						CARD NO.	0183
EAT 1	1	84	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0184
EAT 1	2	84	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0185
HYGIENE	1	85	2	3	N	1			J	.33	.10	0.0	30.						CARD NO.	0186
HYGIENE	2	85	2	3	N	1			J	.33	.10	0.0	30.						CARD NO.	0187
SUIT UP	1	86	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0188
SUIT UP	2	86	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0189
EGRESS	1	87	2	9		2			J	.17	.05	15.0	100.	128.5					CARD NO.	0190
EGRESS	2	87	2	9		2			J	.17	.05	15.0	100.	128.5					CARD NO.	0191
LSSM4	1	88	1	7		4	2	6		3.9	.5	20.	80.		8.0	8.0	181		CARD NO.	0192
SCIENCE	1	88A	1	8		3				6.7	.5	0.	0.				181		CARD NO.	0193
SCIENCE	2	88B	1	8		3				6.7	.5	0.	0.				181		CARD NO.	0194
INGRESS	1	89	2	9		2			J	.17	.05	15.0	100.	135.2					CARD NO.	0195
INGRESS	2	89	2	9		2			J	.17	.05	15.0	100.	135.2					CARD NO.	0196
UNSUIT	1	90	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0197
UNSUIT	2	90	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0198
EAT 2	1	91	2	3	N	1			J	.75	.17	10.0	70.	136.8					CARD NO.	0199
EAT 2	2	91	2	3	N	1			J	.75	.17	10.0	70.	136.8					CARD NO.	0200
SCIENCE	1	92	2	3	N	1			J	.50	.20	0.0	25.						CARD NO.	0201
SCIENCE	2	92	2	3	N	1			J	.50	.20	0.0	25.						CARD NO.	0202
REST	1	93	2	3	N	1			J	1.00	.10	0.0	50.						CARD NO.	0203
REST	2	93	2	3	N	1			J	1.00	.10	0.0	50.						CARD NO.	0204
SUIT C/O	1	94	2	3	N	1			J	.33	.05	10.0	80.	138.7					CARD NO.	0205
SUIT C/O	2	94	2	3	N	1			J	.33	.05	10.0	80.	138.7					CARD NO.	0206
M.R.H	1	95	2	3	N	1			J	1.0	.20	10.0	50.						CARD NO.	0207
M.R.H	2	95	2	3	N	1			J	1.0	.20	10.0	50.						CARD NO.	0208
R.H.P	1	96	1	3	N	1			J	1.0	.20	10.0	50.						CARD NO.	0209
R.H.P	2	96	2	3	N	1			J	1.0	.20	10.0	50.						CARD NO.	0210
EAT 3	1	97	2	3	N	1			J	.75	.17	10.0	70.	141.5					CARD NO.	0211
EAT 3	2	97	2	3	N	1			J	.75	.17	10.0	70.	141.5					CARD NO.	0212
RETIRE	1	98	2	3	N	1			J	.17	.05	0.0	50.						CARD NO.	0213
RETIRE	2	98	2	3	N	1			J	.17	.05	0.0	50.						CARD NO.	0214
SLEEP	1	99	2	1	N	1			J	8.00	0.0	0.0	80.	150.0					CARD NO.	0215
SLEEP	2	99	2	1	N	1			J	8.00	0.0	0.0	80.	150.0					CARD NO.	0216
RISE	1	100	2	3	N	1			J	.33	.05	0.0	20.						CARD NO.	0217
RISE	2	100	2	3	N	1			J	.33	.05	0.0	20.						CARD NO.	0218
EAT 1	1	101	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0219
EAT 1	2	101	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0220
HYGIENE	1	102	2	3	N	1			J	.33	.10	0.0	30.						CARD NO.	0221
HYGIENE	2	102	2	3	N	1			J	.33	.10	0.0	30.						CARD NO.	0222
SUIT UP	1	103	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0223
SUIT UP	2	103	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0224
EGRESS	1	104	2	9		2			J	.17	.05	15.0	100.	152.5				8.	CARD NO.	0225
EGRESS	2	104	2	9		2			J	.17	.05	15.0	100.	152.5				8.	CARD NO.	0226
LOOK	1		1	7		3		6									213		CARD NO.	0227
LOOK	2		1	7		3		5									213		CARD NO.	0228
ESA5	1	105	1	8		3				2.0	.5	30.	30.				214		CARD NO.	0229
ESA7	2	106	1	8		3				2.0	.5	30.	30.				215		CARD NO.	0230
SCIENCE	1	106A	1	8		3				2.5	.2	0.	0.				215		CARD NO.	0231
SCIENCE	2	106B	1	8		3				2.5	.2	0.	0.				215		CARD NO.	0232
INGRESS	1	107	2	9		2			J	.17	.05	15.0	100.	155.0					CARD NO.	0233
INGRESS	2	107	2	9		2			J	.17	.05	15.0	100.	155.0					CARD NO.	0234
UNSUIT	1	108	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0235
UNSUIT	2	108	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0236
EAT 2	1	109	2	3	N	1			J	.75	.17	10.0	70.	156.5					CARD NO.	0237
EAT 2	2	109	2	3	N	1			J	.75	.17	10.0	70.	156.5					CARD NO.	0238
REST	1	110	2	2	N	1			J	1.00	.10	0.0	50.						CARD NO.	0239

TABLE 2-4 (Continued)

REST	2	110	2	2	N	1		J	1.00	.10	0.0	50.						CARD NO. 0240
SCIENCE	1	111	1	3	N	1		J	5.00	.50	5.0	70.						CARD NO. 0241
SCIENCE	2	111	1	3	N	1		J	5.00	.50	5.0	70.						CARD NO. 0242
SUIT C/O	1	112	2	10	N	1		J	.33	.05	10.0	90.						CARD NO. 0243
SUIT C/O	2	112	2	10	N	1		J	.33	.05	10.0	90.						CARD NO. 0244
EAT 3	1	113	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0245
EAT 3	2	113	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0246
M,R,H	1	114	2	3	N	1		J	1.00	.20	10.0	50.						CARD NO. 0247
M,R,H	2	114	2	3	N	1		J	1.00	.20	10.0	50.						CARD NO. 0248
R,H,P	1	115	2	3	N	1		J	1.00	.20	50.0	50.						CARD NO. 0249
R,H,P	2	115	1	3	N	1		J	1.00	.20	50.0	50.						CARD NO. 0250
RETIRE	1	116	2	3	N	1		J	.17	.05	0.0	50.						CARD NO. 0251
RETIRE	2	116	2	3	N	1		J	.17	.05	0.0	50.						CARD NO. 0252
SLEEP	1	117	2	1	N	1		J	8.00	0.0	0.0	50.	174.0					CARD NO. 0253
SLEEP	2	117	2	1	N	1		J	8.00	0.0	0.0	50.	174.0					CARD NO. 0254
RISE	1	118	2	3	N	1		J	.33	.05	0.0	20.						CARD NO. 0255
RISE	2	118	2	3	N	1		J	.33	.05	0.0	20.						CARD NO. 0256
EAT 1	1	119	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0257
EAT 1	2	119	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0258
HYGIENE	1	120	2	3	N	1		J	.33	.10	0.0	30.						CARD NO. 0259
HYGIENE	2	120	2	3	N	1		J	.33	.10	0.0	30.						CARD NO. 0260
SUIT UP	1	121	2	3		1		J	.92	.10	10.0	100.						CARD NO. 0261
SUIT UP	2	121	2	3		1		J	.92	.10	10.0	100.						CARD NO. 0262
EGRESS	1	122	2	9		2		J	.17	.05	15.0	100.	176.5				8.	CARD NO. 0263
EGRESS	2	122	2	9		2		J	.17	.05	15.0	100.	176.5				8.	CARD NO. 0264
LOOK	1	122A	1	7		4	6									247		CARD NO. 0265
LOOK	2	122B	1	7		4	6									247		CARD NO. 0266
LSSM3	1	123	1	8		4 2		J	3.9	.5	20.	80.		6.0	8.0	248		CARD NO. 0267
LSSM3	2	123	1	8		4 2		J	3.9	.5	20.	80.		6.	8.	248		CARD NO. 0268
SCIENCE	1	123A	1	8		3			6.7	.5	0.	0.				248		CARD NO. 0269
SCIENCE	2	123B	1	8		3			6.7	.5	0.	0.				248		CARD NO. 0270
INGRESS	1	124	2	9		2		J	.17	.05	15.0	100.	183.2				2.	CARD NO. 0271
INGRESS	2	124	2	9		2		J	.17	.05	15.0	100.	183.2				2.	CARD NO. 0272
UNSUIT	1	125	2	3		1		J	.92	.10	10.0	100.						CARD NO. 0273
UNSUIT	2	125	2	3		1		J	.92	.10	10.0	100.						CARD NO. 0274
EAT 2	1	126	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0275
EAT 2	2	126	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0276
REST	1	127	2	2	N	1		J	1.00	.10	0.0	50.						CARD NO. 0277
REST	2	127	2	2	N	1		J	1.00	.10	0.0	50.						CARD NO. 0278
SCIENCE	1	128	1	3	N	1		J	.50	.20	0.0	25.						CARD NO. 0279
SCIENCE	2	128	1	3	N	1		J	.50	.20	0.0	25.						CARD NO. 0280
SUIT C/O	1	129	2	3	N	1		J	.33	.05	10.0	50.	187.0					CARD NO. 0281
SUIT C/O	2	129	2	3	N	1		J	.33	.05	10.0	90.	187.0					CARD NO. 0282
M,R,H	1	130	2	3	N	1		J	1.00	.20	10.0	50.						CARD NO. 0283
M,R,H	2	130	2	3	N	1		J	1.00	.20	10.0	50.						CARD NO. 0284
R,H,P	1	131	1	3	N	1		J	1.00	.20	50.0	50.						CARD NO. 0285
R,H,P	2	131	1	3	N	1		J	1.00	.20	50.0	50.						CARD NO. 0286
EAT 3	1	132	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0287
EAT 3	2	132	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0288
RETIRE	1	133	2	3	N	1		J	.17	.05	0.0	50.	190.0					CARD NO. 0289
RETIRE	2	133	2	3	N	1		J	.17	.05	0.0	50.	190.0					CARD NO. 0290
SLEEP	1	134	2	1	N	1		J	8.00	0.0	0.0	50.	198.0					CARD NO. 0291
SLEEP	2	134	2	1	N	1		J	8.00	0.0	0.0	80.	198.0					CARD NO. 0292
RISE	1	135	2	3	N	1		J	.33	.05	0.0	20.						CARD NO. 0293
RISE	2	135	2	3	N	1		J	.33	.05	0.0	20.						CARD NO. 0294
EAT 1	1	136	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0295
EAT 1	2	136	2	3	N	1		J	.75	.17	10.0	70.						CARD NO. 0296
HYGIENE	1	137	2	3	N	1		J	.33	.10	0.0	30.						CARD NO. 0297
HYGIENE	2	137	2	3	N	1		J	.33	.10	0.0	30.						CARD NO. 0298
SUIT UP	1	138	2	3		1		J	.92	.10	10.0	100.						CARD NO. 0299

TABLE 2-4 (Continued)

SUIT UP	2	138	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0300
EGRESS	1	139	2	9		2			J	.17	.05	15.0	100.	200.5				8.	CARD NO.	0301
EGRESS	2	139	2	9		2			J	.17	.05	15.0	100.	200.5				8.	CARD NO.	0302
ESA8	1	140	1	7		4	2	7		1.2	.2	20.	50.		2.0	2.0	281		CARD NO.	0303
LOOK	1		1	7		3		7									281		CARD NO.	0304
LOOK	2		1	7		3		7									281		CARD NO.	0305
ESA9	2	141	1	8		3	2			2.1	.3	10.	50.		.5	.5	282		CARD NO.	0306
SCIENCE	1282A		1	8		3				2.7	.2	0.	0.				282		CARD NO.	0307
SCIENCE	2282B		1	8		3				2.7	.2	0.	0.				282		CARD NO.	0308
INGRESS	1	142	2	9		2			J	.17	.05	15.0	100.	203.2				4.	CARD NO.	0309
INGRESS	2	142	2	9		2			J	.17	.05	15.0	100.	203.2				4.	CARD NO.	0310
UNSUIT	1	143	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0311
UNSUIT	2	143	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0312
EAT 2	1	144	2	3	N	1			J	.75	.17	10.0	70.	205.0					CARD NO.	0313
EAT 2	2	144	2	3	N	1			J	.75	.17	10.0	70.	205.0					CARD NO.	0314
REST	1	145	2	2	N	1			J	1.00	.10	0.0	50.						CARD NO.	0315
REST	2	145	2	2	N	1			J	1.00	.10	0.0	50.						CARD NO.	0316
SCIENCE	1	146	1	3	N	1			J	4.50	.50	0.0	70.						CARD NO.	0317
SCIENCE	2	146	1	3	N	1			J	4.50	.50	0.0	70.						CARD NO.	0318
SUIT C/O	1	147	2	10	N	1			J	.33	.05	10.0	80.						CARD NO.	0319
SUIT C/O	2	147	2	10	N	1			J	.33	.05	10.0	80.						CARD NO.	0320
EAT 3	1	148	2	3	N	1			J	.75	.17	10.0	70.	211.5					CARD NO.	0321
EAT 3	2	148	2	3	N	1			J	.75	.17	10.0	70.	211.5					CARD NO.	0322
M.R.H	1	149	2	3	N	1			J	1.00	.20	10.0	50.						CARD NO.	0323
M.R.H	2	149	2	3	N	1			J	1.00	.20	10.0	50.						CARD NO.	0324
R.H.P	1	150	2	3	N	1			J	1.00	.20	50.0	50.						CARD NO.	0325
R.H.P	2	150	1	3	N	1			J	1.00	.20	50.0	50.						CARD NO.	0326
RETIRE	1	151	2	3	N	1			J	.17	.05	0.0	50.	214.0					CARD NO.	0327
RETIRE	2	151	2	3	N	1			J	.17	.05	0.0	50.	214.0					CARD NO.	0328
SLEEP	1	152	2	1	N	1			J	8.00	0.0	0.0	30.	222.0					CARD NO.	0329
SLEEP	2	152	2	1	N	1			J	8.00	0.0	0.0	30.	222.0					CARD NO.	0330
RISE	1	153	2	3	N	1			J	.33	.05	0.0	20.						CARD NO.	0331
RISE	2	153	2	3	N	1			J	.33	.05	0.0	20.						CARD NO.	0332
HYGIENE	1	154	2	3	N	1			J	.33	.10	0.0	30.						CARD NO.	0333
HYGIENE	2	154	2	3	N	1			J	.33	.10	0.0	30.						CARD NO.	0334
EAT 1	1	155	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0335
EAT 1	2	155	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0336
SUIT UP	1	156	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0337
SUIT UP	2	156	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0338
EGRESS	1	157	2	9		2			J	.17	.05	15.0	100.	224.5					CARD NO.	0339
EGRESS	2	157	2	9		2			J	.17	.05	15.0	100.	224.5					CARD NO.	0340
LOOK	1		1	7		4		7									314		CARD NO.	0341
LOOK	2		1	7		4		7									314		CARD NO.	0342
ESA 10	1	158	1	8		3	2		J	2.7	.3	20.	80.		1.0	1.0	315		CARD NO.	0343
ESA 10	2	158	1	8		3	2		J	2.7	.3	20.	80.				315		CARD NO.	0344
ESA 11	1	159	1	8		3	2		J	2.7	.3	20.	80.		1.0	1.0	316		CARD NO.	0345
ESA 11	2	159	1	8		3	2		J	2.7	.3	20.	80.				316		CARD NO.	0346
SCIENCE	1159A		1	8		3				6.2	.5	0.	0.				316		CARD NO.	0347
SCIENCE	2159B		1	8		3				6.2	.5	0.	0.				316		CARD NO.	0348
INGRESS	1	160	2	9		2			J	.17	.05	15.0	100.	230.7					CARD NO.	0349
INGRESS	2	160	2	9		2			J	.17	.05	15.0	100.	230.7					CARD NO.	0350
UNSUIT	1	161	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0351
UNSUIT	2	161	2	3		1			J	.92	.10	10.0	100.						CARD NO.	0352
EAT 2	1	162	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0353
EAT 2	2	162	2	3	N	1			J	.75	.17	10.0	70.						CARD NO.	0354
REST	1	163	2	2	N	1			J	1.0	.10	0.0	50.						CARD NO.	0355
REST	2	163	2	2	N	1			J	1.0	.10	0.0	50.						CARD NO.	0356
SCIENCE	1	164	1	3	N	1			J	1.0	.40	0.0	50.						CARD NO.	0357
SCIENCE	2	164	1	3	N	1			J	1.0	.40	0.0	50.						CARD NO.	0358
SUIT C/O	1	165	2	10	N	1			J	.33	.05	10.0	80.						CARD NO.	0359

TABLE 2-4 (Continued)

SUIT C/O	2	165	2	10	N	1		J	.33	.05	10.0	80.					CARD NO.	0360
M.R.H	1	166	2	3	N	1		J	1.0	.20	10.0	50.					CARD NO.	0361
M.R.H	2	166	2	3	N	1		J	1.0	.20	10.0	50.					CARD NO.	0362
R.P.H	1	167	1	3	N	1		J	1.0	.20	50.0	50.					CARD NO.	0363
R.P.H	2	167	2	3	N	1		J	1.0	.20	50.0	50.					CARD NO.	0364
EAT 3	1	168	2	3	N	1		J	.75	.17	10.0	70.					CARD NO.	0365
EAT 3	2	168	2	3	N	1		J	.75	.17	10.0	70.					CARD NO.	0366
RETIRE	1	169	2	3	N	1		J	.17	.05	0.0	50.	238.0				CARD NO.	0367
RETIRE	2	169	2	3	N	1		J	.17	.05	0.0	50.	238.0				CARD NO.	0368
SLEEP	1	170	2	1	N	1		J	8.0	0.0	0.0	80.	246.0				CARD NO.	0369
SLEEP	2	170	2	1	N	1		J	8.0	0.0	0.0	80.	246.0				CARD NO.	0370
RISE	1	83	2	3	N	1		J	.33	.05	0.0	20.					CARD NO.	0371
RISE	2	83	2	3	N	1		J	.33	.05	0.0	20.					CARD NO.	0372
EAT 1	1	84	2	3	N	1		J	.75	.17	10.0	70.					CARD NO.	0373
EAT 1	2	84	2	3	N	1		J	.75	.17	10.0	70.					CARD NO.	0374
HYGIENE	1	85	2	3	N	1		J	.33	.10	0.0	30.					CARD NO.	0375
HYGIENE	2	85	2	3	N	1		J	.33	.10	0.0	30.					CARD NO.	0376
SUIT UP	1	86	2	3		1		J	.92	.10	10.0	100.					CARD NO.	0377
SUIT UP	2	86	2	3		1		J	.92	.10	10.0	100.					CARD NO.	0378
EGRESS	18711		2	9		2		J	.17	.05	15.0	100.	248.5			8.	CARD NO.	0379
EGRESS	28711		2	9		2		J	.17	.05	15.0	100.	248.5			8.	CARD NO.	0380
LOOK	1		1	7		4	7								348		CARD NO.	0381
LOOK	2		1	7		4	7								348		CARD NO.	0382
LSSM 4	18811		1	8		4	2		3.9	.5	20.	80.		8.0 8.0	349		CARD NO.	0383
SCIENCE	1		1	8		3			6.7	.5	0.	0.			349		CARD NO.	0384
SCIENCE	2		1	8		3			5.7	.5	0.	0.			349		CARD NO.	0385
INGRESS	1	89	2	9		2		J	.17	.05	15.0	100.	255.2				CARD NO.	0386
INGRESS	2	89	2	9		2		J	.17	.05	15.0	100.	255.2				CARD NO.	0387
UNSUIT	1	90	2	3		1		J	.92	.10	10.0	100.					CARD NO.	0388
UNSUIT	2	90	2	3		1		J	.92	.10	10.0	100.					CARD NO.	0389
EAT 2	19111		2	3	N	1		J	.75	.17	10.0	70.	256.8				CARD NO.	0390
EAT 2	29111		2	3	N	1		J	.75	.17	10.0	70.	256.8				CARD NO.	0391
SCIENCE	1	92	2	3	N	1		J	.50	.20	0.0	25.					CARD NO.	0392
SCIENCE	2	92	2	3	N	1		J	.50	.20	0.0	25.					CARD NO.	0393
REST	1	93	2	3	N	1		J	1.00	.10	0.0	50.					CARD NO.	0394
REST	2	93	2	3	N	1		J	1.00	.10	0.0	50.					CARD NO.	0395
SUIT C/O	19411		2	3	N	1		J	.33	.05	10.0	90.	258.7				CARD NO.	0396
SUIT C/O	29411		2	3	N	1		J	.33	.05	10.0	90.					CARD NO.	0397
M.R.H	1	95	2	3	N	1		J	1.0	.20	10.0	50.					CARD NO.	0398
M.R.H	2	95	2	3	N	1		J	1.0	.20	10.0	50.					CARD NO.	0399
R.H.P	1	96	1	3	N	1		J	1.0	.20	10.0	50.					CARD NO.	0400
R.H.P	2	96	2	3	N	1		J	1.0	.20	10.0	50.					CARD NO.	0401
EAT 3	19711		2	3	N	1		J	.75	.17	10.0	70.	261.5				CARD NO.	0402
EAT 3	29711		2	3	N	1		J	.75	.17	10.0	70.	261.5				CARD NO.	0403
RETIRE	1	98	2	3	N	1		J	.17	.05	0.0	50.					CARD NO.	0404
RETIRE	2	98	2	3	N	1		J	.17	.05	0.0	50.					CARD NO.	0405
SLEEP	19911		2	1	N	1		J	8.00	0.0	0.0	80.	270.0				CARD NO.	0406
SLEEP	29911		2	1	N	1		J	8.00	0.0	0.0	80.	270.0				CARD NO.	0407
RISE	1	49	2	3	N	1		J	.33	.05	0.0	20.					CARD NO.	0408
RISE	2	49	2	3	N	1		J	.33	.05	0.0	20.					CARD NO.	0409
EAT 1	1	50	2	3	N	1		J	.75	0.17	10.0	70.					CARD NO.	0410
EAT 1	2	50	2	3	N	1		J	.75	0.17	10.0	70.					CARD NO.	0411
HYGIENE	1	51	2	3	N	1		J	.33	0.10	0.0	30.					CARD NO.	0412
HYGIENE	2	51	2	3	N	1		J	.33	0.10	0.0	30.					CARD NO.	0413
SUIT UP	1	52	2	3		1		J	.92	0.10	10.0	100.					CARD NO.	0414
SUIT UP	2	52	2	3		1		J	.92	0.10	10.0	100.					CARD NO.	0415
EGRESS	15311		2	9		2		J	.17	.05	15.0	100.	272.5				CARD NO.	0416
EGRESS	25311		2	9		2		J	.17	.05	15.0	100.	272.5				CARD NO.	0417
LOOK	1		1	7		4	7								381		CARD NO.	0418
LOOK	2		1	7		4	7								381		CARD NO.	0419

TABLE 2-4 (Continued)

LSSM 3	15411	1 8		4	2	J	3.0	.5	20.	90.		6.0	8.0	382		CARD NO. 0420
LSSM3	25411	1 8		4	2	J	3.9	.5	20.	90.		6.	8.	382		CARD NO. 0421
SCIENCE	1	1 8		3			6.7	.5	0.	0.				382		CARD NO. 0422
SCIENCE	2	1 8		3			6.7	.5	0.	0.				382		CARD NO. 0423
INGRESS	1 55	1 9		2		J	.17	0.05	15.0	100.	279.2				2.	CARD NO. 0424
INGRESS	2 55	2 9		2		J	.17	0.05	15.0	100.	279.2				2.	CARD NO. 0425
UNSUIT	1 56	2 3		1		J	.92	0.10	10.0	100.						CARD NO. 0426
UNSUIT	2 56	2 3		1		J	.92	0.10	10.0	100.						CARD NO. 0427
EAT 2	1 57	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0428
EAT 2	2 57	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0429
SCIENCE	1 A58	1 3	N	1		J	.5	0.2	0.0	25.						CARD NO. 0430
SCIENCE	2 A58	1 3	N	1		J	.5	0.2	0.0	25.						CARD NO. 0431
REST	1 58	2 2	N	1		J	1.0	0.1	0.0	50.						CARD NO. 0432
REST	2 58	2 2	N	1		J	1.0	0.1	0.0	50.						CARD NO. 0433
SUIT C/O	15911	210	N	1		J	.33	.05	10.0	90.	283.0					CARD NO. 0434
SUIT C/O	25911	210	N	1		J	.33	.05	10.0	90.	283.0					CARD NO. 0435
M.R.H	1 60	210	N	1		J	1.0	0.2	10.0	50.						CARD NO. 0436
M.R.H	2 60	210	N	1		J	1.0	0.2	10.0	50.						CARD NO. 0437
R.H.P	2 61	2 3	N	1		J	1.0	0.2	50.0	50.						CARD NO. 0438
R.H.P	1 61	1 3	N	1		J	1.0	0.2	50.0	50.						CARD NO. 0439
EAT 3	1 62	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0440
EAT 3	2 62	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0441
RETIRE	16311	2 3	N	1		J	.17	.05	0.0	50.	286.0					CARD NO. 0442
RETIRE	26311	2 3	N	1		J	.17	.05	0.0	50.	286.0					CARD NO. 0443
SLEEP	16411	2 1	N	1		J	8.00	0.0	0.0	90.	294.0					CARD NO. 0444
SLEEP	26411	2 1	N	1		J	8.0	0.0	0.0	90.	294.0					CARD NO. 0445
RISE	1 49	2 3	N	1		J	.33	.05	0.0	20.						CARD NO. 0446
RISE	2 49	2 3	N	1		J	.33	.05	0.0	20.						CARD NO. 0447
EAT 1	1 50	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0448
EAT 1	2 50	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0449
HYGIENE	1 51	2 3	N	1		J	.33	0.10	0.0	30.						CARD NO. 0450
HYGIENE	2 51	2 3	N	1		J	.33	0.10	0.0	30.						CARD NO. 0451
SUIT UP	1 52	2 3		1		J	.92	0.10	10.0	100.						CARD NO. 0452
SUIT UP	2 52	2 3		1		J	.92	0.10	10.0	100.						CARD NO. 0453
EGRESS	15312	2 9		2		J	.17	.05	15.0	100.	296.5					CARD NO. 0454
EGRESS	25312	2 9		2		J	.17	.05	15.0	100.	296.5					CARD NO. 0455
LOOK	1	1 7		4	7									414		CARD NO. 0456
LOOK	2	1 7		4	7									414		CARD NO. 0457
LSSM 3	15412	1 8		4	2	J	3.9	.5	20.	90.		6.0	8.0	415		CARD NO. 0458
LSSM3	25412	1 8		4	2	J	3.9	.5	20.	90.		6.	8.	415		CARD NO. 0459
SCIENCE	1	1 8		3			6.7	.5	0.	0.				415		CARD NO. 0460
SCIENCE	2	1 8		3			6.7	.5	0.	0.				415		CARD NO. 0461
INGRESS	1 55	1 9		2		J	.17	0.05	15.0	100.	303.2				2.	CARD NO. 0462
INGRESS	2 55	2 9		2		J	.17	0.05	15.0	100.	303.2				2.	CARD NO. 0463
UNSUIT	1 56	2 3		1		J	.92	0.10	10.0	100.						CARD NO. 0464
UNSUIT	2 56	2 3		1		J	.92	0.10	10.0	100.						CARD NO. 0465
EAT 2	1 57	2 3		1		J	.75	0.17	10.0	70.						CARD NO. 0466
EAT 2	2 57	2 3		1		J	.75	0.17	10.0	70.						CARD NO. 0467
SCIENCE	1 A58	1 3	N	1		J	.5	0.2	0.0	25.						CARD NO. 0468
SCIENCE	2 A58	1 3	N	1		J	.5	0.2	0.0	25.						CARD NO. 0469
REST	1 58	2 2	N	1		J	1.0	0.1	0.0	50.						CARD NO. 0470
REST	2 58	2 2	N	1		J	1.0	0.1	0.0	50.						CARD NO. 0471
SUIT C/O	15912	210	N	1		J	.33	.05	10.0	90.	307.0					CARD NO. 0472
SUIT C/O	25912	210	N	1		J	.33	.05	10.0	90.	307.0					CARD NO. 0473
M.R.H	1 60	210	N	1		J	1.0	0.2	10.0	50.						CARD NO. 0474
M.R.H	2 60	210	N	1		J	1.0	0.2	10.0	50.						CARD NO. 0475
R.H.P	1 61	1 3	N	1		J	1.0	0.2	50.0	50.						CARD NO. 0476
R.H.P	2 61	2 3	N	1		J	1.0	0.2	50.0	50.						CARD NO. 0477
EAT 3	1 62	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0478
EAT 3	2 62	2 3	N	1		J	.75	0.17	10.0	70.						CARD NO. 0479

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Los Angeles, California

TABLE 2-4 (Continued)

```
RETIRE    16312 2 3 N 1       1  .17   .05   0.0  50.       310.0
RETIRE    26312 2 3 N 1       J  .17   .05   0.0  50.       310.0
SLEEP     16412 2 1 N 1       J 50.0   .0    0.0  0.        318.0
SLEEP     26412 2 1 N 1       1  8.0   .0    0.0  0.        318.0

/PRIORITY LIST
X
X               G   S S T P                                      DIST
X               P C H A R L J                       MILE          FROM  OTHER
X TASK          E A I F A   I  AVG   TIME  T-UP  PCNT    POST  TASK LAST  OPER    OXGN
X NAME     NUM  C T T E V   T  TIME  DEV   TIME  ESS     TIME  DIST TASK  TASK    SUPP
X
ESA1            2 7   3 1 1    1.0   .15   75.   10.           .5    .5
ESA2            1 7   3 1 2    2.0   .5    20.   10.           0.    0.
LSS12           1 7   4 2 3    4.9   .5    10.   10.           1.    1.0
ESA4            1 7   3 2 4    2.6   .5    20.   10.          1.25  1.25
ESA5            1 7   3 2 5    2.4   .5    20.   10.           2.0   2.0
LSS14           1 7   4 2 5    3.9   .5    20.   10.           8.0   8.0
ESA3            1 7   3 2 7    1.3   .5    50.   10.           2.0   2.0

/PLOTS
X
X DEP  IND          UNITS     NAME                     NAME                     UNITS
X VAR  VAR          (DEP)     (DEP)                    (IND)                    (IND)
X
    1   18                    P SCI TASKS COMP         OPERATOR SPEED
    2   18                    AVG SAFETY LEVEL         OPERATOR SPEED
    3   13                    SLEEP TIME               OPERATOR SPEED
    5   18                    MISC. TIME              OPERATOR SPEED
    8   18                    TRAVEL TIME              OPERATOR SPEED
    9   13                    PL TIME                  OPERATOR SPEED
   23   18                    SAFETY VALUE             OPERATOR SPEED

/INTERRUPT
1  .08        .33
2  .20        .4
3  .02        .6
4  .50      .5

/OPERATOR
X
XNO SPEED PROF 1    PROF 2    AWAKE TIME      SPECIALITY
X
1  1.0    .75       .75       0.                 1
2  1.0    .75       .75       0.                 1

/MISCELLANEOUS
            1           10  0.      .8       6.0        0.      318.
 2.         3.0          .5         1.       1.        .3       1.        1.
02

/OPERATOR
XNO SPEED PROF 1    PROF 2    AWAKE TIME      SPECIALITY
1   .6    .75       .75       0.                 1
2   .6    .75       .75       0.                 1

/OPERATOR
XNO SPEED PROF 1    PROF 2    AWAKE TIME      SPECIALITY
```

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CARD NO.  0480
CARD NO.  0481
CARD NO.  0482
CARD NO.  0483
CARD NO.  0484
CARD NO.  0485
CARD NO.  0486
CARD NO.  0487
CARD NO.  0488
CARD NO.  0489
CARD NO.  0490
CARD NO.  0491
CARD NO.  0492
CARD NO.  0493
CARD NO.  0494
CARD NO.  0495
CARD NO.  0496
CARD NO.  0497
CARD NO.  0498
CARD NO.  0499
CARD NO.  0500
CARD NO.  0501
CARD NO.  0502
CARD NO.  0503
CARD NO.  0504
CARD NO.  0505
CARD NO.  0506
CARD NO.  0507
CARD NO.  0508
CARD NO.  0509
CARD NO.  0510
CARD NO.  0511
CARD NO.  0512
CARD NO.  0513
CARD NO.  0514
CARD NO.  0515
CARD NO.  0516
CARD NO.  0517
CARD NO.  0518
CARD NO.  0519
CARD NO.  0520
CARD NO.  0521
CARD NO.  0522
CARD NO.  0523
CARD NO.  0524
CARD NO.  0525
CARD NO.  0526
CARD NO.  0527
CARD NO.  0528
CARD NO.  0529
CARD NO.  0530
CARD NO.  0531
CARD NO.  0532
CARD NO.  0533
CARD NO.  0534
CARD NO.  0535
CARD NO.  0536
CARD NO.  0537
CARD NO.  0538
CARD NO.  0539
```

3. Outside — time delay and emergency return

4. Repair — time required during scheduled repair period

The first type may occur during any task executed inside the shelter (not including ingress/egress tasks). A time delay is introduced in the schedule whenever this type of interrupt occurs. Since this tends to increase the astronaut's stress and his response capability, it will modify experimental task time.

The second and third interrupt types may occur any time an astronaut is outside the shelter. A type 2 interrupt again introduces a time delay into the normal sequence of task execution. On the other hand, a type 3 interrupt causes a disruption in the schedule as well as a time delay. In this case, the astronaut is forced to return to the shelter prematurely and to bypass remaining tasks in the base schedule. Computation of travel time for the return is based on the distance away from the shelter for the task and the rate of travel in the emergency mode. The actual interrupt time could account for a rescue trip by the other astronaut, time for minor equipment repair, or additional time required for return due to a slower-than-average travel rate.

The fourth interrupt represents time spent in repair during schedule repair periods. Any time a repair task is encountered in the base schedule, a draw is made to determine if there is anyting to repair at this time. If there is, a time for repair is drawn from the input time distribution.

Two inputs are required for each interrupt category:

- o Probability of occurrence of the appropriate interrupt corresponding to a given task

- o Median time duration for the delay induced by the interrupt.

In this study the interrupts were introduced with a frequency which would result in about one malfunction per mission, which would cause an emergency return while doing surface exploration, and one incident per day which would cause a schedule delay. These problems were introduced into the schedule as random events with variable time requirements. Schedule delays of 1/2-, 1-, and 3-hr mean time were investigated. (Preliminary information indicates that interruptions up to 1/2 hr were a mission certainty, whereas interruptions between 1/2 to 3 hr had a probability of 0.016 per mission.)

The interrupt application is discussed further in Section 3, Case 2, in connection with its initial application in this report.

PARAMETRIC VARIATIONS

In addition to the analysis of a normal schedule with and without interrupts, various vehicle/astronaut speed conditions were assumed. The various conditions represent effects the lunar environment or vehicle design may have on the ELS/LSSM mission. Normal astronaut speed and achievement of design vehicle rate are found in Case 1 of Section 3.

Many of the results reported herein were conducted independently by Honeywell. They are introduced into the report to indicate more comprehensively the result of varying performance and contingency situations.

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pages 2-17 through 2-24

TABLE 2-12

THREE-MAN TIMELINES FOR FIRST LSSM SORTIE (APPLIES TO ALL MISSIONS)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG.	Comments
1	Outside shelter	10	Check out and load LSSM	Spare PLSS	29	Carried from shelter to LSSM	L	
2	LSSM	1	Climb to driver's seat of LSSM	---	---	---	L	Includes strapping into seat
3	LSSM	10	Drive on heading, 1 km	Control stick	---	---	S	
4	Surface	25	Set up, operate gravimeter, NMP; take surface samples; plot location of samples; make on-spot preliminary analysis of samples	Gravimeter NMP *Geological samples* kit, surveying staff	5.9 15.5 2.7 13.0	Set up on surface, turn on. Carry away from vehicle 25 m. Chip samples with hammer, collect. Held in hand. Measure of height and depth of surface irregularities	L L L L	Several different measurements to make. Note good location for ESS emplacement.
5	LSSM	11	Drive 1 km	As in 2, 3	---	---	L-S	
6	Surface	25	Same as 4, except survey marker must be implanted beside LSSM.	As in 4 Survey marker	0.9	Same as 4 Pound into lunar soil with mallet.	L	Marker must be set if last marker or shelter will be out of sight at next stop - unlikely for this short sortie
7	LSSM	11	Drive 1 km			Same as above	S	
8	Surface	25	Experiments			Same as above	L	
9	LSSM	11	Drive 1 km			Same as above	S	
10	Surface	25	Experiments			Same as above	L	
11	LSSM	11	Drive final distance to ELS			Same as above	S	
12	Surface outside shelter	15	Unload geo. samples and used PLSS; transport to shelter	Geo. sample boxes Used PLSS	1.8 24	Carried to shelter from LSSM (3 m)	L	One astronaut must also hook up LSSM for recharge if batteries instead of RTG are used.

Buffer time 20 min.

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG.	Comments
1	Outside Shelter	10	Same as Astronaut I	2nd PLSS	29	Same as Astronaut I	L	Concurrent with No. 1 activity
2	LSSM	1	Climb to pass. seat	---	---	---	L	Includes strapping into seat.
3	LSSM	10	Turn on magnetometer	Magnetometer mounted on LSSM	4	Turn on, check	S	Does not require constant attention.
4	LSSM	25	Plot location, take photographic and radiographic pictures of surrounding area	Topo surveying gear Photometry and radiometry gear	23 39	Aim, note readings verbally to ELS; take about 8 different exposures of each object, field, or sky segment chosen; 8 different cameras involved.	S S	All used on LSSM, from seated position. Some pencil work required on maps.
5	LSSM	11	As in 2, 3.	---	---	---	S	Turns on magnetometer as in 3.
6	LSSM	25	Same as 4	---	---	---	S	As in 4.
7	LSSM	11	As in 2, 3, some map work.	---	---	Same	---	Map work while moving, if possible. Also photographs from photography equipment while moving.
8	LSSM	25	As in 4.	---	---		---	
9	LSSM	11	As in 2, 3, some map work	---	---	---	---	
10	LSSM	25	As in 4.	---	---	---	---	
11	LSSM	11	As in 2, 3.	---	---	---	---	
12	Surface outside shelter	15	Same as Astronaut I; also returns photo. and radiometry equipment.	Used PLSS Film packs	24 1.8	Same as Astronaut I.	L	Concurrent with Astronaut I activity

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG.	Comments
1	Shelter	10	Monitor No. 1 and No. 2	Visual, radio contact	---	---	S	Keep track of checkout, read checkout list.
2	Shelter	1	Some analysis, equipment setup	Microscope, pestle, slides	2.3	By hand	S	
3	Shelter	20	Continue analysis equipment setup	Microscope, pestle, slides	2.3	By hand	ML	
4	Shelter	15	Locate LSSM with range-finder. Monitor stop. Plot location, elevation of LSSM. Record data.	Visual, radio	---	From seated position.		Involves plotting on maps, switching data recording equipment to correct channel, independent ranging with laser theodolite.
5	Shelter	21	Analysis of samples	As in 3	---	From seated position.	S	Using equipment setup in 3.
6	Shelter	15	As in 4.	---	---	---	S	All from seated position.
7	Shelter	21	Analysis of samples	---	---	---	S	
8	Shelter	15	As in 4				S	
9	Shelter	21	Write-up of analysis of results				S	
10	Shelter	15	As in 4	---	---	---	S	
11	Shelter	21	Write up; take down analysis equipment	---	---	---	ML	
12	Shelter	5	Monitor crew return, air lock functioning	Same as 1			ML, S	

NOTES ON THIS SORTIE

(1) All measurements are in kilograms and kilometers.

(2) This is the first sortie, on Lunar Maria with few distinguishing features. Its main purpose is training of the LSSM crew and procedures evaluation. This timeline applies to all lunar missions.

(3) The same measurements are made at all stops on this sortie. No scientific equipment is emplaced on the surface.

(4) The astronaut who dismounts at each stop sets up the gravimeter, walks 25 m away from the LSSM with the nuclear measurements package, sets it up, makes nuclear measurements, makes a 60 m reconnoiter around the NMP collecting samples, returns to the LSSM, and repacks the gravimeter and NMP. This sequence is the same for all LSSM sorties.

(5) Since total mission time with buffer period is 3:20, no PLSS exchange will be necessary. Extra PLSS's are carried as a safety measure only.

(6) PLSS's, if not used, can probably be left on LSSM for next mission.

SORTIE SUMMARY

Range . . . . 5 km
Radius . . . . 2 km
Time . . . . 3 hours
+
Buffer . . . . 20 min
Total time 3:20
Stops . . . . Four at 25 minutes each

MEASUREMENTS TAKEN

Continuous

(1) Magnetism
(2) Sample collection

At Each Stop

(1) Gravity gradient
(2) Nuclear measurements
(3) Range and bearing to ELS and geological formations
(4) Photography and radiometry
(5) Height - depth of local surface irregularities
(6) Plot significant features on map
(7) Sample photography and collection

ROUTE

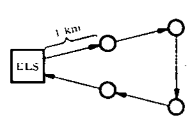

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TABLE 2-13

THREE-MAN TIMELINES FOR SECOND LSSM SORTIE (APPLIES TO ALL MISSIONS EXCEPT ALPHONSUS LSSM - LSV; EXPANDED SATELLITE ESS SORTIE IS FOR EXPANDED ESS MISSION)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	15	Check out and load LSSM	PLSS-power pkg. for ESS	29 34 102	Transported from ELS to LSSM	L L L	One man can carry ESS, two men carry to LSSM
2	LSSM	11	Drive 1 km	Control stick	---	By hand	S	Must scan for correct ESS area
3	Surface	20	Unload 3 m. drill - set up	3 m. drill	14	Lift off LSSM, set on ground	L	Must check area for suitable location
4	Surface	150	Drill 3 m. hole; help with setup of ESS	3 m. drill ESS	14 102	Feed bit through drill. Lift ESS from LSSM to ground near 3 m. drill. Main package unfolded, sensors checked and aligned, power plugged in.	L VL	Must spend 50 min. with 3 m. drill during 150-min. drilling time. Monitor drill progress at 10-minute intervals.
5	Surface	30	Replace PLSS	Spare PLSS	29	Strapped on from LSSM	L	Includes new PLSS checkout time
6	Surface	15	Pack up 3 m. drill, load on LSSM	3 m. drill	14	Loaded by hand	L	Leave drill corings for Astronaut II to load
7	Surface	10	Final check of ESS system	Transceiver on shelter	--	--	S	Corrections may have to be made to instruments and connections
8	LSSM	11	Drive to shelter	Control stick	--	By hand	S	
9	Surface outside shelter	15	Unload used PLSS, 3 m. drill	PLSS, 3m. drill	24 14	Carried to shelter	L	Three trips, LSSM-shelter, shelter-LSSM, LSSM-shelter
	Buffer time	35 minutes						

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	15	Checkout	PLSS-3 m. drill ESS	129 14 102	Transported from shelter to LSSM	L	Included in Astronaut I's equipment list
2	LSSM	11	Prepare ESS for unloading	---	---	From seated position	S	Minor adjustments to ESS while riding on LSSM
3	Surface	20	Unload 34 kg. portion of ESS	Power pkg. for ESS	34	Set up 25 m. from drill	L	
4	Surface	150	Continue setup of ESS pkg. Unload main ESS with help of Astronaut I. Setup of ESS.	ESS All parts of ESS	102 135	Emplace, turn on power supply. Lift ESS from LSSM to ground. Carry two instruments away from main ESS and emplace on ground.	L VL L	Lifting ESS on or off LSSM takes 4 minutes of high effort
5	Surface	30	Aid Astronaut I in PLSS Checkout		29	Strap on from rack on LSSM	L	
6	Surface	15	Insert sensors from ESS in drill hole. Collect drill corings, place in sample bags	Sensors from main ESS	2.3 4.5	Pushed into hole by hand. Insert 75-cm lengths in tubes provided on LSSM	L L	
7	Surface	10	Same as Astronaut I	Same as Astronaut I	--	Same	S	
8	LSSM	11	Ride LSSM	---	---	---	S	
9	Surface outside shelter	15	Unload used PLSS	PLSS	24	Carried by hand	L	

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Shelter	15	Monitor outside activity	Visual, radio contact	---	---	S	Read check list to driver, check ESS radio operating correctly
2	Shelter	11	Earth data transmittal	Radio	---	By hand-seated	S	Also monitor LSSM
3	Shelter	10	Monitor LSSM	Laser range-finder	---	By hand-standing up behind rangefinder	ML	Determine position of 3 m. drill, plot
4	Shelter	120	Earth data transmittal. Perform some geological analysis. Spot monitoring of LSSM Crew.	Radio Mass Spectrometer Biotelemetry system	---	From seated position	S	Analysis of samples from sortie No. 1. Check on work rate during high energy tasks.
5	Shelter	30 20	Begin check of ESS functions. Complete check, read off checklist	ESS transceiver ESS checklist	---	From seat. From seat. May have to move about to check ESS functions	S	
6	Shelter	25	Complete scientific task.	Mass spectrometer	---	Seated	S	
7	Shelter	10	OK final check	Transciever	---	Standing	S	
8	Shelter	11	Prepare PLSS recharge equipment	---	---	Sitting	S	
9		15	Monitor crew return, air-lock functioning					

NOTES ON THIS SORTIE

(1) *Total sortie devoted to emplacing main ESS 1 km from shelter.*

(2) Maximum time is 5 hours, 12 minutes. This means Sortie 1 is a poor candidate for the same day as Sortie 2. Local ESA could be performed on the same day, though.

(3) For emplacing satellite ESS's, activities 2 and 8 are: 61 min. drive 6 km; 4 and 6 are reduced to 5 min each. Buffer time is increased to 40 min. Total mission time is 6 hours 32 min.

SORTIE SUMMARY

Range	2 km	(12 km for satellite ESA emplacement)
Radius	1 km	(6 km for satellite ESA emplacement)
Time	4:42	(5:52 for satellite ESA emplacement)
+		
Buffer	:35	(:40 for satellite ESA emplacement)
Total time	- 5:12	(6:32 for satellite ESA emplacement)
Stops	- 1 for 225 minutes	

MEASUREMENTS TAKEN

Continuously

Sample collection on return trip

At the Stop

(1) Drill core collection
(2) Plot of position of ESS on LSSM map

ROUTE

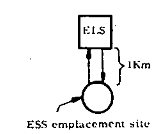

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TABLE 2-14

THREE-MAN TIMELINES FOR THIRD LSSM SORTIE (APPLIES TO ALL MISSIONS)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside near shelter	10	Checkout and load LSSM	Spare PLSS, Gas Analyzer	29 4.5	Carried from ELS to LSSM in two trips	VL	Gas Analyzer stowed on LSSM for removal during sortie stops.
2	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Includes time to get on LSSM. Drives on heading to first stop.
3	Surface	15	Set up gravimeter, turn on, operate NMP Collect geo. samples, plot location of geo. samples, measure terrain irregularities, return gravimeter to LSSM	Gravimeter, NMP Geo. sample kit, Verbal report to ELS, Surveying Staff, Gravimeter	5.9 15 2.7 0 13 5.9	Set up on surface, turn on. Carry 25 m. from LSSM, make measurements, bring back. Pick up samples, place in containers. Describe location over radio. Carry back to LSSM.	L S L VL	Measures height of surface, holes. Also can take pictures of sample location.
4	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Continue on heading
5	Surface	15	As in 3	---	---	---	L	---
6	LSSM	21	Drive 3 km	Control stick	---	By hand	S	Continue on heading
7	Surface	25	As in 3, and gas analysis	Same Gas Analyzer (mass spectrometer)	4.5	Set up spectrometer near gas source or on ground. Then take down readings (AC waveform digitalized to 4 bits of information)	L ML S	Measurement takes 10 min. after regular measurements are made
8	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Turn onto far leg of sortie
9	Surface	25	As in 7	Same	---	By hand	VL, L	---
10	LSSM	21	Drive 2 km	Control stick	---	By hand	S	Continue on far leg
11	LSSM	30	PLSS exchange	Spare PLSS	29	Put on from rack of LSSM	L, VL	Also help Astronaut II don PLSS
12	Surface	15	As in 3	Same	---	---	VL, L	No gas analysis planned
13	LSSM	21	Drive 2 km	---	---	---	S	Turn to shelter
14	Surface	15	As in 3	---	---	---	VL, L	
15	LSSM	21	Drive 2 km				S	Continue to shelter
16	Surface	15	As in 3				VL, L	
17	LSSM	21	Drive 2 km				S	Drive remaining distance to shelter
18	Outside shelter	15	Unload LSSM, transport gear to shelter	Used PLSS Gas Analyzer Geo. samples	24 4.5 4.5	Carry to ELS in 3 round trips	VL L	

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside near shelter	10	Load LSSM, assist Astronaut I in checkout.	Spare PLSS, Penetrometer, surface electrical and radiometry pkg	29 2.7 1.5 3.2	Carried from ELS to LSSM in 3 trips	VL L L	Instruments constitute In Situ measurements pkg. Stowed on LSSM near gas Analyzer.
2	LSSM	21	Sample collection Magnetometer activation	Sample scoop Magnetometer	0.2	Scoop samples by hand - turn on Magnetometer	S S	Samples collected if interesting ones appear enroute. Magnetometer performance monitored. Note readings verbally to ELS. Mark on map. Survey gear is fixed to LSSM. Some cameras are hand-held, others are mounted on LSSM.
3	Surface	15	Plot location of LSSM *Take photos and spectrographs* Modify map Install survey marker	Laser rangefinder *and theodolite* Photography and radiometry gear Map and pen	23 39 0.9	Take a fix on last *marker* About 8 different exposures of each object, area or sky segment. Plot location on map. Pounded into surface.	S ML S S L	
4	LSSM	21	As in 2	---	---	---	--	---
5	Surface	15	As in 3	---	---	---	--	---
6	LSSM	21	As in 2	---	---	---	--	---
7	Surface	25	As in 3, and In Situ measurements Surface electrical pkg.	Same Penetrometer Radiometry pkg.	2.7 1.5 3.2	Set on surface, trigger, take readings. Insert electrodes into surface, then take readings. Take reflectance readings.	ML ML	In Situ measurements are used to determine penetration distance, bulk density, reflectance properties, electrical conductivity and dielectric constant. Each series takes about 20 min so multi-band photo and radiometry task will be curtailed. Continue to collect samples.
8	LSSM	21	As in 2	---	---		S	
9	Surface	25	As in 7	Same	---	---	L, S	
10	LSSM	21	As in 2	Same	---	---	S	
11	LSSM	30	PLSS exchange	Spare PLSS	29	Put on from rack on LSSM	VL, L	Also help Astronaut I don PLSS
12	Surface	15	As in 3	---	---	---	ML, S	No In Situ measurements
13	LSSM	21	As in 2		---	---	S	
14	Surface	15	As in 3	---	---	---	ML, S	
15	LSSM	21	As in 2				S	
16	Surface	15	As in 3				ML, S	
17	LSSM	21	As in 2				S	
18	Outside shelter	15	Unload LSSM, transport gear to shelter	Used PLSS-In Situ pkg., film pkg.	24 39 1.8	Carry to ELS in 2 round trips	VL VL	

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Shelter	10	Monitor egress, read LSSM checklist	Visual, Radio	---	Check communications system and data transmittal equipment	S S	Also notify earth that sortie has begun.
2	Shelter	26	Set up geological equipment	Petrographic analysis kit, microscope, sections, oil baths	6.8	Set up on shelter work table	ML S	
3	Shelter	10	Monitor and record comments by Astronauts I and II; plot LSSM location	Radio Laser rangefinder and theodolite	--- 23	From seat at worktable Must get up and aim through window	ML	
4	Shelter	26	Continue geological analysis	---	---	---	--	---
5	Shelter	10	As in 3	---	---	---	--	---
6	Shelter	26	Put away geo. analysis gear. Conduct ESS checkout.	Geo. equipment	6.8	---	--	ESS checkout - involves testing data channels, sensor performance, power
7	Shelter	20	Monitor LSSM, record gas analysis and In Situ results. Plot LSSM position	Radio communication channels. Laser rangefinder-theodolite	23	From seat. From window if LSSM still visible; otherwise use LSSM reported position	S ML	
8	Shelter	26	Earth report - systems checkout	Radio	---	From seated position	S	Check life support systems
9	Shelter	20	As in 7, and begin sample packaging		---	Sort samples and package them	S	
10	Shelter	26	Complete sample packaging	Sample pkg.	---	From seated position	S	
11	Shelter	30	Checkout packaging PLSS exchange	Radio, biotelemetry system	---	From seat	S	Check comm., read PLSS checklist
12	Shelter	10	As in 3	---	---	---	ML, S	
13	Shelter	26	Begin film analysis from previous sortie	---	---	Seated-analyze and package film	S	
14	Shelter	10	As in 3	---	---		S	
15	Shelter	26	Film analysis				S	
16	Shelter	10	As in 3				S	
17	Shelter	21	Store equipment-ready PLSS recharge equipment				ML	
18	Shelter	15	Monitor airlock LSSM activity					

Buffer period 40 minutes

NOTES ON THIS SORTIE

(1) This is the standard 6-hour scientific measurements and sample collection sortie which was scheduled for 8 out of 12 LSSM sorties on the four baseline missions.

(2) Twenty extra minutes have been added to the timeline to make gas analysis and in situ measurements. These occur on 2 or 3 of the 8 sorties. Other sorties would be 20 minutes shorter.

(3) The revised timeline of this sortie, based on workload estimates and task times reported in the NASA Guidelines, makes allowance for 7 15-minute *stops enroute instead of 11 5-minute and 6 10-minute stops as specified by* existing sortie schedules.

(4) Stops will be at points of geological interest, such as in Dark Halo material, crater wall-floor contact areas, red-blue contact lines, Fra Mauro formations, or fumaroles. The 2-km distance between stops used in this timeline is intended only as an average distance.

(5) PLSS exchange will occur when about 45 minutes of life-support expendibles are left in the PLSS in use. This can happen anywhere from 2 to 4 hours into the sortie.

(6) Driving times are based on an average speed of 6 kmh, with 1 minute to mount, buckle in and start.

SORTIE SUMMARY

Range	16 km
Radius	6 km
Time	5:48
+	
Buffer	*0.40*
Total time	6.28
Stops:	Five at 15 min each Two at 25 min each

MEASUREMENTS TAKEN

Continuously

(1) Magnetism
(2) Sample collection

At Each Stop

(1) Gravity gradient
(2) Nuclear measurements
(3) Range and bearing to ELS and geological formations
(4) Photography and radiometry
(5) Height or depth of local surface irregularities
(6) Plot significant features on map
(7) Sample photography and collection

At Two of the Stops

(1) Gas analysis (mass spectrometry)
(2) In situ measurements (see chart for description)

ROUTE

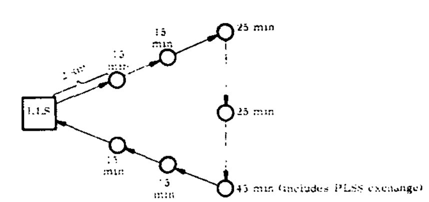

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TABLE 2-15

THREE-MAN TIMELINES FOR FOURTH LSSM SORTIE (APPLIES TO ALL MISSIONS)

Astronaut I

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	10	Checkout, load LSSM	Spare PLSS, deep seismic equipment package	29 90	Carried to LSSM Carried to back of LSSM	VL VL	Shared activity with Astronaut II
2	LSSM	21	Drive 2 km	Control stick	--	By hand	S	Drive 2 km on course away from shelter
3	Surface	15	Implant charge Some sample collection	Charge detonator wire Sample bags Scoops	0.25 0.25 0.45 0.45	Gets charge and detonator from equipment pkg. Pokes holes in ground, places detonator in charge, secures wire to ground	L	Nuclear measurements and gravimetry omitted. Sample collection as time permits.
4	LSSM	11	Drive 1 km	Control stick	--	---	S	On same heading
5	LSSM	1	Monitor II	---	--	From seat	S	
6	LSSM	10	Drive 1 km	Control stick	--	By hand	S	On same heading
7	Surface	15	Same as 3	---	--	---	L	
8	LSSM	11	Drive 1 km	Control stick	--	---	S	On same heading
9	LSSM	1	Monitor II				S	
10	LSSM	10	Drive 1 km				S	On same heading
11	Surface	15	Same as 3				L	
12	LSSM	11	Drive 1 km	Control stick	--	---	S	Same heading
13	LSSM	1	Monitor II				S	
14	LSSM	10	Drive 1 km				S	Same heading
15	Surface	15	Same as 3				L	
16	LSSM	11	Drive 1 km	Control stick			S	Head back to shelter
17	Surface	15	Same as 3				L	
18	Surface	30	PLSS exchange	Spare PLSS	29	Put on from rack	VL	Also aid Astronaut II don PLSS
19	LSSM	11	Drive 1 km	Control stick			S	Same heading
20	LSSM	1	Monitor II				S	
21	LSSM	10	Drive 1 km				S	Same heading
22	Surface	15	Same as 3				L	Same heading
23	LSSM	22	Drive 2 km	Includes stop to set off charge			S	Same heading
24	Surface	15	Same as 3				L	
25	LSSM	22	Drive 2 km	Control stick			S	Same heading
26	Surface	15	Same as 3				L	
27	LSSM	11	Drive to ELS	Control stick			S	Same heading
28	Outside shelter	15	Unload LSSM	Used PLSS-geo. samples	24 4.5		S VL	Same heading
Buffer 40 minutes								

Astronaut II

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Outside shelter	10	Load LSSM	Spare PLSS, deep seismic equipment package	29 90	Carry to back of LSSM	VL VL	Shared activity with Astronaut I; package is 3' x 2' x 2'.
2	LSSM	21	Continuous sample collection, magnetometer activation	---	--	Seated on LSSM	S	
3	Surface	15	Plot location Photography and radiometry Modify map	Laser rangefinder and theodolite Camera package Map table	23 39 --	From seat. Take bearing on last site and relay to ELS	ML	Must also monitor Astronaut I during emplacement of charge
4	LSSM	11	Lay out wire	Wire reel	0.9	From seat	S	Wire is automatically unwound from reel. Astronaut II must monitor operation to prevent snags.
5	LSSM	1	Set off charge	Terminal posts	---	From seat	S	Connect wires, monitor explosion
6	LSSM	10	Sample collection while moving		--	From seat	S	
7	Surface	15	Same as 3				ML	
8	LSSM	11	Lay out wire				S	
9	LSSM	1	Set off charge				S	
10	LSSM	10	Sample collection				S	
11	Surface	15	Same as 3				ML	
12	LSSM	11	Lay out wire				S	
13	LSSM	1	Set off charge				S	
14	LSSM	10	Sample collection				S	
15	Surface	15	Same as 3				ML	
16	LSSM	11	Lay out wire				S	
17	Surface	15	Same as 3, but set off charge first				ML	
18	Surface	30	PLSS exchange	Spare PLSS	29	Put on from rack	VL	
19	LSSM	11	Layout wire				S	
20	LSSM	1	Set off charge				S	
21	LSSM	10	Sample collection				S	
22	Surface	15	Same as 3				ML	
23	LSSM	22	Same as 4, 5, 6 - includes stop to set off charge				S	
24	Surface	15	Same as 3				ML	
25	LSSM	22	Same as 23				S	
26	Surface	15	Same as 3				ML	
27	LSSM	11	Lay out wire				S	
28	Outside Shelter	15	Unload LSSM	Used PLSS Seismic pkg.	24 90		S VL	Set off final charge from inside shelter

Astronaut III

Activity Number	Location	Time	Activity	Equipment	Weight (kg)	How Used	MG	Comments
1	Shelter	10	Monitor egress Read LSSM checklist	Radio	--	Seated	S	
2	Shelter Shelter	10	Turn on geophone recording apparatus, check each phone. Plot LSSM position.	Recorders, plugs Map	Not lifted	Must stand up to activate geophones	S ML ML	With laser theodolite
3	Shelter	27	Report, log keeping, earth data transmittal	Radio, logs, tape decks	Not lifted	Seated	S	
4	Shelter	5	Final check on geophone net			Seated	S	
5	Shelter	11	Monitor shot results			Standing	S	Communicate results to crew for modification of charge placement
6	Shelter	6 20	Plot LSSM Location Set up geological analysis equipment			Seated	S	
7								
8								
9		11	Monitor shot results			Standing	S	
10		6 20 11	Same as 7 Conduct cursory examination of samples returned on last sorti Monitor shot results				S	
11								
12								
13								
14	Snelter	6 20 56	Same as 7 Further analysis of interesting samples. Monitor shot results, then data transmittal. Complete geological examination			Seated	S	
15								
16								
17								
18	Shelter	11	Monitor shot results			Seated	S	
19								
20								
21		26 11	Plot LSSM location Stow geological equipment Monitor shot results			Seated	S	
22								
23								
24		26 11	Checklist LSSM location - Plot location check geophone set Monitor shot				S	
25								
26								
27								
28	Shelter	41	Monitor return to ELS				S	

NOTES ON THIS SORTIE

(1) Main purpose of this sortie is to emplant seismic charges at 1-km intervals from shelter and detonate them. Readings from the previously emplaced geophone net (Local ESA 5) are taken by the third astronaut, in the shelter.

(2) Since much of Astronaut III's time is taken up with recording the seismic shots, there is only 1 hour, 47 minutes available for other scientific tasks during the mission.

(3) Gravimetry and nuclear measurements are deleted from the mission since Astronaut I's time is used to emplace the explosive charges at each stop. Some sample collection could still be done.

(4) PLSS exchange occurs when about 45 minutes of life support expendables remain in the PLSS being worn. This will probably occur sooner for Astronaut I since his level of activity is higher. The 30 minutes allowed can be used in two 15-minute segments.

(5) This sortie was planned using the NASA guideline range of 8 km. If a 6 km sortie limit is acceptable or if LSSM speed can be raised to 12 kmh, then it would not be necessary to follow the same course out and back, and more samples could be collected. Using the present speeds, desired range, and PLSS duration times, a retracing of the outbound route is necessary.

(6) A safety hazard exists during this mission if material from each seismic charge is thrown by the explosion. In the light lunar gravity, rocks could travel the 1 km to the LSSM, causing damage when they land. No analysis of this hazard has been performed. The 1 km range for setting off each charge has been arbitrarily chosen. Longer ranges impose wire weight penalties.

SORTIE SUMMARY

Range	16 km
Radius	8 km
Time	5:50
+	
Buffer	:40
Total	6:30
Stops	8, 15 min each 7, 1 min each to detonate explosives

MEASUREMENTS TAKEN

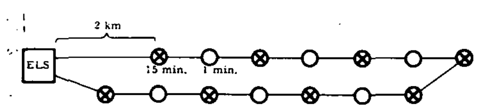
Continuous

(1) Magnetometer readings
(2) Sample collection

At Each Stop

(1) Multiband photography and radiometry
(2) Range and bearing to ELS and geological formations
(3) Plot significant features on map
(4) Sample collection
(5) Some nuclear measurements by Astronaut II
(6) Deep seismic reflection readings at shelter

ROUTE



SECTION 3

RESULTS

GENERAL

The HASSLE program has been applied to the schedule in Section 2. Each application is iterated 30 times by the program to establish the mean and its variance of designated parameters. Variations are due to the introduction of human variability and stochastic interruptions by Monte Carlo techniques. The following cases were analyzed by the program:

<u>Case 1</u> - <u>Perfect "nominal design" mission</u>.

<u>Case 2</u> - <u>Effect of a minimum schedule interrupt on a "nominal design" mission</u>.

<u>Case 3</u> - <u>Effect of variations in LSSM speed</u>.

<u>Case 4</u> - <u>Effect of variations in astronaut speed</u>.

<u>Case 5</u> - <u>Effect of 7 vehicle/astronaut conditions</u>.

<u>Case 6</u> - <u>Effect of increased schedule interrupt</u>.

These results summarize the data of over 2000 iterations or executions of the schedule in various situations. The use of an analytical model of the operators to conduct "experiments" or iterations is the only known way of studying the sensitivity of the man-vehicle-mission model to various contingencies or design changes.

CASE 1 - PERFECT "NOMINAL DESIGN" MISSION

<u>Conditions</u>

Normal Astronaut Speed	Nominal
Nominal LSSM Speed	$6 \frac{km}{hr}$
Scheduled Interruptions	None

<u>Discussion</u>

In this case, the proposed schedule is carried out as per plan, with only an occasional repair task occurring during an allocated time. This would correspond to a perfect nominal mission with schedule preventive maintenance. Under this condition, 76 percent of the assigned scientific tasks are accomplished. Only 76 percent of the schedule scientific tasks are accomplished due to the introduction of the "Science" tasks mentioned in Section 2. These tasks are beyond the expected "normal" capability of the crew but do not interfere with any essential or priority tasks. In this case, all priority tasks are accomplished and require 12.6 ± 0.8 hr per mission. The variance is due to the expected human variation for each task and mission. Nonpriority scientific tasks are accomplished for 96.6 ± 3.5 hr while 30.4 ± 2.8 hr are ignored.

The HASSLE program summarizes the 30 iterations of each into graphical-numerical outputs. Figure 3-1 is a summary of the time spent in various categories of activity for this condition. Ten categories of events are handled within the program:

1. Sleep
2. Rest
3. Miscellaneous (reports, planning, eating, suiting)
4. (Not used in this analysis)
5. Monitoring (computed)
6. Travel time
7. Priority scientific tasks
8. Nonpriority scientific tasks
9. Ingress/Egress
10. Repair (M, R, H - Suit C/O)

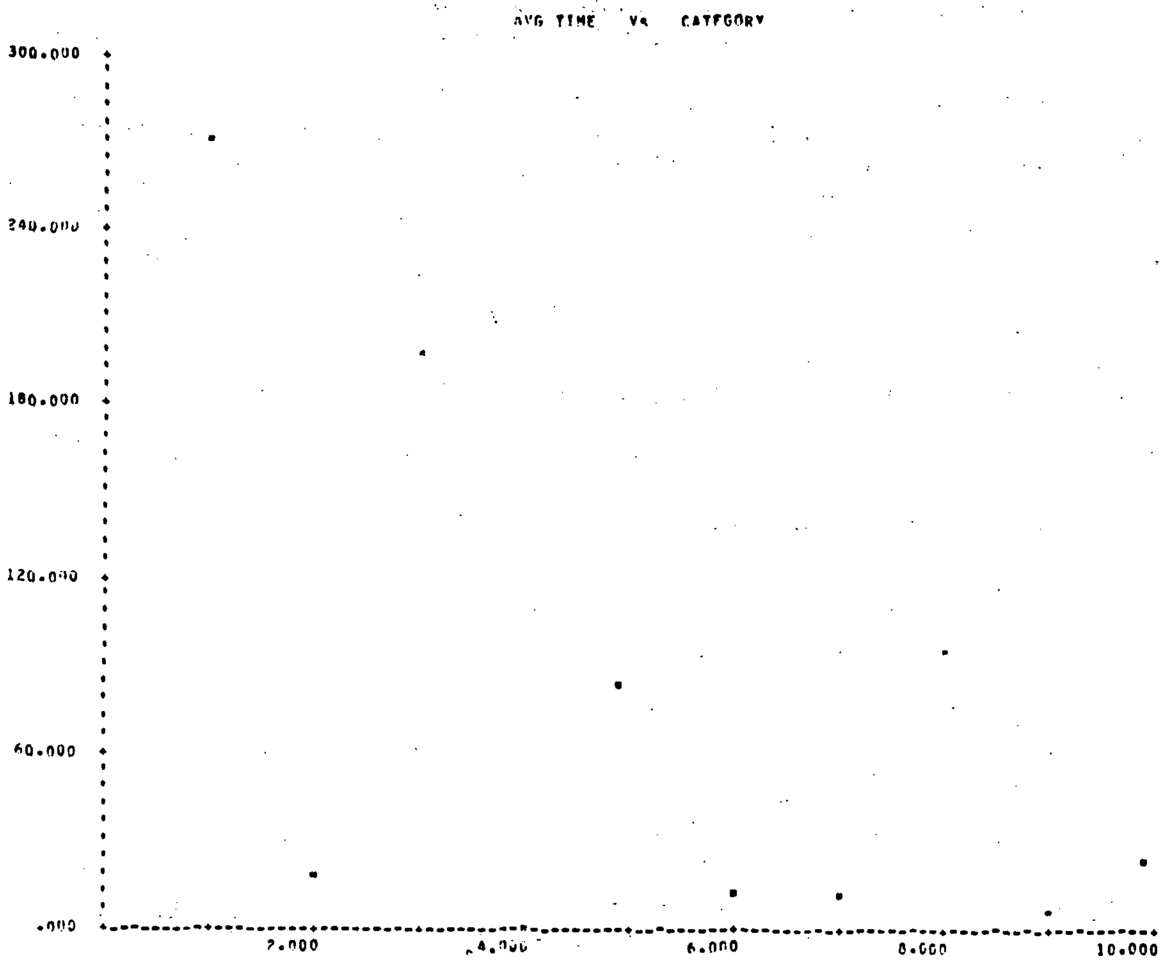
Other data summaries are available within the program. Figure 3-2 is a tabulation of the activities which must be ignored during the mission, due to all contingencies such as lack of time, interruptions, and lack of priority.

Variation of safety level and astronaut stress is shown in Figures 3-3 and 3-4. The stress levels are conducive to good performance, and the amount of time at highest (3 and 4) safety levels is nominal. (Safety level 1 is defined as the safest level.) Category 5 level of Figure 3-7 is the total interrupt delay introduced into the schedule, zero in Case 1.

Conclusion

The conclusion is reached that the astronaut will be able to complete the nominal schedules, even when normal human variations are experienced.

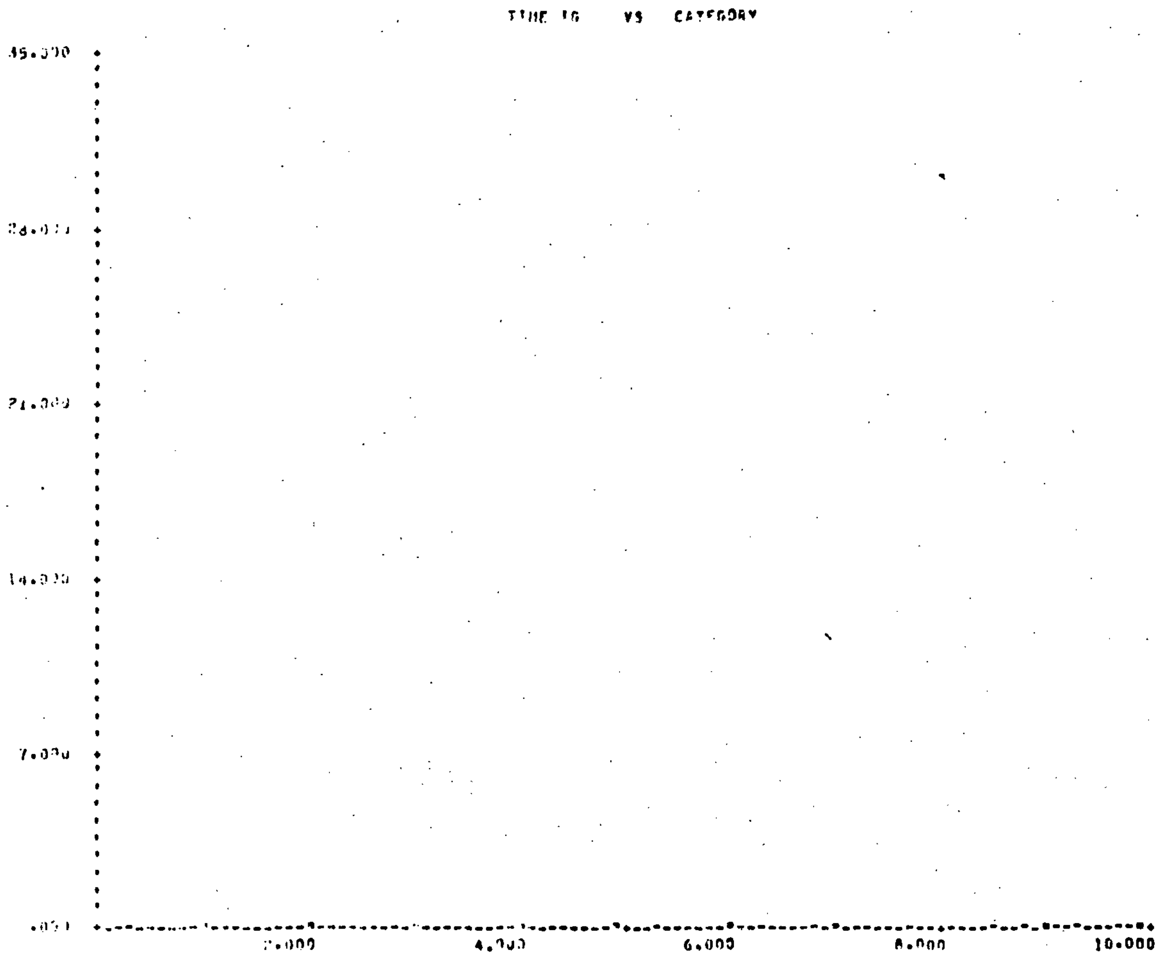
The importance of this "normal" case is the comparison of it to other potential situations.



AVG TIME	CATEGORY
.26927E 03	.10000E 01
.15293E 02	.20000E 01
.19576E 03	.30000E 01
.00000E-80	.40000E 01
.84984E 02	.49990E 01
.12649E 02	.60000E 01
.12600E 02	.70000E 01
.96565E 02	.80000E 01
.66508E 01	.90000E 01
.24817E 02	.99990E 01

.9028E 01 .5091E 00 .5314E 01 .0000E-80 .2366E 01 .4003E 00 .8094E 00 .3498E 01 .3913E 00 .2248E 01

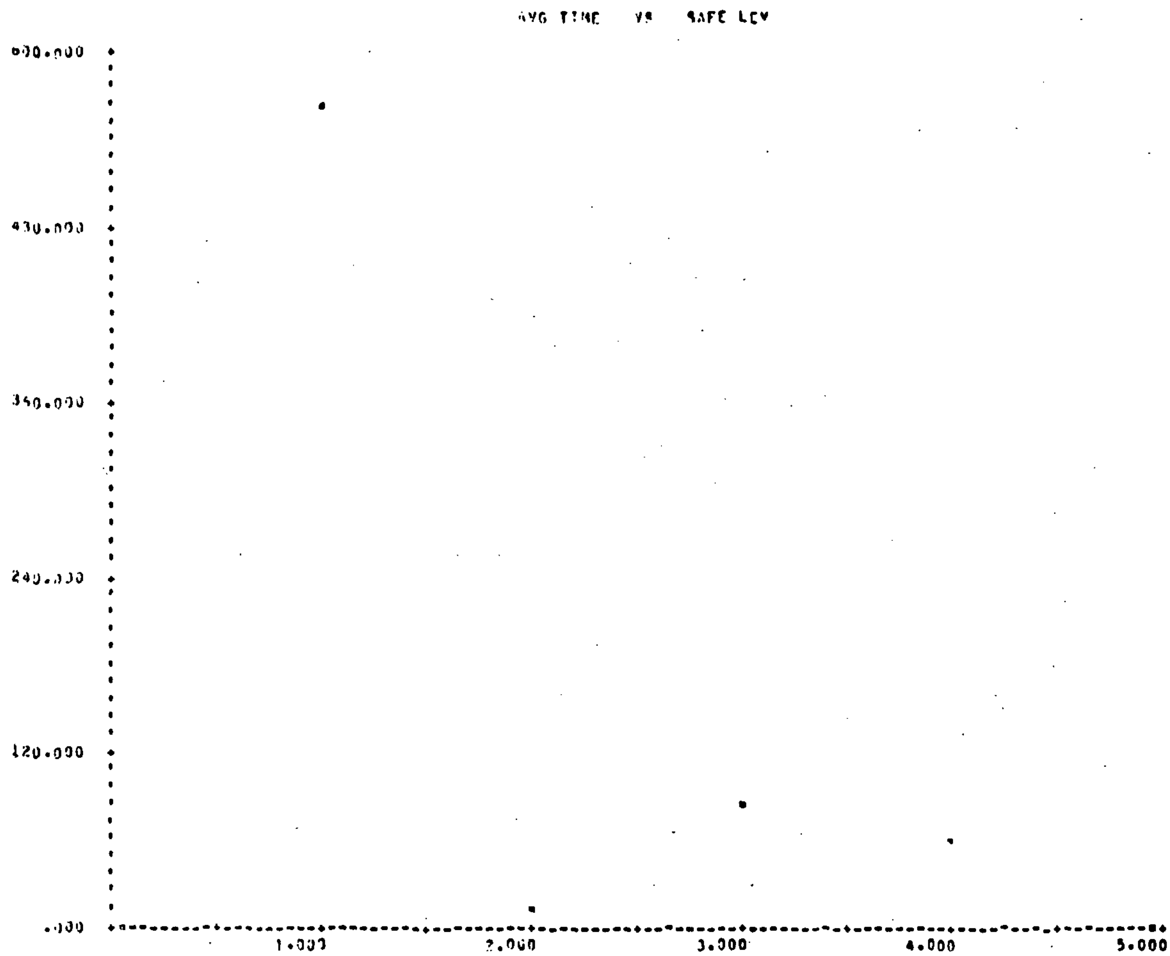
Figure 3-1. Case 1 - Perfect Nominal Design Mission.
Average Time vs Category



TIME IG	CATEGORY
.62328E-01	.10000E 01
.00000E-80	.20000E 01
.27137E 00	.30000E 01
.00000E-80	.40000E 01
.00000E-80	.49990E 01
.00000E-80	.60003E 01
.00000E-80	.70003E 01
.30376E 02	.80000E 01
.34798E-11	.90000E 01
.00000E-80	.99400E 01

.2199E 00	.0000E-80	.4309E 00	.1000E-80	.0000E-80	.0000E-80	.0000E-80	.2752E 01	.1628E-11	.0000E-80

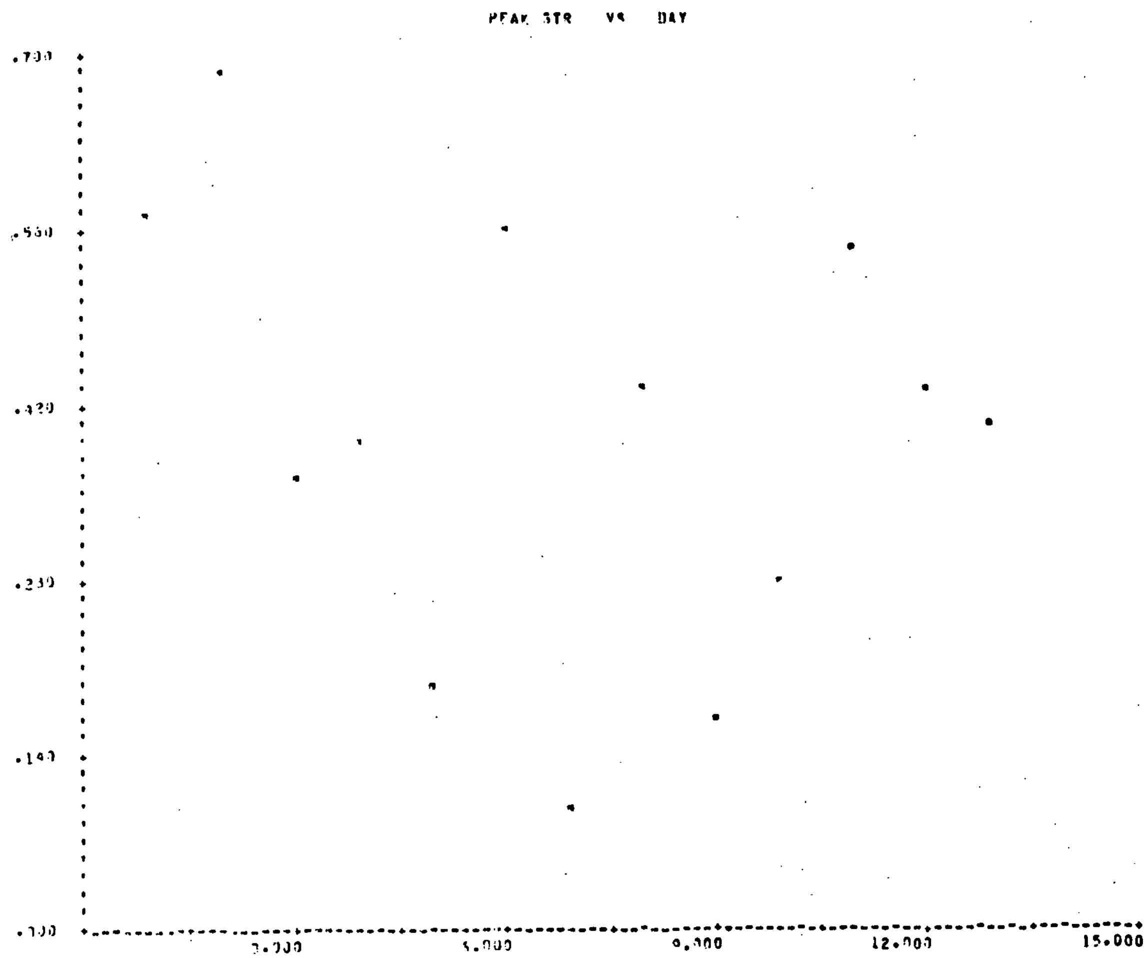
Figure 3-2. Case I - Perfect Nominal Mission.
Time Ignored vs Category



AVG TIME	SAFE LEV
.56748E 03	.10000E 01
.95403E 01	.20000E 01
.86914E 02	.30000E 01
.54232E 02	.40000E 01
.40759E-01	.49990E 01
.00000E-99	.10000E-02

.2462E 01 .2153E 01 .3753E 01 .1864E 01 .1224E 00

Figure 3-3. Case I - Average Time vs Safety Level
Perfect Nominal Mission



PEAK STR	DAY
.569998E 00	.100000E 01
.683310E 00	.200000E 01
.367567E 00	.300000E 01
.337722E 00	.400000E 01
.197994E 00	.500000E 01
.555516E 00	.600000E 01
.964375E-01	.700000E 01
.427995E 00	.800000E 01
.165591E 00	.900000E 01
.299343E 00	.100000E 02
.546277E 00	.110000E 02
.431916E 00	.120000E 02
.403320E 00	.130000E 02

.1991E 00 .2849E-01 .1069E-01 .1644E 00 .1228E-01 .1682E-01 .5475E-02 .1519E-01 .1453E-01 .1251E-01

.2480E-01 .2367E-01 .2539E-01

Figure 3-4. Case I - Peak Astronaut. Stress vs Day.
Perfect Nominal Mission

CASE 2 - EFFECT OF A MINIMUM SCHEDULE INTERRUPT ON "NOMINAL DESIGN" MISSION

Conditions

Astronaut Speed	Normal
LSSM Speed	6 km/hr (Nominal)
Interrupt Condition	P_I (defined below)

P_I = Type	Probability/ Task	Mean Time, hr
1 inside time delay	0.08	0.33
2 outside time delay	0.02	0.04
3 outside-emergency	0.02	0.6
4 repair (scheduled)	0.50	0.5

Discussion

The following procedure is used to introduce the interrupt forcing function into the HASSLE program. For each task, the program determines whether or not an interrupt occurs according to the logic of Figure 3-5.

The type of each interrupt is determined in terms of the type of task being accomplished, e.g., repair, inside, or outside the ELS task. Whether or not the interruption takes place is determined from a random number draw, whose distribution is defined by the input schedule probabilities. If a delay occurs, the exact time of the delay is also randomly determined with a mean value of delay assigned by the input schedule. The schedule is repeated 30 times to allow the evaluation of the interrupts occurring at random times under various circumstances. HASSLE prints out one output schedule (the initial iteration) of each condition to allow a detailed analysis of what is occurring and a summary of the results of the 30 runs for the particular condition. Table 3-1 is an output schedule for Case 2.

Interrupt probability P_I will cause the individual missions to experience about 1 or 2 "type 3" interrupts (outside interrupt causing an emergency return to the ELS) per mission. About one mission in four will not have a type-3 interrupt. Detailed examination of 12 schedule iterations indicated 18, type-3 interrupts occurred. The sample schedule for Case 2 (Table 3-1) contains two "type-3" interrupts. The first one occurs at mission time 107.70 hr, after the priority task ESA 5 is completed and does not affect the primary schedule. The second occurs at mission time 176.50 hr and causes an immediate ingress without accomplishing the priority scientific exploration task.

Type-1 and -2 interrupts are time delays which affect schedule and modify astronaut behavior. They will occur on the average of once a day. A detailed

HASSLE INTERRUPT LOGIC

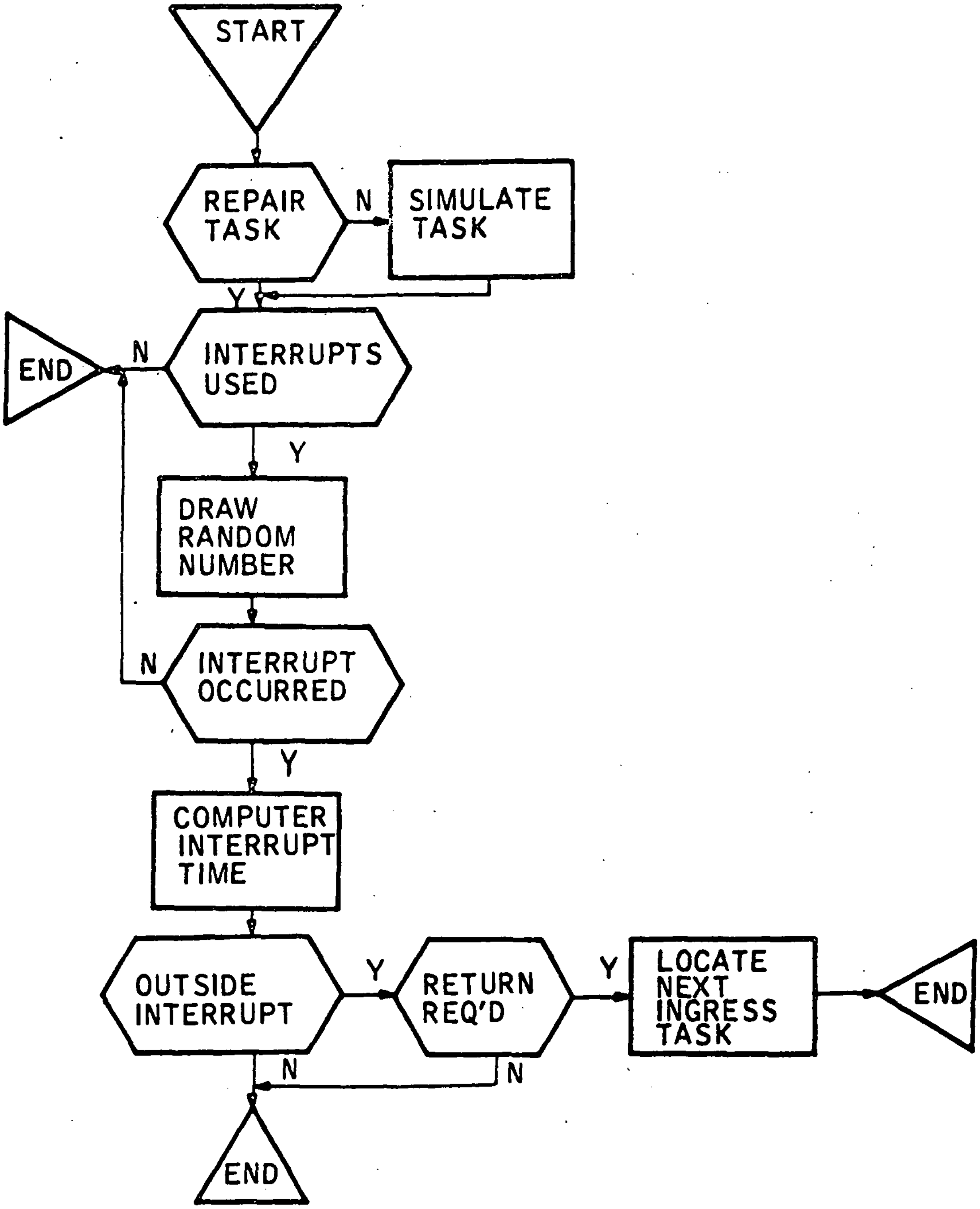


Figure 3-5. HASSLE Interrupt Logic

TABLE 3-1

CASE 2-SCHEDULE OUTPUT

TASK	OPERATOR	NUMBER	EFFICIENCY	TASK TIME	TRAVEL TIME	CUMULATIVE TIME	MILEPOST TIME	TIME IGNORED	OXYGEN SUPPLY	ASTRONAUT PERFORMANCE ELEMENTS					EFFECTIVE STRESS	SAFETY LEVEL CHANGE	
MISC	1	1	.76	15.40	.00	15.40	12.75	.00	8.00	.36	.00	.00	.00	.00	.00	0	2
EAT 2	1	2	.72	.82	.00	16.22	12.75	.35	8.00	.73	.00	.00	.00	.00	.00	0	3
	INTERRUPT			TYPE 1	TIME=	.87 HOURS											
REST	1	3	.78	.38	.00	17.47	12.75	.88	8.00	.74	.00	.00	.00	.00	.00	0	4
SUIT UP	1	4	.73	1.10	.00	18.57	18.40	.00	8.00	.74	.00	.00	.00	.00	.00	0	5
EGRESS	1	5	.74	.16	.00	18.73	18.40	.00	7.84	.83	.00	.00	.40	.25	.06	0	6A
INGRESS	1	7	.80	.14	.00	18.87	18.40	.00	7.86	.79	.00	5.00	.00	.94	.30	0	8
UNSUIT	1	8	.96	.55	.00	19.42	19.30	.00	16.00	.88	.00	5.00	.00	.99	.53	-1	9
EAT 3	1	9	.90	.52	.00	19.94	22.00	.00	16.00	.81	.00	5.00	.00	.98	.69	-1	10
	INTERRUPT			TYPE 4	TIME=	.32 HOURS											
M.R.H	1	10	.90	.00	.00	20.25	22.00	.00	15.68	.81	.00	5.00	.00	.95	.69	0	11
R.H.P	1	11	1.02	.42	.00	20.67	22.00	.00	15.68	.86	.00	5.00	.00	.98	.81	-1	12
SLEEP	1	12	1.05	9.33	.00	30.00	30.00	.00	15.68	.85	.00	5.00	.00	.97	-1.00	0	13
RISE	1	13	.99	.24	.00	30.24	30.33	.00	15.68	.39	.00	5.00	.00	.67	.67	-1	14
EAT 1	1	14	.96	.47	.00	30.71	32.50	.00	15.68	.40	.00	5.00	.00	.68	.67	-1	15
	INTERRUPT			TYPE 1	TIME=	.12 HOURS											
HYGIENE	1	15	.96	.32	.00	31.15	32.50	.00	15.68	.39	.00	5.00	.00	.67	.67	-1	16
SUIT UP	1	16	.94	.56	.00	31.71	32.50	.00	15.68	.41	.00	5.00	.00	.68	.68	-1	17
EGRESS	1	17	.97	.12	.00	31.83	32.50	.00	15.57	.39	.00	5.00	.00	.67	.68	-1	19
LSSM1	1	18	.91	1.17	.33	33.33	38.17	1.17	14.50	.42	.32	5.00	.24	.95	.74	-1	19
PLSS CHG	1	19	1.03	.06	.33	33.72	38.17	.00	14.50	.49	.00	3.77	.00	.55	.71	-1	208
ESA1	1		1.04	.59	.62	34.94	.00	.00	6.78	.41	.00	4.69	.69	.96	.77	-1	209
SCIENCE	2	20B	.90	2.78	.00	36.50	38.17	.00	4.01	.44	.00	4.69	.41	.85	.70	-1	20
ESA2	1		.87	.71	.00	35.65	.00	.00	3.30	.52	.00	1.18	.00	.18	.63	-1	21
SCIENCE	1	20A	.90	2.68	.00	38.33	38.17	.00	.61	.49	.00	1.18	1.89	1.10	.72	-1	21
INGRESS	1	21	.95	.10	.00	38.43	38.17	.00	.51	.71	.00	.85	.00	.15	.60	-1	22
UNSUIT	1	22	.91	.68	.00	39.12	39.00	.00	16.00	.74	.00	.85	.00	.15	.46	0	23
EAT 2	1	23	.83	.65	.00	39.76	39.75	.00	16.00	.75	.00	.85	.00	.15	.34	0	24
	INTERRUPT			TYPE 1	TIME=	.57 HOURS											
REST	1	24	.82	.82	.00	41.15	40.75	.00	16.00	.77	.00	.85	.00	.16	.27	0	25
SCIENCE	1	25	.75	1.12	.00	42.27	46.00	.00	16.00	.83	.00	.85	.00	.16	.22	0	25
SUIT C/O	1	26	.75	.00	.00	42.27	46.00	.00	16.00	.83	.00	.85	.00	.16	.22	0	27
M.R.H	1	27	.75	.00	.00	42.27	46.00	.00	16.00	.83	.00	.85	.00	.16	.22	0	28
R.H.P	1	28	.78	.87	.00	43.14	46.00	.00	16.00	.89	.00	.85	.00	.17	.20	0	29
EAT 3	1	29	.77	.95	.00	44.10	46.00	.00	16.00	.89	.00	.85	.00	.17	.19	0	30
RETIRE	1	30	.79	.21	.00	44.30	46.00	.00	16.00	.90	.00	.85	.00	.17	.18	0	31
SLEEP	1	31	.83	9.70	.00	54.00	54.00	.00	16.00	.81	.00	.85	.00	.16	-1.00	0	32
RISE	1	32	.91	.47	.00	54.47	54.33	.00	16.00	.41	.00	.85	.00	.12	.12	0	33
	INTERRUPT			TYPE 1	TIME=	.29 HOURS											
EAT 1	1	33	.77	.70	.00	55.47	56.50	.00	16.00	.41	.00	.85	.00	.12	.12	0	34
HYGIENE	1	34	.81	.35	.00	55.82	56.50	.00	16.00	.41	.00	.85	.00	.12	.12	0	35
SUIT UP	1	35	.77	.99	.00	56.81	56.50	.00	16.00	.47	.00	.85	.00	.12	.12	0	36
EGRESS	1	36	.78	.13	.00	56.94	56.50	.00	15.87	.46	.00	.85	.00	.12	.12	0	38
LSSM2	1		.91	4.19	.17	61.30	.00	.00	11.64	.48	.58	.56	.58	.65	.25	0	38
ESA 3	2	38	.78	.85	.00	57.78	63.87	.85	10.79	.42	.00	.56	.61	.36	.18	0	37
SCIENCE	2	38B	.77	5.63	.00	63.42	63.87	.00	5.16	.50	.00	.59	.37	.27	.22	0	37
SCIENCE	1	38A	.93	2.40	.17	63.87	63.87	2.56	2.59	.66	.00	.43	1.86	1.12	.50	-1	39
INGRESS	1	39	.86	.08	.00	63.95	63.87	.00	2.51	.90	.00	.49	.00	.10	.47	0	40
UNSUIT	1	40	.88	.63	.00	64.58	64.83	.00	2.00	.83	.00	.49	.00	.09	.36	0	41
EAT 2	1	41	.84	.68	.00	65.26	65.59	.00	2.00	.82	.00	.49	.00	.09	.27	0	42
REST	1	42	.84	.37	.00	65.63	66.25	.00	2.00	.85	.00	.49	.00	.10	.20	0	43
SUIT C/O	1	43	.84	.00	.00	65.63	66.25	.00	2.00	.85	.00	.49	.00	.10	.20	0	44
	INTERRUPT			TYPE 4	TIME=	.66 HOURS											
M.R.H	1	44	.84	.00	.00	66.29	67.25	.00	1.34	.85	.00	.49	.00	.10	.20	0	45
R.H.P	1	45	.84	.99	.00	67.28	68.25	.00	1.34	.84	.00	.49	.00	.10	.16	0	46
EAT 3	1	46	.81	.87	.00	68.15	69.25	.00	1.34	.85	.00	.49	.00	.10	.13	0	47
RETIRE	1	47	.83	.19	.00	68.34	70.00	.00	1.34	.89	.00	.49	.00	.10	.12	0	48
SLEEP	1	48	.84	9.66	.00	78.00	78.00	.00	1.34	.89	.00	.49	.00	.10	-1.00	0	49
RISE	1	49	.85	.35	.00	78.35	80.50	.00	1.34	.41	.00	.49	.00	.07	.07	0	50

TABLE 3-1 (Continued)

TASK	OPERATOR	NUMBER	EFFICIENCY	TASK TIME	TRAVEL TIME	CUMULATIVE TIME	MILEPOST TIME	TIME IGNORED	OXYGEN SUPPLY	ASTRONAUT PERFORMANCE ELEMENTS					EFFECTIVE STRESS	SAFETY LEVEL CHANGE	
[illegible]	1	50	.83	.89	.00	79.24	80.50	.38	1.34	.43	.00	.49	.00	.07	.07	0	51
HYGIENE	1	51	.81	.48	.00	79.72	80.50	.00	1.34	.41	.00	.49	.00	.07	.07	0	52
SUIT UP	1	52	.79	1.11	.00	80.83	80.50	.00	1.34	.41	.00	.49	.00	.07	.07	0	53
EGRESS	1	53	.81	.19	.00	81.02	80.50	.00	1.15	.49	.00	.49	.00	.07	.07	0	
ESA4	1		.76	3.25	.21	84.48	.00	.00	12.55	.42	.54	.45	.49	.54	.19	0	
INGRESS	1	55	.75	.14	.00	84.83	87.17	.00	7.86	.60	.00	1.24	.00	.20	.22	0	56
UNSUIT	1	56	.89	.84	.00	85.67	91.00	.00	4.00	.58	.00	1.24	.00	.20	.22	0	57
EAT 2	1	57	.84	.73	.00	86.41	91.00	.00	4.00	.66	.00	1.24	.00	.21	.22	0	A59
SCIENCE	1	A58	.79	.47	.00	86.88	91.00	.00	4.00	.68	.00	1.24	.00	.22	.22	0	58
REST	1	58	.87	.79	.00	87.67	91.00	.00	4.00	.75	.00	1.24	.00	.23	.22	0	59
INTERRUPT			TYPE 4		TIME= .67 HOURS												
SUIT C/O	1	59	.87	.00	.00	88.35	91.00	.00	3.33	.75	.00	1.24	.00	.23	.22	0	60
M.R.H	1	60	.87	.00	.00	88.35	94.00	.00	3.33	.75	.00	1.24	.00	.23	.22	0	61
R.H.P	1	61	.78	.86	.00	89.21	94.00	.00	3.33	.75	.00	1.24	.00	.23	.22	0	62
EAT 3	1	62	.81	.53	.00	89.74	94.00	.00	3.33	.77	.00	1.24	.00	.23	.22	0	63
RETIRE	1	63	.81	.16	.00	89.90	94.00	.00	3.33	.82	.00	1.24	.00	.24	.23	0	64
SLEEP	1	64	.85	12.10	.00	102.00	102.00	.00	3.33	.79	.00	1.24	.00	.23	-1.00	0	65
RISE	1	65	.86	.24	.00	102.24	104.50	.00	3.33	.39	.00	1.24	.00	.17	.17	0	66
EAT 1	1	66	.88	.57	.00	102.81	104.50	.00	3.33	.40	.00	1.24	.00	.17	.17	0	67
HYGIENE	1	67	.83	.10	.00	102.91	104.50	.00	3.33	.41	.00	1.24	.00	.17	.17	0	68
SUIT UP	1	68	.84	.76	.00	103.67	104.50	.00	3.33	.45	.00	1.24	.00	.18	.17	0	69
EGRESS	1	69	.83	.12	.00	103.78	104.50	.00	3.21	.46	.00	1.24	.00	.18	.17	0	71
SCIENCE	1	71A	.77	3.05	.00	106.83	107.70	.00	12.95	.46	.00	1.24	.00	.18	.18	0	71
ESA5	2		.80	2.43	.33	106.54	.00	.00	10.19	.39	.23	1.03	.00	.24	.20	0	72
SCIENCE	2	71B	.77	.99	.33	107.86	107.70	1.98	8.87	.47	.00	1.03	.00	.15	.19	0	72
INTERRUPT			TYPE 3		TIME= 1.24 HOURS												
INGRESS	2	72	.75	.17	.00	109.28	107.70	.00	7.83	.71	.00	1.06	.00	.19	.18	0	73
UNSUIT	2	73	.79	.84	.00	110.12	109.50	.00	16.00	.67	.00	1.06	.00	.18	.18	0	74
EAT 2	2	74	.80	.45	.00	110.57	109.50	.19	16.00	.70	.00	1.06	.00	.19	.18	0	75
REST	2	75	.73	.53	.00	111.09	115.50	.53	16.00	.77	.00	1.06	.00	.20	.19	0	76
SCIENCE	2	76	.77	3.33	.00	114.42	115.50	.88	16.00	.75	.00	1.06	.00	.19	.19	0	77
SUIT C/O	2	77	.77	.00	.00	114.42	115.50	.00	16.00	.75	.00	1.06	.00	.19	.19	0	78
EAT 3	2	78	.74	.59	.00	115.01	115.50	.00	16.00	.79	.00	1.06	.00	.20	.19	0	79
M.R.H	2	79	.81	.79	.00	115.80	118.00	.00	16.00	.82	.00	1.06	.00	.20	.19	0	80
R.H.P	2	80	.81	.80	.00	116.60	118.00	.00	16.00	.86	.00	1.06	.00	.21	.20	0	81
RETIRE	2	81	.77	.14	.00	116.74	118.00	.00	16.00	.83	.00	1.06	.00	.20	.20	0	82
INTERRUPT			TYPE 1		TIME= .77 HOURS												
SLEEP	2	82	.79	9.26	.00	126.77	126.00	.00	16.00	.85	.00	1.06	.00	.21	-1.00	0	83
RISE	2	83	.74	.07	.00	126.85	128.50	.29	16.00	.38	.00	1.06	.00	.14	.14	0	84
EAT 1	2	84	.77	.60	.00	127.44	128.50	.26	16.00	.43	.00	1.06	.00	.15	.14	0	85
HYGIENE	2	85	.78	.25	.00	127.69	128.50	.00	16.00	.38	.00	1.06	.00	.14	.14	0	86
SUIT UP	2	86	.79	.81	.00	128.50	128.50	.00	16.00	.39	.00	1.06	.00	.14	.14	0	87
EGRESS	2	87	.75	.19	.00	128.69	128.50	.00	15.91	.41	.00	1.06	.00	.15	.14	0	88
LSSM4	1		.93	2.15	1.33	132.18	.00	.00	12.51	.43	2.10	.95	.51	1.35	.45	0	883
SCIENCE	2	88B	.73	6.59	.00	135.29	135.20	.00	5.92	.38	.00	.95	.10	.17	.15	0	89
SCIENCE	1	83A	.88	2.85	1.33	136.36	135.20	1.39	1.74	.48	.00	.80	1.32	.76	.60	-1	89
INGRESS	1	89	.97	.12	.00	136.48	135.20	.00	1.62	.73	.00	.78	.00	.14	.53	-1	90
UNSUIT	1	90	.94	.61	.00	137.10	136.80	.00	16.00	.65	.00	.78	.00	.13	.41	0	91
EAT 2	1	91	.91	.30	.00	137.40	136.80	.13	16.00	.74	.00	.78	.00	.14	.31	0	92
SCIENCE	1	92	.88	.29	.00	137.69	138.70	.00	16.00	.79	.00	.78	.00	.15	.25	0	93
REST	1	93	.90	.81	.00	138.50	138.70	.00	16.00	.73	.00	.78	.00	.14	.20	0	94
SUIT C/O	1	94	.88	.29	.00	138.79	138.70	.00	16.00	.73	.00	.78	.00	.14	.18	0	95
M.R.H	1	95	.86	.92	.00	139.71	141.50	.00	16.00	.78	.00	.78	.00	.15	.16	0	95
R.H.P	1	96	.79	.72	.00	140.44	141.50	.00	16.00	.85	.00	.78	.00	.15	.16	0	97
EAT 3	1	97	.83	1.10	.00	141.53	141.50	.00	16.00	.83	.00	.78	.00	.15	.15	0	98
RETIRE	1	98	.88	.16	.00	141.69	150.00	.00	16.00	.87	.00	.78	.00	.15	.15	0	99
SLEEP	1	99	.86	8.31	.00	150.00	150.00	.00	16.00	.81	.00	.78	.00	.15	-1.00	0	100
RISE	1	100	.88	.30	.00	150.30	152.50	.00	16.00	.39	.00	.78	.00	.11	.11	0	101
EAT 1	1	101	.89	.79	.00	151.09	152.50	.00	16.00	.37	.00	.78	.00	.10	.10	0	102
HYGIENE	1	102	.90	.27	.00	151.36	152.50	.00	16.00	.38	.00	.78	.00	.10	.10	0	103

TABLE 3-1 (Continued)

TASK	OPERATOR	NUMBER	EFFICIENCY	TASK TIME	TRAVEL TIME	CUMULATIVE TIME	MILEPOST TIME	TIME IGNORED	OXYGEN SUPPLY	ASTRONAUT PERFORMANCE ELEMENTS					EFFECTIVE STRESS	SAFETY LEVEL CHANGE	
SUIT UP	1	103	.85	1.01	.00	152.37	152.50	.00	16.00	.39	.00	.78	.00	.11	.10	0	104
EGRESS	1	104	.84	.24	.00	152.62	152.50	.00	15.76	.46	.00	.78	.00	.11	.11	0	
ESA6	1	105	.75	1.78	.00	154.39	155.00	.44	14.22	.47	.00	.78	.00	.11	.11	0	
ESA7	2	106	.78	1.08	.00	153.70	155.00	.27	13.14	.43	.00	.76	.00	.11	.11	0	106A
SCIENCE	2	106B	.81	1.13	.00	154.83	155.00	1.95	12.01	.47	.00	.75	.00	.11	.11	0	106A
SCIENCE	1	106A	.76	.44	.00	154.83	155.00	2.16	11.57	.57	.00	.77	.00	.12	.11	0	107
INGRESS	1	107	.85	.12	.00	154.95	155.00	.00	11.46	.69	.00	.81	.00	.14	.12	0	108
UNSUIT	1	108	.90	.88	.00	155.83	156.50	.00	16.00	.67	.00	.81	.00	.14	.13	0	109
EAT 2	1	109	.89	.71	.00	156.54	156.50	.00	16.00	.73	.00	.81	.00	.14	.13	0	110
REST	1	110	.91	1.08	.00	157.62	174.00	.00	16.00	.78	.00	.81	.00	.15	.14	0	111
SCIENCE	1	111	.75	5.49	.00	163.11	174.00	.00	16.00	.76	.00	.81	.00	.15	.14	0	112
SUIT C/O	1	112	.75	.00	.00	163.11	174.00	.00	16.00	.76	.00	.81	.00	.15	.14	0	113
EAT 3	1	113	.90	.59	.00	153.70	174.00	.00	16.00	.86	.00	.81	.00	.16	.15	0	114
M.R.H	1	114	.86	.84	.00	164.53	174.00	.00	16.00	.78	.00	.81	.00	.15	.15	0	115
R.H.P	1	115	.87	.96	.00	165.49	174.00	.00	16.00	.81	.00	.81	.00	.15	.15	0	116
RETIRE	1	116	.85	.18	.00	165.67	174.00	.00	16.00	.79	.00	.81	.00	.15	.15	0	117
SLEEP	1	117	.91	8.33	.00	174.00	174.00	.00	16.00	.84	.00	.81	.00	.16	-1.00	0	118
RISE	1	118	.89	.35	.00	174.35	176.50	.00	16.00	.37	.00	.81	.00	.11	.11	0	119
EAT 1	1	119	.84	.83	.00	175.18	176.50	.00	16.00	.41	.00	.81	.00	.11	.11	0	120
HYGIENE	1	120	.85	.56	.00	175.74	176.50	.00	16.00	.38	.00	.81	.00	.11	.11	0	121
SUIT UP	1	121	.87	1.06	.00	176.80	176.50	.00	16.00	.38	.00	.81	.00	.11	.11	0	122
	INTERRUPT			TYPE 3		TIME= 1.29 HOURS											
EGRESS	1	122	.91	.17	.00	178.26	176.50	.00	7.83	.41	.00	.81	.00	.11	.11	0	122B
INGRESS	1	124	.88	.28	.00	178.54	183.20	.00	7.72	.39	.00	1.23	.00	.17	.12	0	125
UNSUIT	1	125	.86	.93	.00	179.47	187.00	.00	4.00	.48	.00	1.23	.00	.18	.14	0	125
EAT 2	1	126	.86	.63	.00	180.10	187.00	.00	4.00	.50	.00	1.23	.00	.18	.16	0	127
REST	1	127	.91	.88	.00	180.98	187.00	.00	4.00	.45	.00	1.23	.00	.17	.16	0	128
SCIENCE	1	128	.93	.46	.00	181.44	187.00	.00	4.00	.45	.00	1.23	.00	.17	.17	0	129
SUIT C/O	1	129	.87	.36	.00	181.81	187.00	.00	4.00	.46	.00	1.23	.00	.18	.17	0	130
	INTERRUPT			TYPE 1		TIME= .14 HOURS											
M.R.H	1	130	.92	.71	.00	182.66	190.00	.00	4.00	.44	.00	1.23	.00	.17	.17	0	131
R.H.P	1	131	.77	1.03	.00	183.69	190.00	.00	4.00	.52	.00	1.23	.00	.19	.18	0	132
EAT 3	1	132	.87	.93	.00	184.62	190.00	.00	4.00	.53	.00	1.23	.00	.19	.18	0	133
RETIRE	1	133	.89	.14	.00	184.76	190.00	.00	4.00	.52	.00	1.23	.00	.19	.18	0	134
SLEEP	1	134	.86	13.24	.00	198.00	198.00	.00	4.00	.52	.00	1.23	.00	.19	-1.00	0	135
RISE	1	135	.89	.26	.00	198.26	200.50	.00	4.00	.39	.00	1.23	.00	.17	.17	0	136
EAT 1	1	136	.93	.73	.00	198.98	200.50	.00	4.00	.40	.00	1.23	.00	.17	.17	0	137
HYGIENE	1	137	.90	.31	.00	199.29	200.50	.00	4.00	.43	.00	1.23	.00	.17	.17	0	138
SUIT UP	1	138	.95	1.02	.00	200.31	200.50	.00	4.00	.39	.00	1.23	.00	.17	.17	0	139
EGRESS	1	139	.90	.20	.00	200.51	200.50	.00	3.80	.45	.00	1.23	.00	.18	.17	0	
ESA8	1		.80	.73	.33	201.58	.00	.00	14.94	.41	.38	1.20	.00	.34	.21	0	
ESA9	2	141	.76	1.03	.08	201.63	203.20	1.03	13.83	.45	.13	1.20	.00	.23	.19	0	140
SCIENCE	1	282A	.81	1.45	.33	203.36	203.20	.83	12.04	.46	.00	1.20	.00	.17	.21	0	282B
SCIENCE	2	282B	.82	1.40	.00	203.03	203.20	1.18	10.64	.47	.00	1.18	.00	.17	.19	0	142
INGRESS	2	142	.79	.17	.00	203.54	203.20	.00	10.46	.59	.00	1.17	.00	.19	.19	0	143
UNSUIT	2	143	.77	.86	.00	204.40	205.00	.00	8.00	.57	.00	1.17	.00	.18	.19	0	144
EAT 2	2	144	.82	.80	.00	205.20	205.00	.00	8.00	.63	.00	1.17	.00	.19	.19	0	145
REST	2	145	.82	.79	.00	205.99	211.50	.00	8.00	.67	.00	1.17	.00	.20	.19	0	146
SCIENCE	2	146	.77	3.79	.00	209.78	211.50	.00	8.00	.67	.00	1.17	.00	.20	.19	0	147
	INTERRUPT			TYPE 4		TIME= .25 HOURS											
SUIT C/O	2	147	.77	.00	.00	210.03	211.50	.00	7.75	.67	.00	1.17	.00	.20	.19	0	148
EAT 3	2	148	.76	.67	.00	210.71	211.50	.00	7.75	.84	.00	1.17	.00	.23	.20	0	149
M.R.H	2	149	.80	1.03	.00	211.74	214.00	.00	7.75	.83	.00	1.17	.00	.22	.21	0	150
R.H.P	2	150	.81	1.10	.00	212.84	214.00	.00	7.75	.86	.00	1.17	.00	.23	.22	0	151
RETIRE	2	151	.83	.12	.00	212.96	214.00	.00	7.75	.96	.00	1.17	.00	.23	.22	0	152
SLEEP	2	152	.79	9.04	.00	222.00	222.00	.00	7.75	.85	.00	1.17	.00	.23	-1.00	0	153
RISE	2	153	.78	.44	.00	222.44	224.50	.00	7.75	.40	.00	1.17	.00	.16	.16	0	154
HYGIENE	2	154	.77	.36	.00	222.80	224.50	.00	7.75	.44	.00	1.17	.00	.16	.16	0	155
EAT 1	2	155	.77	.83	.00	223.62	224.50	.00	7.75	.43	.00	1.17	.00	.16	.16	0	156
SUIT UP	2	156	.80	.86	.00	224.48	224.50	.00	7.75	.44	.00	1.17	.00	.16	.16	0	157

TABLE 3-1 (Continued)

TASK	OPERATOR	NUMBER	EFFICIENCY	TASK TIME	TRAVEL TIME	CUMULATIVE TIME	MILEPOST TIME	TIME IGNORED	OXYGEN SUPPLY	ASTRONAUT PERFORMANCE ELEMENTS					EFFECTIVE STRESS	SAFETY LEVEL CHANGE	
EGRESS	2	157	.80	.18	.00	224.66	224.50	.00	7.57	.40	.00	1.17	.00	.16	.16	0	
ESA 10	2	158	.77	2.07	.00	226.73	230.70	.52	13.93	.42	.00	1.17	.47	.38	.22	0	159
ESA 11	2	159	.78	2.03	.00	228.75	230.70	.51	11.90	.40	.00	1.14	.30	.32	.25	0	159A
SCIENCE	1	159A	.83	1.78	.00	230.83	230.70	3.63	10.13	.49	.00	1.11	.07	.20	.25	0	159B
	INTERRUPT			TYPE 2	TIME= .33 HOURS												
SCIENCE	2	159B	.80	1.78	.00	230.86	230.70	2.47	8.02	.69	.00	1.13	.26	.35	.29	0	160
INGRESS	2	160	.80	.20	.00	231.06	230.70	.00	7.82	.87	.00	1.14	.00	.23	.28	0	161
UNSUIT	2	161	.85	.90	.00	231.96	238.00	.00	16.00	.88	.00	1.14	.00	.23	.27	0	162
EAT 2	2	162	.85	.73	.00	232.69	238.00	.00	16.00	.89	.00	1.14	.00	.23	.25	0	163
REST	2	163	.84	.65	.00	233.35	238.00	.00	16.00	.55	.00	1.14	.00	.22	.24	0	164
SCIENCE	2	164	.80	1.29	.00	234.64	238.00	.00	16.00	.55	.00	1.14	.00	.22	.23	0	165
SUIT C/O	2	165	.80	.00	.00	234.64	238.00	.00	16.00	.55	.00	1.14	.00	.22	.23	0	166
M.R.H	2	166	.80	.80	.00	235.43	238.00	.00	16.00	.54	.00	1.14	.00	.22	.23	0	167
R.P.H	2	167	.83	.88	.00	236.31	238.00	.00	16.00	.89	.00	1.14	.00	.23	.23	0	168
EAT 3	2	168	.87	.75	.00	237.06	238.00	.00	16.00	.90	.00	1.14	.00	.23	.23	0	169
RETIRE	2	169	.85	.16	.00	237.22	238.00	.00	16.00	.83	.00	1.14	.00	.22	.23	0	170
	INTERRUPT			TYPE 1	TIME= .48 HOURS												
SLEEP	2	170	.81	8.78	.00	246.48	246.00	.00	16.00	.90	.00	1.14	.00	.23	-1.00	0	83
RISE	2	83	.83	.35	.00	246.83	248.50	.00	16.00	.41	.00	1.14	.00	.16	.16	0	84
EAT 1	2	84	.83	.55	.00	247.38	248.50	.24	16.00	.46	.00	1.14	.00	.16	.16	0	85
HYGIENE	2	85	.80	.17	.00	247.55	248.50	.00	16.00	.41	.00	1.14	.00	.16	.16	0	86
SUIT UP	2	86	.85	.88	.00	248.43	248.50	.00	16.00	.46	.00	1.14	.00	.16	.16	0	8711
EGRESS	2	8711	.84	.21	.00	248.64	248.50	.00	15.79	.46	.00	1.14	.00	.16	.16	0	
LSSM 4	1	8811	.88	2.09	1.33	252.06	255.20	.52	12.58	.48	2.38	1.14	.51	1.58	.52	-1	
SCIENCE	2		.82	6.33	.00	254.97	255.20	.00	6.25	.47	.00	1.11	.09	.21	.17	0	
SCIENCE	1		.95	2.97	.00	255.03	255.20	1.21	3.28	.47	.00	1.01	1.20	.73	.66	-1	89
INGRESS	1	89	1.07	.17	.00	255.20	255.20	.00	3.11	.79	.00	.99	.00	.18	.58	-1	90
UNSUIT	1	90	1.00	.70	.00	255.90	256.80	.00	16.00	.73	.00	.99	.00	.18	.46	0	9111
EAT 2	1	9111	.92	.45	.00	256.35	256.80	.00	16.00	.81	.00	.99	.00	.19	.36	0	92
SCIENCE	1	92	.95	.52	.00	256.87	258.70	.00	16.00	.84	.00	.99	.00	.19	.29	0	93
REST	1	93	.93	.78	.00	257.66	258.70	.00	16.00	.87	.00	.99	.00	.20	.25	0	9411
SUIT C/O	1	9411	.95	.23	.00	257.89	258.70	.00	16.00	.84	.00	.99	.00	.19	.23	0	95
M.P.H	1	95	.96	1.13	.00	259.01	261.50	.00	16.00	.55	.00	.99	.00	.19	.21	0	96
R.H.P	1	96	.79	1.02	.00	260.04	261.50	.00	16.00	.84	.00	.99	.00	.19	.20	0	9711
EAT 3	1	9711	.93	.72	.00	260.75	261.50	.00	16.00	.85	.00	.99	.00	.19	.20	0	98
RETIRE	1	98	.94	.11	.00	260.86	270.00	.00	16.00	.89	.00	.99	.00	.20	.20	0	9911
SLEEP	1	9911	.94	9.14	.00	270.00	270.00	.00	16.00	.89	.00	.99	.00	.20	-1.00	0	49
RISE	1	49	.95	.35	.00	270.35	272.50	.00	16.00	.41	.00	.99	.00	.14	.14	0	50
EAT 1	1	50	.93	.55	.00	270.91	272.50	.00	16.00	.41	.00	.99	.00	.14	.14	0	51
HYGIENE	1	51	.88	.31	.00	271.22	272.50	.00	16.00	.46	.00	.99	.00	.14	.14	0	52
SUIT UP	1	52	.95	1.18	.00	272.40	272.50	.00	16.00	.43	.00	.99	.00	.14	.14	0	5311
EGRESS	1	5311	.89	.33	.00	272.72	272.50	.00	15.67	.46	.00	.99	.00	.14	.14	0	
LSSM 3	1	5411	.86	2.02	1.33	276.08	279.20	.50	12.65	.42	1.51	.99	.51	1.08	.37	0	
SCIENCE	1		.82	2.95	.00	279.03	279.20	1.60	9.69	.57	.00	.97	.09	.20	.39	0	
SCIENCE	2		.85	2.95	.00	279.03	279.20	1.64	6.74	.44	.00	.95	.42	.33	.42	0	55
INGRESS	2	55	.85	.06	.00	279.09	279.20	.00	6.68	.76	.00	.94	.00	.17	.37	0	56
	INTERRUPT			TYPE 1	TIME= .37 HOURS												
UNSUIT	2	56	.82	.78	.00	280.24	283.00	.00	4.00	.70	.00	.94	.00	.16	.31	0	57
EAT 2	2	57	.83	.88	.00	281.12	283.00	.00	4.00	.83	.00	.94	.00	.18	.26	0	A58
	INTERRUPT			TYPE 1	TIME= .24 HOURS												
SCIENCE	2	A58	.82	.37	.00	281.72	283.00	.00	4.00	.81	.00	.94	.00	.18	.23	0	58
REST	2	58	.84	.72	.00	282.44	283.00	.00	4.00	.82	.00	.94	.00	.18	.21	0	5911
SUIT C/O	2	5911	.84	.00	.00	282.44	283.00	.00	4.00	.82	.00	.94	.00	.18	.21	0	60
	INTERRUPT			TYPE 4	TIME= 1.14 HOURS												
M.R.H	2	60	.84	.00	.00	283.58	286.00	.00	2.86	.82	.00	.94	.00	.18	.21	0	61
R.H.P	2	61	.83	1.08	.00	284.66	286.00	.00	2.86	.80	.00	.94	.00	.18	.19	0	62
EAT 3	2	62	.81	.77	.00	285.43	286.00	.00	2.86	.82	.00	.94	.00	.18	.19	0	6311
RETIRE	2	6311	.83	.15	.00	285.59	286.00	.00	2.86	.91	.00	.94	.00	.19	.19	0	6411
SLEEP	2	6411	.84	8.41	.00	294.00	294.00	.00	2.86	.83	.00	.94	.00	.18	-1.00	0	49
RISE	2	49	.85	.38	.00	294.38	296.50	.00	2.86	.41	.00	.94	.00	.13	.13	0	50

TABLE 3-1 (Continued)

TASK	OPERATOR	NUMBER	EFFICIENCY	TASK TIME	TRAVEL TIME	CUMULATIVE TIME	MILEPOST TIME	TIME IGNORED	OXYGEN SUPPLY	ASTRONAUT PERFORMANCE ELEMENTS					EFFECTIVE STRESS	SAFETY LEVEL CHANGE		
[illegible]	2	50	.82	.52	.00	294.90	296.50	.00	2.86	.42	.00	.94	.00	.13	.13	0	51
HYGIENE	2	51	.85	.40	.00	295.30	296.50	.00	2.86	.41	.00	.94	.00	.13	.13	0	52
SUIT UP	2	52	.87	1.05	.00	296.35	296.50	.00	2.86	.45	.00	.94	.00	.13	.13	0	5312
EGRESS	2	5312	.83	.16	.00	296.51	296.50	.00	2.70	.42	.00	.94	.00	.13	.13	0	
LSSM3	2	5412	.83	1.81	1.33	299.66	303.20	.45	12.85	.49	1.46	.94	.51	1.12	.38	0	
SCIENCE	1		.86	3.37	.00	303.03	303.20	.97	9.48	.51	.00	.92	.07	.17	.39	0	
SCIENCE	2		.90	3.37	.00	303.03	303.20	.81	6.11	.48	.00	.90	.45	.35	.43	0	55
INGRESS	2	55	.94	.10	.00	303.13	303.20	.00	6.01	.81	.00	.88	.00	.17	.38	0	56
UNSUIT	2	56	.87	.78	.00	303.91	307.00	.00	4.00	.76	.00	.88	.00	.16	.31	0	57
EAT 2	2	57	.89	.72	.00	304.62	307.00	.00	4.00	.81	.00	.88	.00	.17	.26	0	A53
SCIENCE	2	A58	.79	.72	.00	305.35	307.00	.00	4.00	.83	.00	.88	.00	.17	.22	0	58
REST	2	58	.83	.94	.00	306.29	307.00	.00	4.00	.85	.00	.88	.00	.17	.20	0	5912
	INTERRUPT		TYPE 4		TIME= .29 HOURS												
SUIT C/O	2	5912	.83	.00	.00	306.57	307.00	.00	3.71	.85	.00	.88	.00	.17	.20	0	60
M.R.H	2	60	.83	.00	.00	306.57	310.00	.00	3.71	.85	.00	.88	.00	.17	.20	0	61
R.H.P	2	61	.87	1.01	.00	307.59	310.00	.00	3.71	.83	.00	.88	.00	.17	.19	0	62
EAT 3	2	62	.84	.74	.00	308.33	310.00	.00	3.71	.83	.00	.88	.00	.17	.18	0	6312
RETIRE	2	6312	.85	.21	.00	308.54	310.00	.00	3.71	.88	.00	.88	.00	.17	.18	0	6412
SLEEP	2	6412	.84	9.46	.00	318.00	318.00	.00	3.71	.89	.00	.88	.00	.17	-1.00	0	-000

examination of 10 schedule iterations indicated 150 type-1 and -2 interrupts occurred or a mean of 15 per 14-day mission. The sample schedule for Case 2 (Table 3-1) contains 10 type-1 and -2 interrupts. In Case 2, these interrupts have a mean time of 1/2 hr, a minor daily delay. Type-4 interrupts occur as schedule tasks that have minimum effect on schedule output. These interrupts represent casual or preventive type of maintenance.

The P_1 frequency of interrupts is felt to be a minimum type of schedule contingency which would occur. It is considered realistic for the system complexity being considered, with equipment which is highly reliable and operated correctly. The P_1 probability of interrupt is used throughout this analysis. Other cases investigate the impact of increasing the mean interrupt times, but not the frequency of occurrence. P_2 will represent interruptions with a mean delay time of one hour and P_3 a mean interrupt time of three hours.

Figures 3-6 through 3-9 are summaries of the schedule results of introducing the P_1 interrupt forcing function into the basic schedule. The percentage of total input scientific tasks achieved is reduced to 65 percent, about a 16.5 percent decrease in total achievement from the normal or Case 1 sit .tion. Totals of 1.27 hr in priority tasks ($\simeq$10 percent of the total priority tasks) and 47.0 hr in nonpriority ($\simeq$25 percent of total nonpriority tasks) are being ignored on the average astronaut stress and safety were not affected by the minor schedule interruptions of P_1.

Summary

The schedule accomplishment appears very sensitive to minor contingency conditions. The problem may lie in the inability to reschedule the long LSSM sorties in the present schedule. The tasks vary greatly in time requirements, so it is difficult to find a new schedule time for longer tasks. Since the longer LSSM sorties are near the limits of system capability, the apparent solution is to reduce the range of LSSM sorties when faced with reschedule problems. The study predicts this may happen.

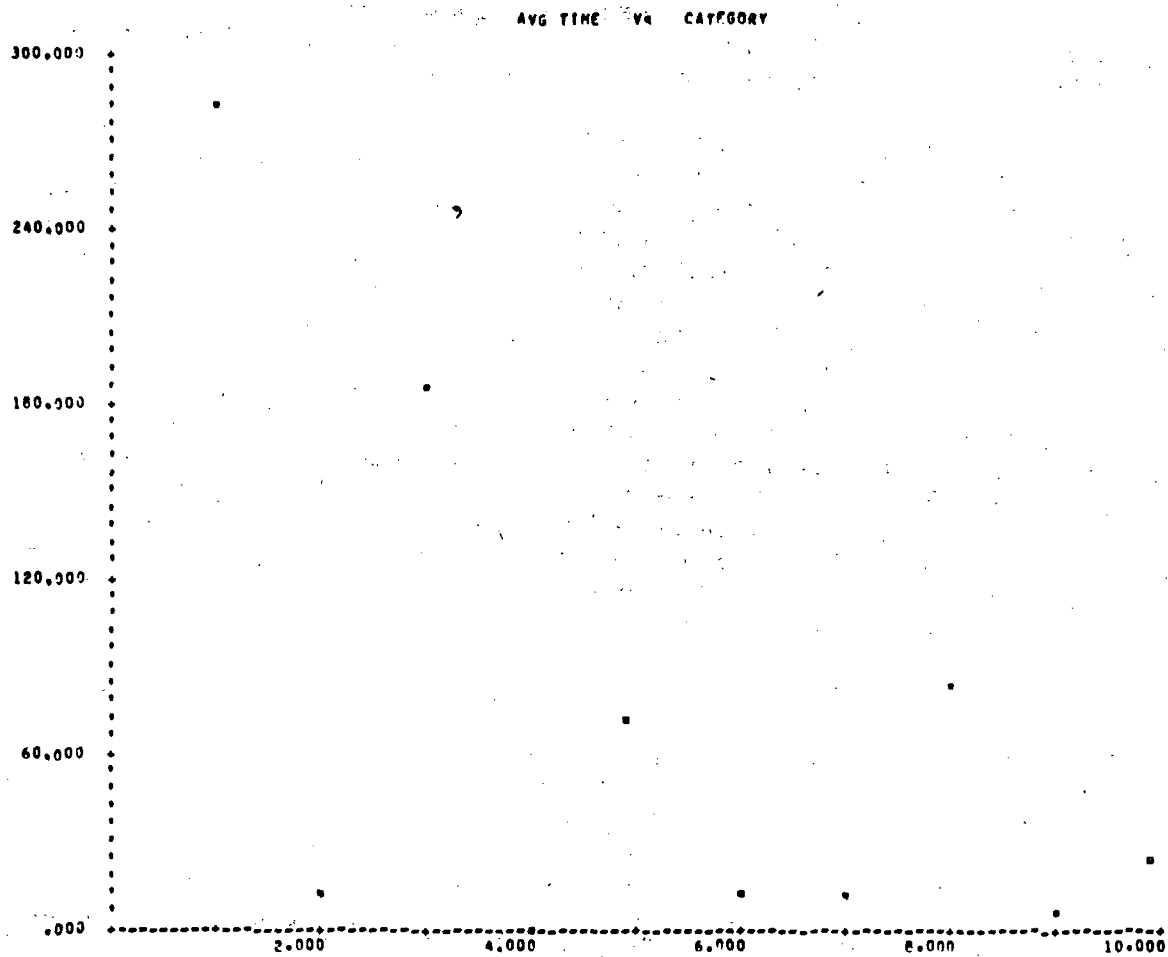
CASE 3 - VARIATIONS IN LSSM SPEED

Conditions

Astronaut Speed	Nominal
Interrupt	P_1
Vehicle Speeds	2, 4.33, 6, 15 and 30 km.

Discussion

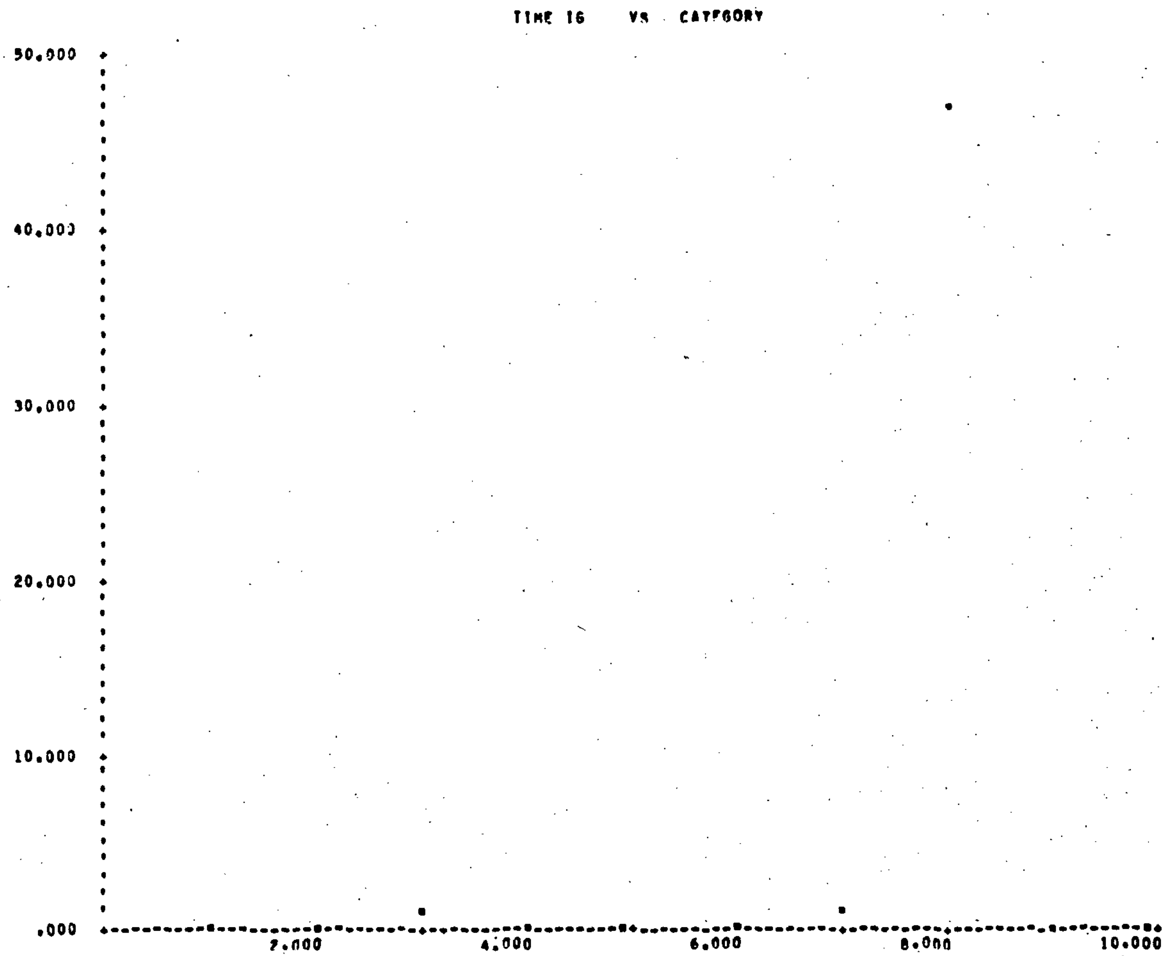
Figure 3-10 is a summary of scientific accomplishment versus LSSM speed for P_1 interrupts. Each point plotted represents the mean of 30 iterations. A major effect in schedule capability is forecast if LSSM speeds are below 5 km/hr. Additional LSSM speed appears to have little advantage for the proposed schedule. Figures 3-11 and 3-12 are data summaries of the P_1 interrupt



AVG TIME	CATEGORY
.27943E 03	.10000E 01
.14094E 02	.20000E 01
.18492E 03	.30000E 01
.00000E-80	.40000E 01
.73235E 02	.49990E 01
.12239E 02	.60000E 01
.13201E 02	.70000E 01
.84845E 02	.80000E 01
.63996E 01	.90000E 01
.23675E 02	.99990E 01

.2107E 02 .1057E 01 .1197E 02 .0000E-80 .9301E 01 .6360E 00 .1314E 01 .9811E 01 .6360E 00 .2163E 01

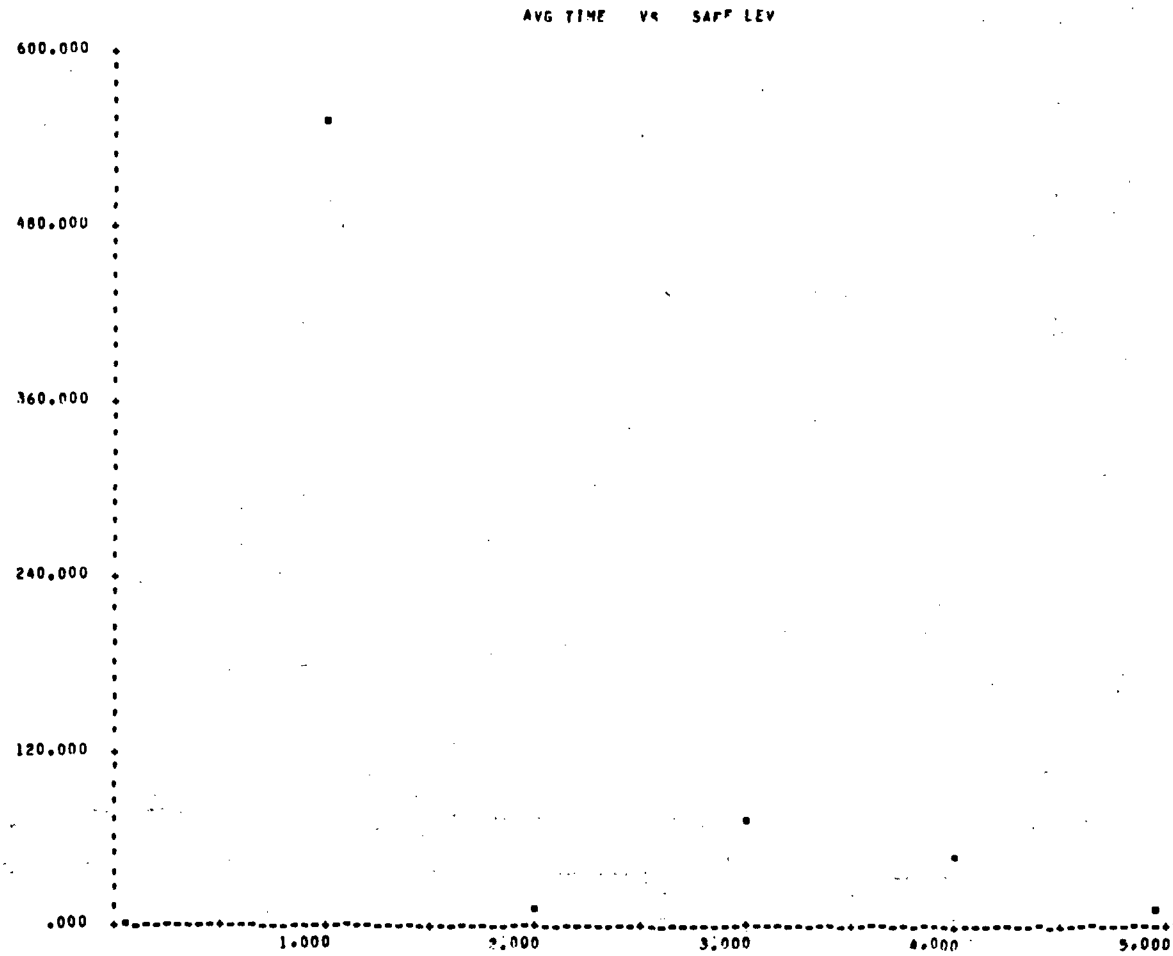
Figure 3-6. Case 2 - Average Time vs Category P_1 Interrupts on Nominal Mission



TIME IG	CATEGORY
.24859E 00	.10000E 01
.17402E 00	.20000E 01
.83823E 00	.30000E 01
.00000E-80	.40000E 01
.00000E-80	.49990E 01
.00000E-80	.60000E 01
.12767E-01	.70000E 01
.46997E 02	.80000E 01
.50553E-11	.90000E 01
.00000E-80	.99990E 01

.6080E 00	.4184E 00	.7466E 00	.0000E-80	.0000E-80	.0000E-80	.2453E 01	.1437E 02	.2122E-11	.0000E-80

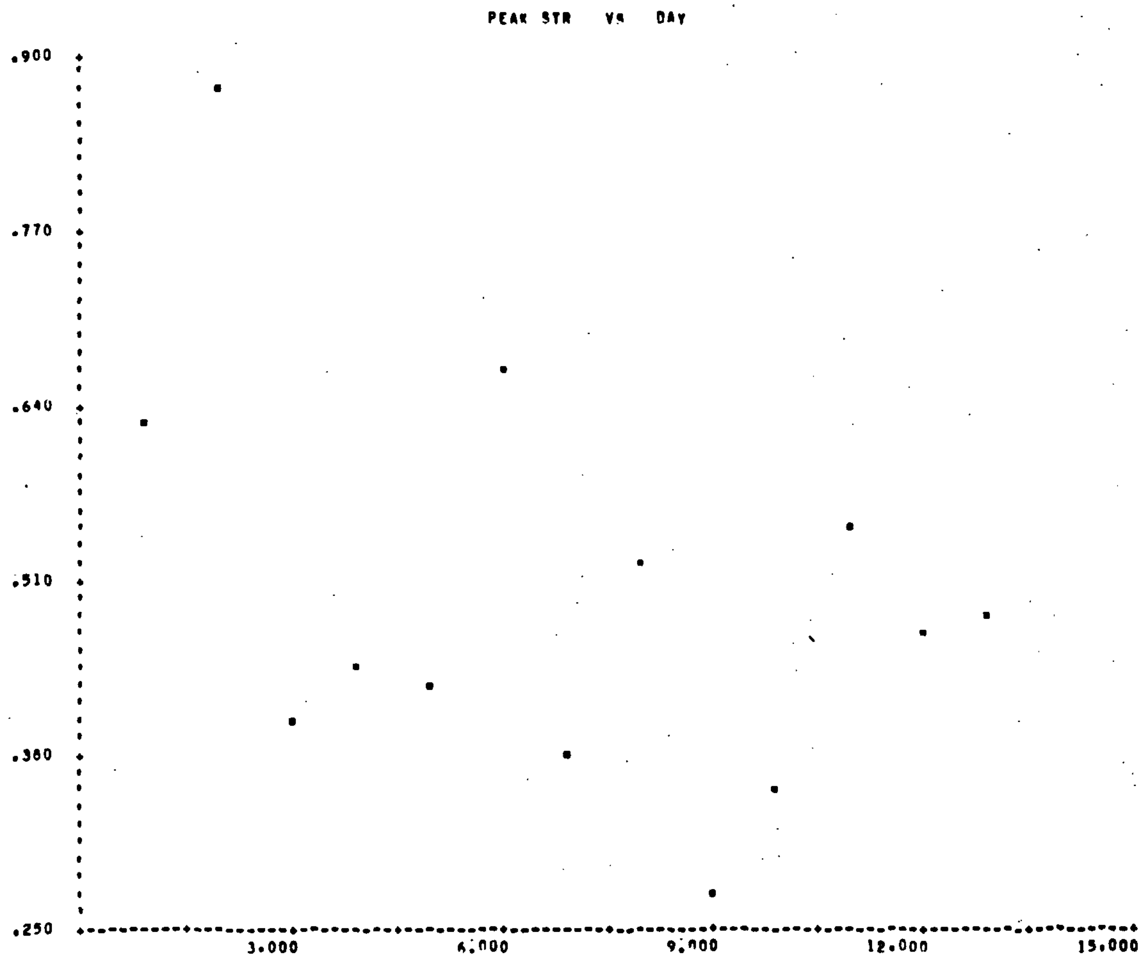
Figure 3-7. Case 2 - Time Ignored vs Category.
P_1 Interrupts on Nominal Schedule



AVG TIME	SAFE LEV
.55290E 03	.10000E 01
.10464E 02	.20000E 01
.75936E 02	.30000E 01
.52335E 02	.40000E 01
.80260E 01	.49990E 01
.00000E-80	.10000E-02

.5603E 01 .2938E 01 .9538E 01 .2929E 01 .2825E 01

Figure 3-8. Case 2 - Average Time vs Safety Level. P_1 Interrupts on Nominal Mission

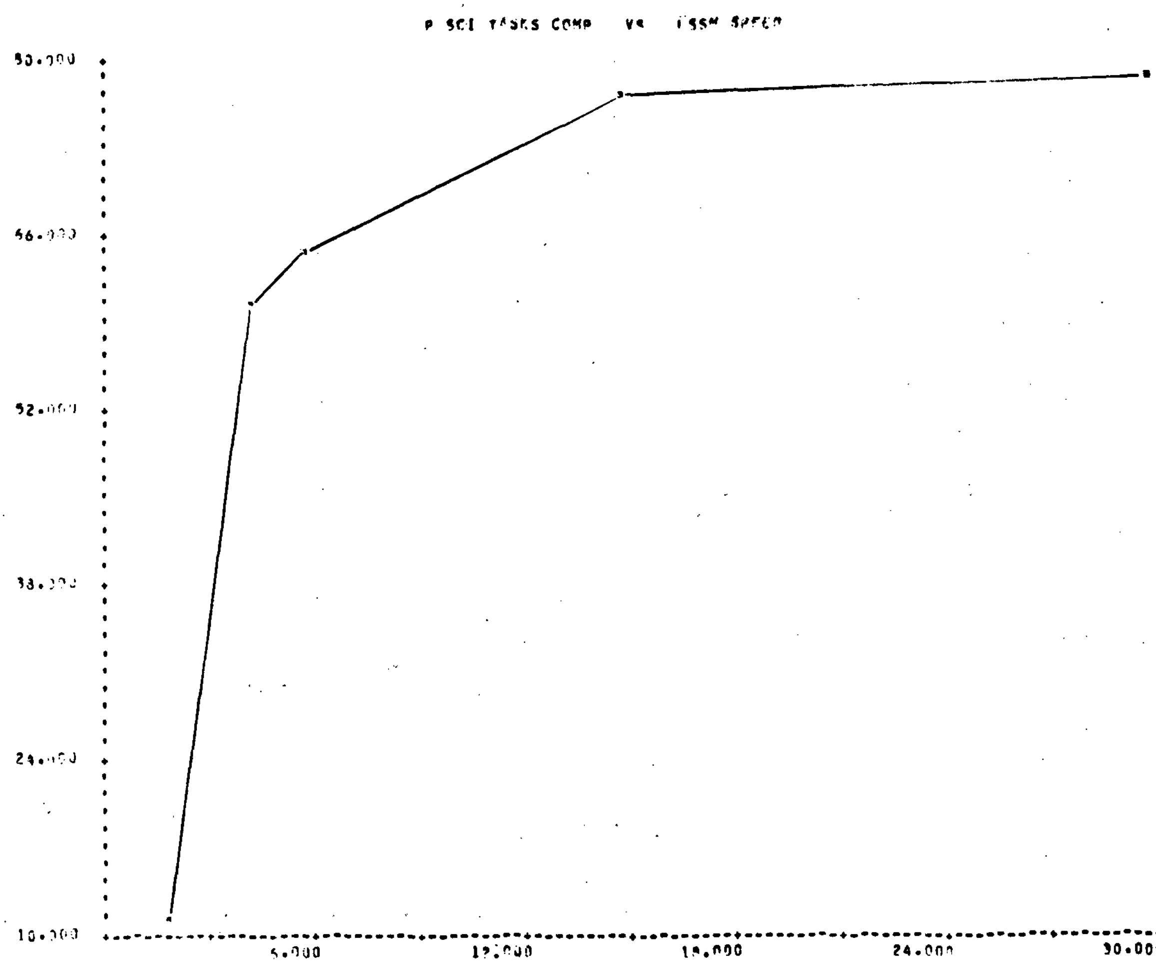


PEAK STR	DAY
.62757E 00	.10000E 01
.87074E 00	.20000E 01
.40019F 00	.30000E 01
.44788E 00	.40000E 01
.43243E 00	.49990E 01
.66612E 00	.60000E 01
.37622E 00	.70000E 01
.52809F 00	.80000E 01
.27054E 00	.90000E 01
.35022E 00	.99990E 01
.55078F 00	.11000E 02
.47510E 00	.12000E 02
.48171E 00	.13000E 02

.1557E 00 .1347E 00 .5905E-02 .3952E-01 .3637E-01 .2088E-01 .1831F 00 .3677E-01 .4549E-01 .3816E-01

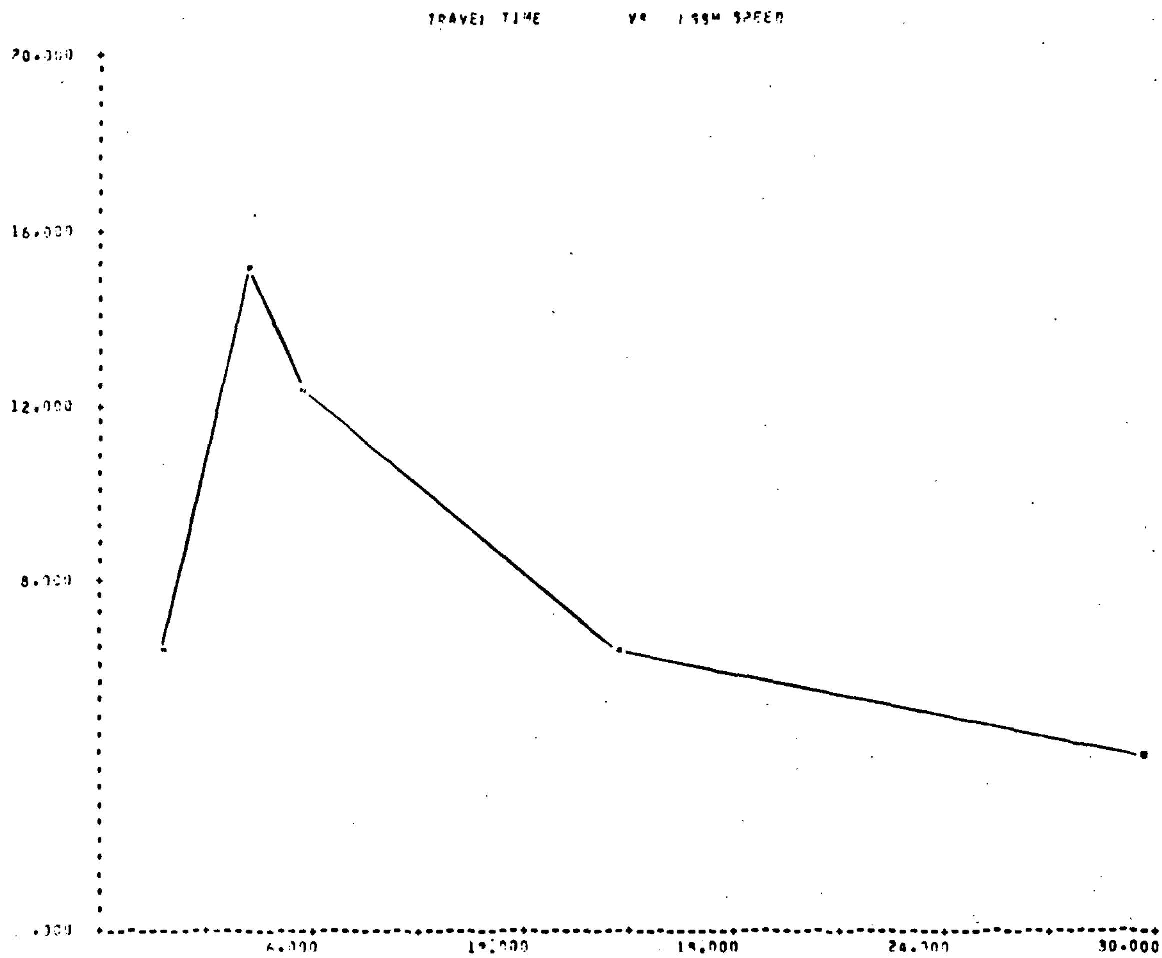
.3293E-01 .4724E-01 .4998E-01

Figure 3-9 Case 2 - Peak Stress vs Day. P_1 Interrupts on Nominal Mission



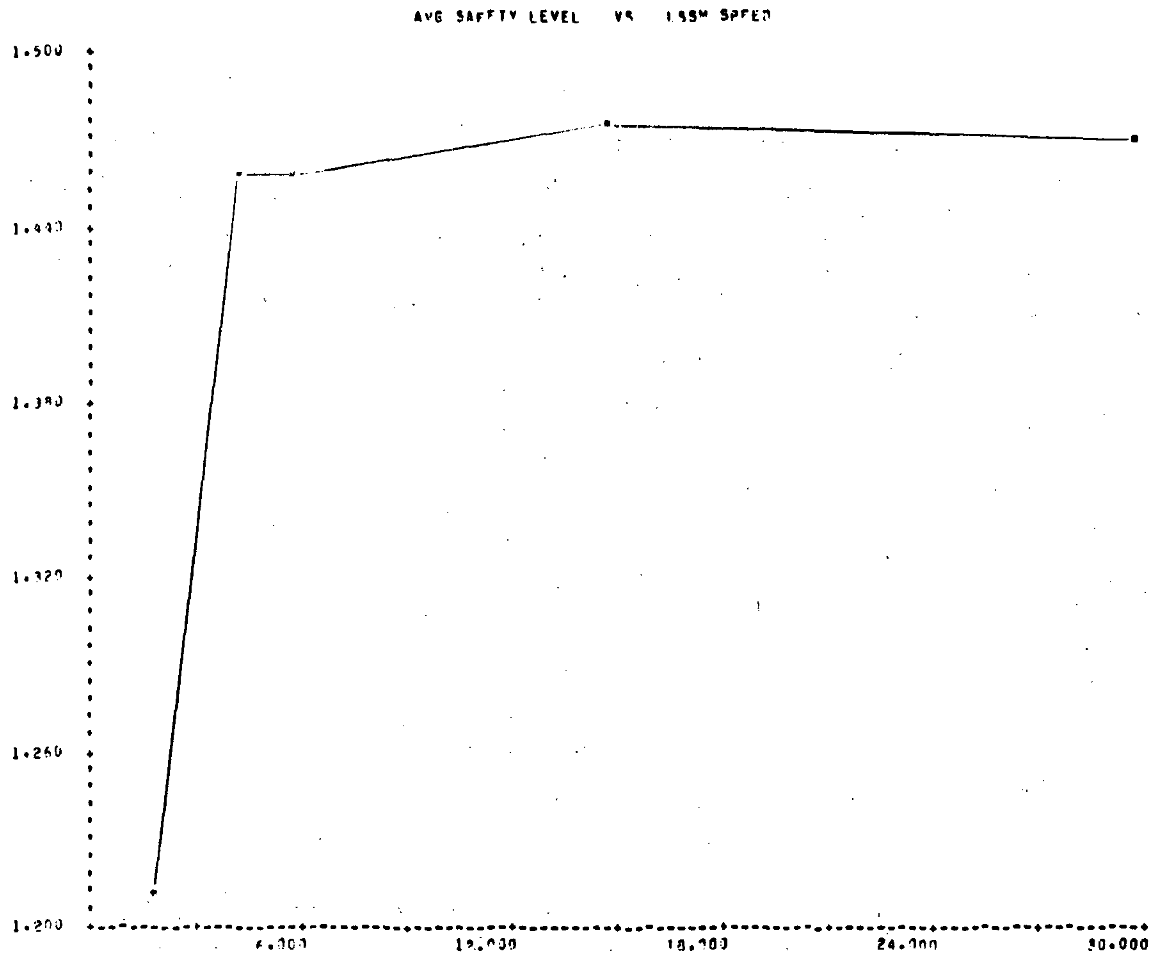
P SCI TASKS COMP	LSSM SPEED
.646902E 02	.600000E 01
.779195E 02	.300000E 02
.759815E 02	.150000E 02
.604650E 02	.433300E 01
.113649E 02	.200000E 01

Figure 3-10. Case 3 - Variation in LSSM Speed Percent Scientific Tasks Completed vs LSSM Speed



TRAVEL TIME	LSSM SPEED
.12239E 02	.63000E 01
.40583E 01	.30000E 02
.64900E 01	.15000E 02
.15168E 02	.43300E 01
.63250E 01	.20000E 01

Figure 3-11. Case 3 - Variations in LSSM Speeds Travel Time vs LSSM Speed



AVG SAFETY LEVEL	LSSM SPEED
.14606E 01	.60000E 01
.14702E 01	.30000E 02
.14791E 01	.15000E 02
.14563E 01	.43300E 01
.12094E 01	.20000E 01

Figure 3-12. Case 3 - Variations in LSSM Speeds
Average Safety Level vs LSSM Speed

case for travel time and average safety level. The reduction in travel time, seen at speeds less than 4.33 km/hr (Figure 3-11) is due to the inability of the program to attempt the longer sorties. This causes the astronauts to remain within the "Safe" ELS. Figure 3-12 indicates the relative stability of the predicted safety levels for speeds above 4.33 km/hr at the P_I - 1/2-hr interrupt case.

Conclusion

Schedule achievement is very sensitive to slight reductions in vehicle speed capability. Major revisions in schedule will be required if vehicle design or operational conditions (lighting, terrain, etc.) are encountered. Schedule achievement is relatively insensitive to increases in vehicle speed capability. Astronaut safety and stress seem insensitive to the vehicle speeds other than the case where the LSSM sorties are abandoned due to lack of vehicle capability.

CASE 4 - EFFECT OF VARIATIONS IN ASTRONAUT SPEED

Conditions

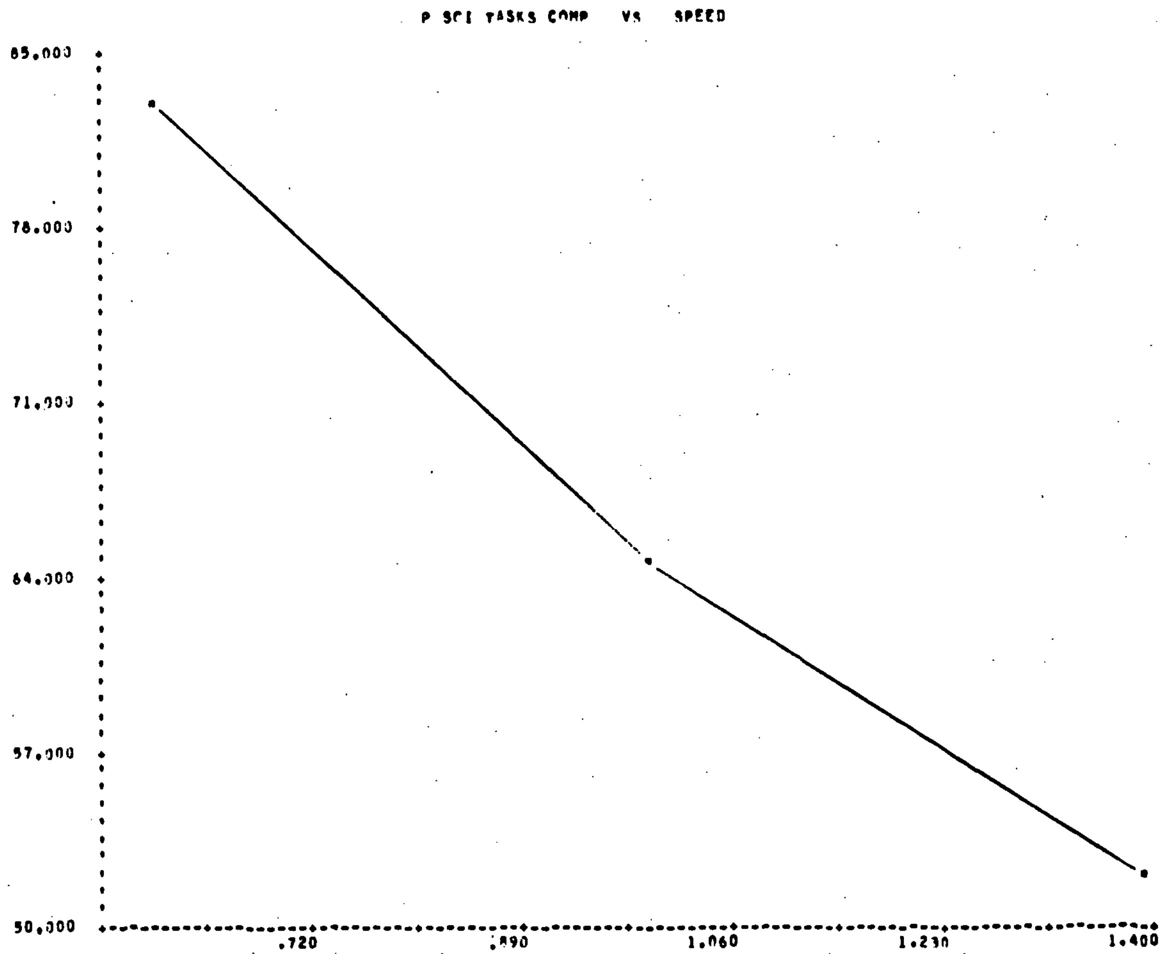
Astronaut Speed	Normal
Reduction in capability	40 percent
Increase in capability	40 percent
LSSM Speed	Nominal (6 km/hr)
Interrupt Condition	P_I

Discussion

Figures 3-13 and 3-14 summarize the important results of variations in schedule accomplishment as astronaut speed is varied. The 1/6-g lunar environment is reported to produce a major impact on astronaut mechanical capability (see References 3, 4, and 5). If this is the case, an estimate of the effect is of interest. The HASSLE program introduces the astronaut speed to vary the rate at which astronaut tasks are accomplished. Figure 3-13 indicates that the accomplishment of scientific tasks is highly dependent upon this factor. The 0.6 speed point represents the astronaut accomplishing tasks at 60 percent of the time required nominally.

The program predicts major improvements in safety with increased astronaut capability (Figure 3-14). The increased capability creates additional spare time in the ELS (Figure 3-15), since unused time within the ELS is programmed to added sleep at the conclusion of each day.

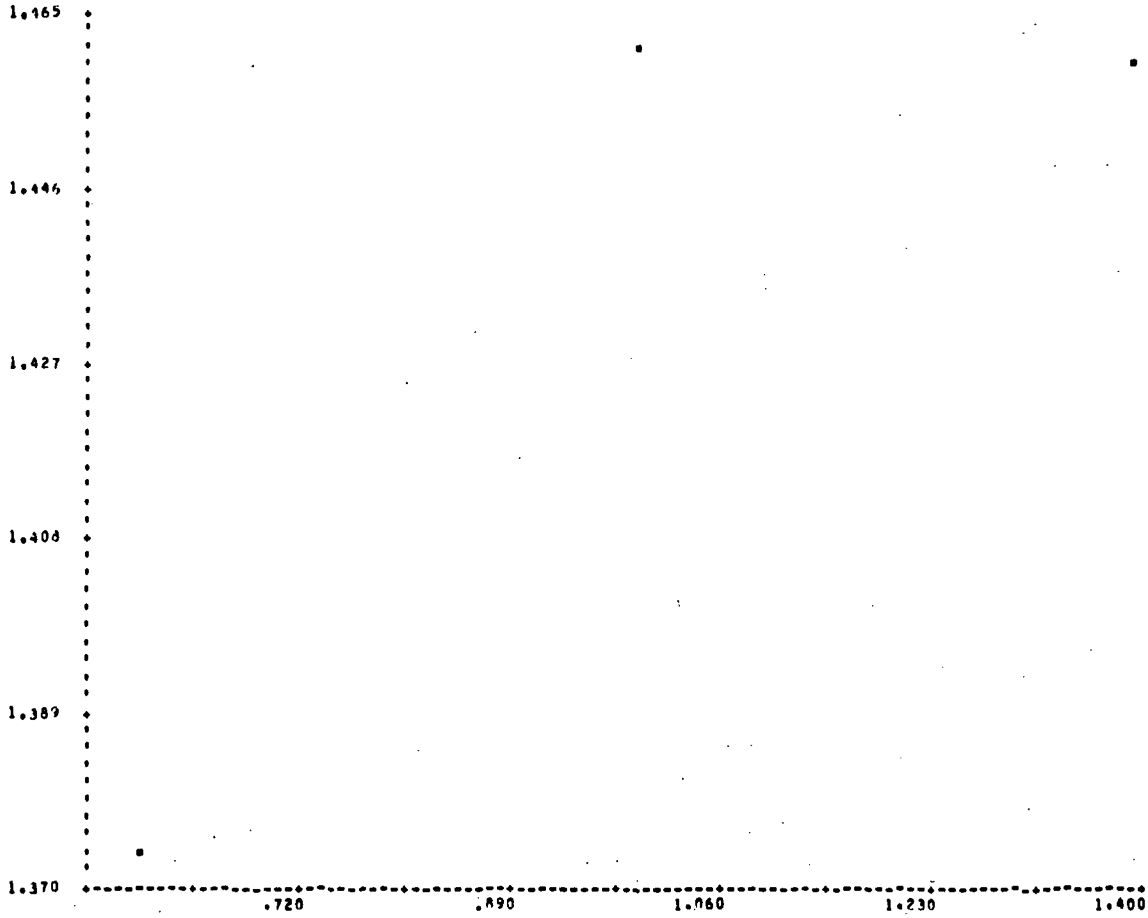
These results are interesting in terms of their implication to lunar exploration. The development of schedules predicated on task time requirement nominals associated with either earth- or 0-g can lead to a major schedule disparity. This situation could result in having a major mismatch of man and his equipment.



P SCI TASKS COMP	SPEED
.64692E 02	.10000E 01
.82687E 02	.60000E 00
.52348E 02	.14000E 01

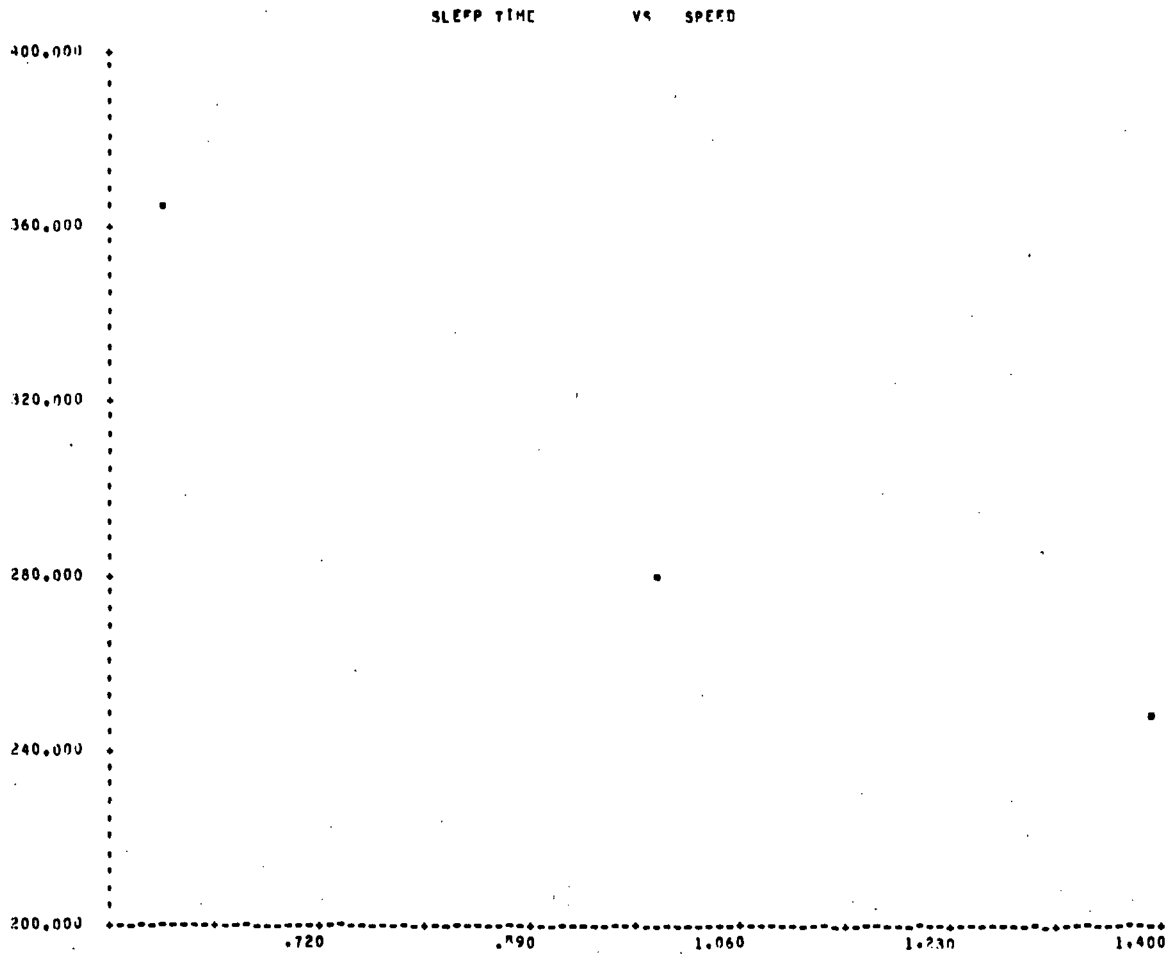
Figure 3-13. Case 4 - Variation in Astronaut Speed Percent Scientific Tasks Completed vs Astronaut Speed

AVG SAFETY LEVEL VS SPEED



AVG SAFETY LEVEL	SPEED
.14606E 01	.10000E 01
.13739E 01	.60000E 00
.14591E 01	.14000E 01

Figure 3-14. Case 4 - Variation in Astronaut Speed Average Safety Level vs Astronaut Speed



SLEEP TIME	SPEED
.27943E 03	.10000E 01
.36520E 03	.60000E 00
.24869E 03	.14000E 01

Figure 3-15. Case 4 - Variation in Astronaut Speed Total Mission Sleep vs Astronaut Speed

Conclusion

The nominal task times to be employed in constructing lunar exploration schedules should be the subject of a major study.

CASE 5 - EFFECT OF 7 VEHICLE-ASTRONAUT CONDITIONS

Conditions

	Astronaut Speed (x, normal rate)	Vehicle Speed km/hr
1	1.5	2.00
2	1.4	3.67
3	1.2	4.33
4	1.0	6.00
5	0.8	15.0
6	0.6	24.0
7	0.5	30.0

Interrupt P_I

Discussion

The lunar environment will impose constraints on the LSSM/ELS system. Prior to the obtaining of additional information from a manned landing or from unmanned vehicles, mission, and vehicle planning must consider the effect of a range of expected environmental conditions. As examples, simulations of lunar lighting conditions have shown that the astronaut may have difficulty in driving vehicles safely at any but extremely slow rates. NASA Langley Research Center (LRC) simulations of pressure-suited 1/6-g mobility indicate a surprising increase in capability.

To investigate the probable effect of this on the proposed mission, seven conditions were chosen which represent one spectrum of expected astronaut and vehicle conditions. These conditions are listed above and summarized in Figure 3-16. It was assumed that conditions which hinder vehicle travel would also hamper astronaut performance, e.g., lighting problems would cause reduced vehicle speed and would also cause the astronaut to spend more time in his tasks. Condition 4 represents a nominal astronaut with a vehicle operating at design speed of 6 km/hr. All analyses were conducted with a P_I interrupt present.

Figure 3-17 is a summary chart relating predicted scientific accomplishment for the seven conditions. The mission appears extremely sensitive to small reduction in vehicle-astronaut capabilities and does not appear to have

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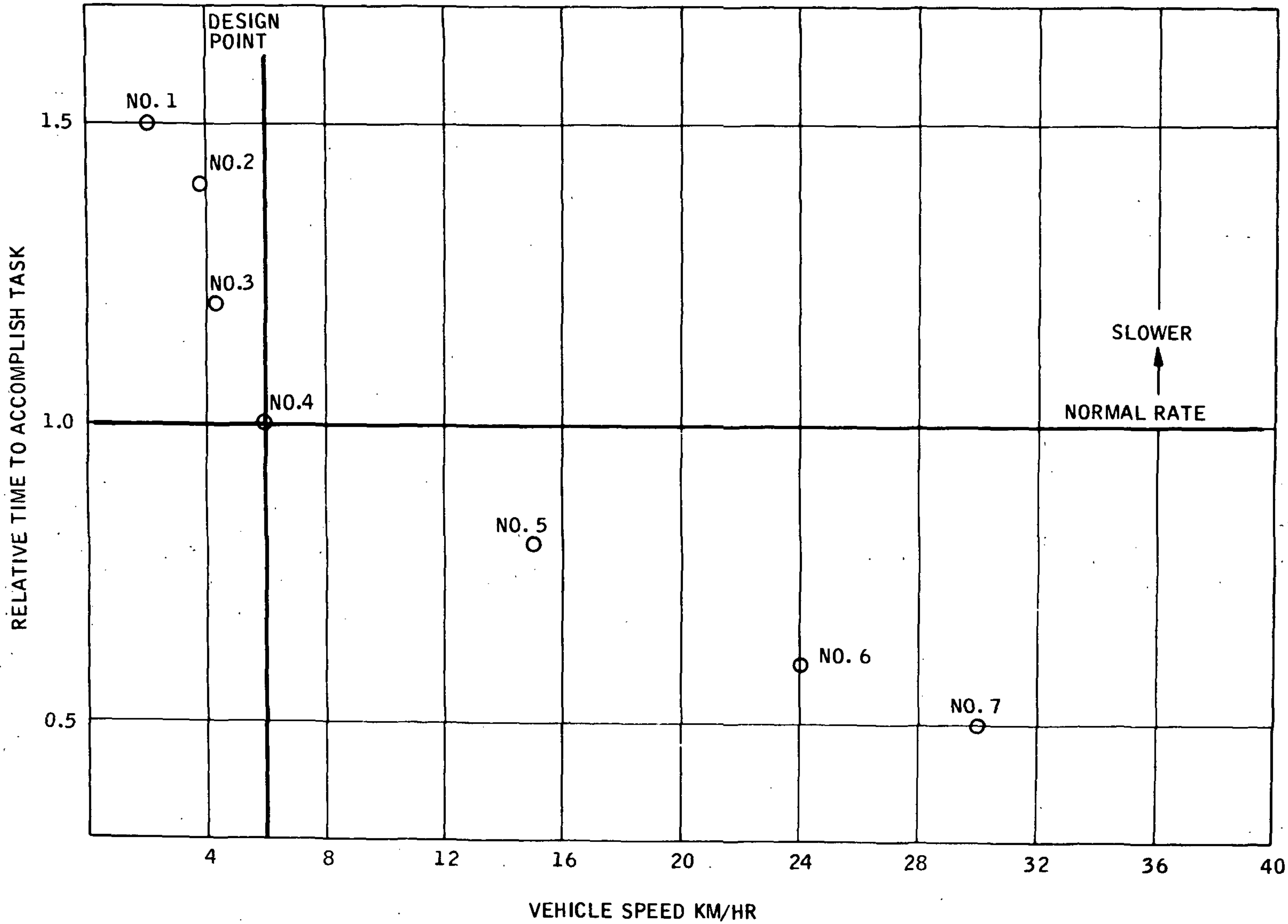


Figure 3-16. Case 5 - Seven Vehicle Astronaut Speed Conditions of Study

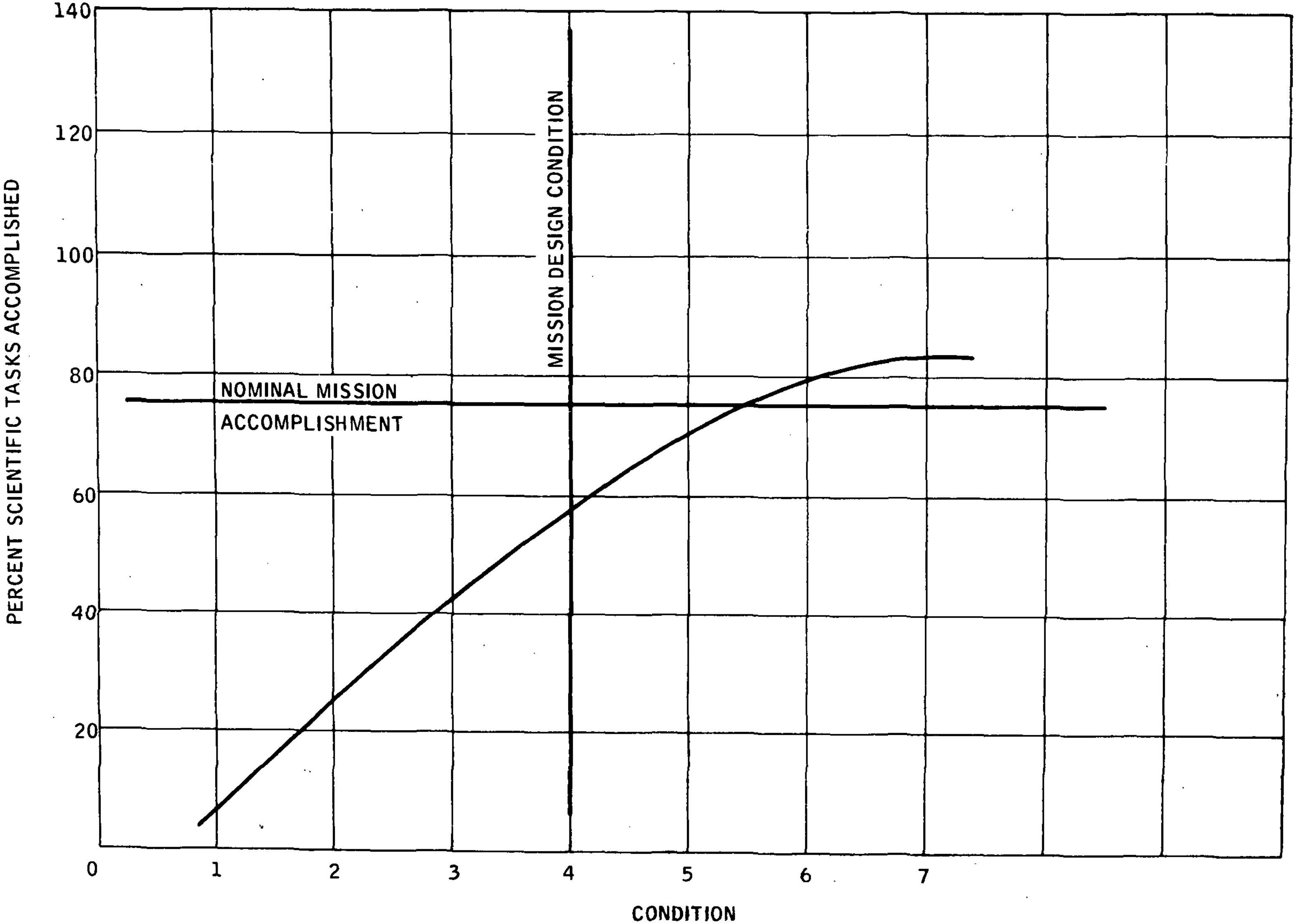


Figure 3-17. Case 5 - Scientific Task Accomplishment vs Conditions with 1/2-hr Average Interrupts of P (0.08, 0.02, 0.02, 0.5)

much capability to recover until major changes in LSSM and operator speed are made (at least to condition 5). The nonpriority scientific tasks are very sensitive to vehicle/astronaut speed conditions (Figure 3-18).

Performance below condition 3 appears to be very restrictive to mission accomplishment. This is evidenced by the inability to attempt the longer missions under such conditions (see Figure 3-19). Travel time decreases for conditions 1 and 2 because the LSSM sortie is impossible for these situations.

Safety levels for the various conditions are not affected as one might expect with reduced performance (Figure 3-20). This is a result of the program not undertaking sorties under low performance conditions, and thereby having the astronaut remain in his "safe" shelter. If the program attempted the lower performance mission, high hazard levels would be predicted. Increased vehicle/astronaut capability serves to reduce hazards as expected.

The HASSLE program relegates leftover time in the ELS to sleep and rest. An analysis of spare time indicates that the interrupt schedule tends to create more time for ELS operations. After utilizing as much of this spare time as possible, the remainder of the spare time can be described as schedule "slack". This is plotted in Figure 3-21. The saddle point occurs near the mission design point. The low-performance conditions of operations 1 and 2 result in large amounts of unusable spare time. The high-performance condition spare time could be utilized with increased scientific activity on the exterior of the ELS, since the added "science" tasks appear to be near completion in conditions 6 and 7.

Figures 3-22 to 3-49 summarize plots of tasks, tasks ignored, safety levels, and peak astronaut stress for the seven conditions.

Conclusions

The designed mission is sensitive to variations in vehicle and astronaut speeds under mild schedule contingencies. This is especially true of reduced performance conditions. Increased capability in LSSM/astronaut performance has a moderate capability to buy back schedule performance.

The severe schedule reduction caused by conditions 1 and 2 is noteworthy. The nominal mission has more capability than required by the schedule, as evidenced by the many hours of nonpriority task 8 "Science" tasks which are accomplished. This slack is quickly used up with reduced performance conditions and priority tasks are omitted.

The planned schedule does not appear to introduce astronaut stress or safety problems but does create a great deal of ELS slack time. It is suggested that the ELS scientific capability be further investigated.

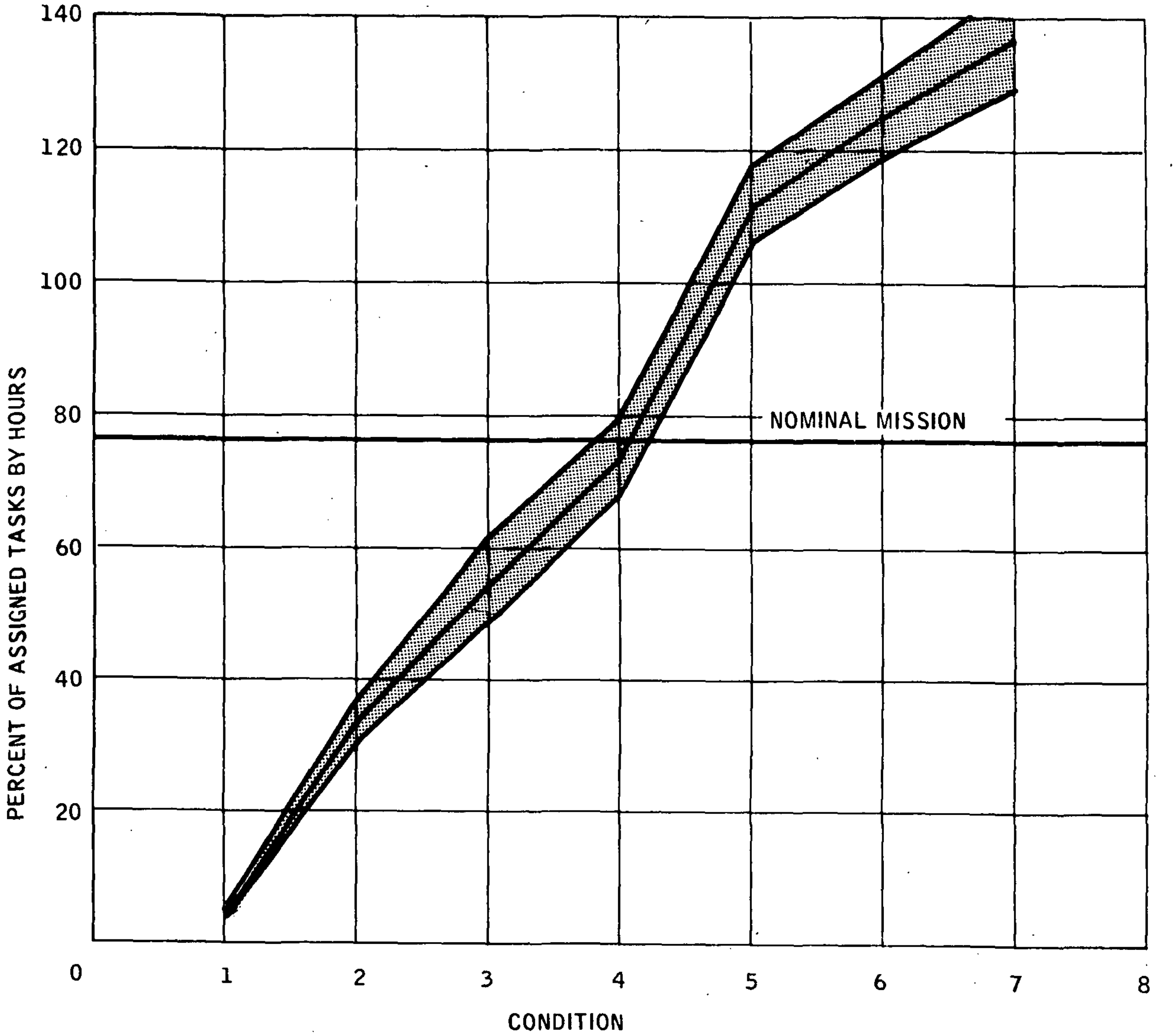


Figure 3-18. Case 5 - Category 8 Accomplishment vs Conditions with 1/2-hr Average Interrupts of P (0.08, 0.02, 0.02, 0.50)

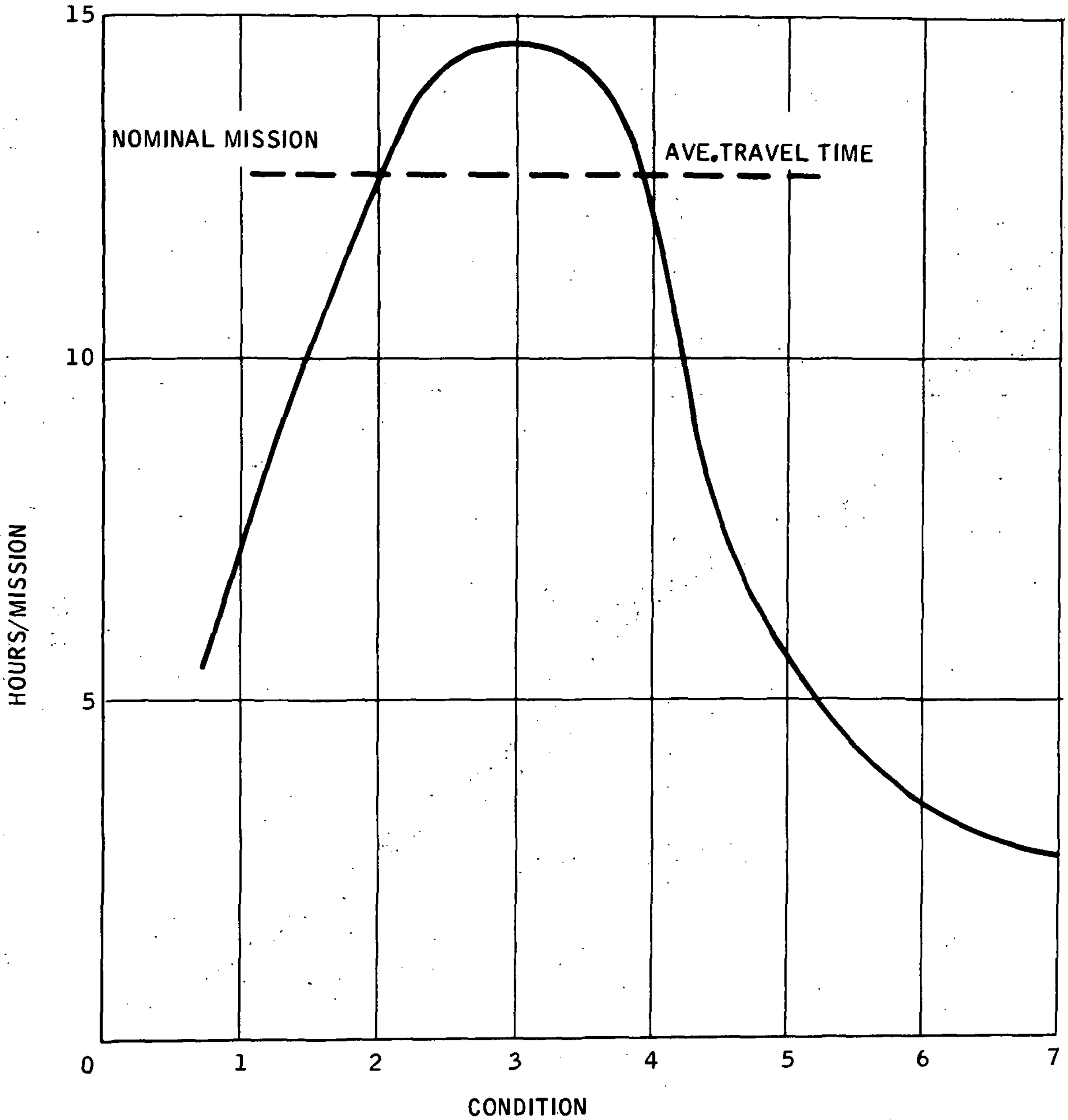


Figure 3-19. Case 5 - Travel Time vs Conditions with 1/2-hr Average Interrupts of P (0.08, 0.02, 0.02, 0.5)

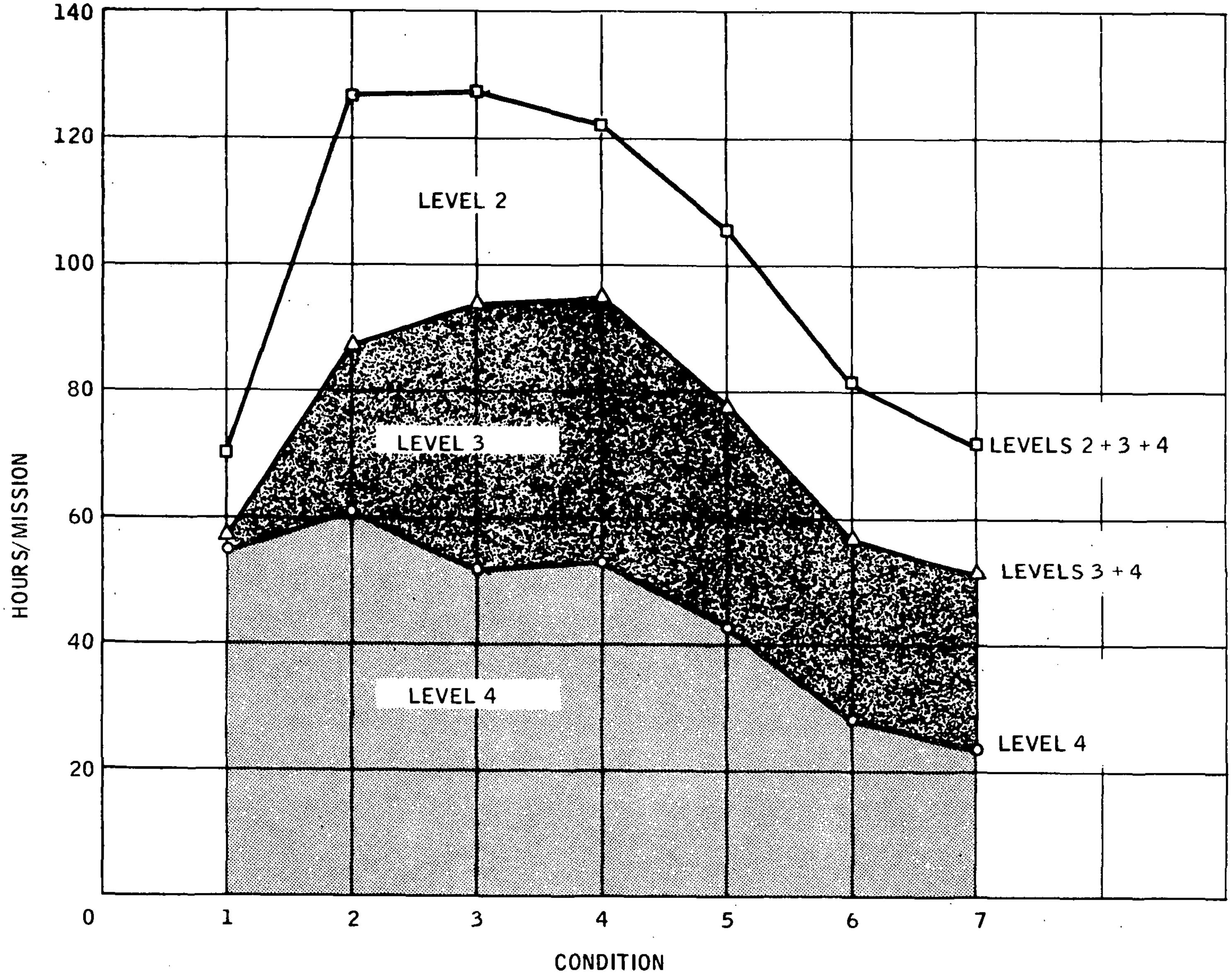


Figure 3-20. Case 5 - Three Safety Levels vs Conditions with 1/2-hr Average Interrupts of P (0.08, 0.02, 0.02, 5.0)

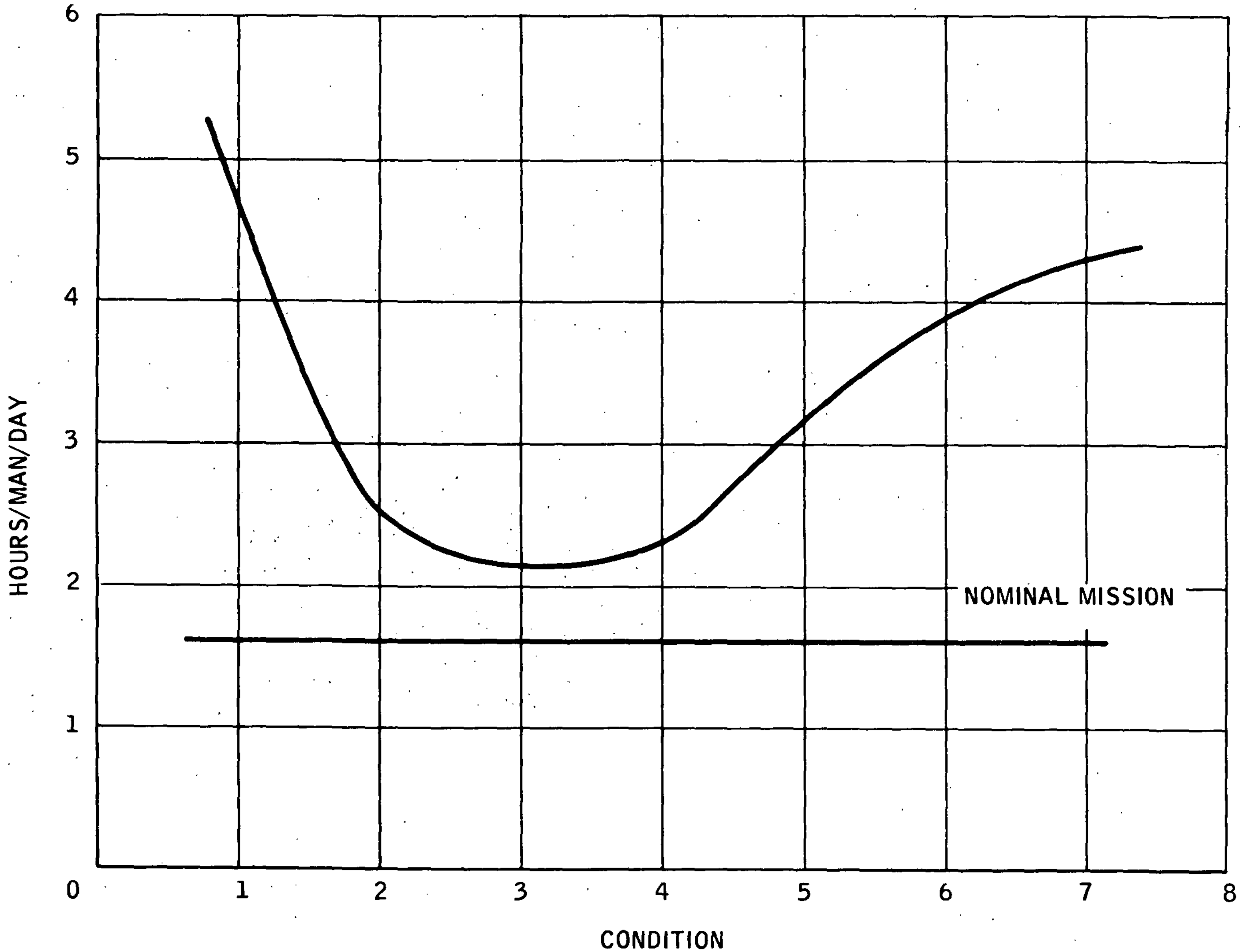
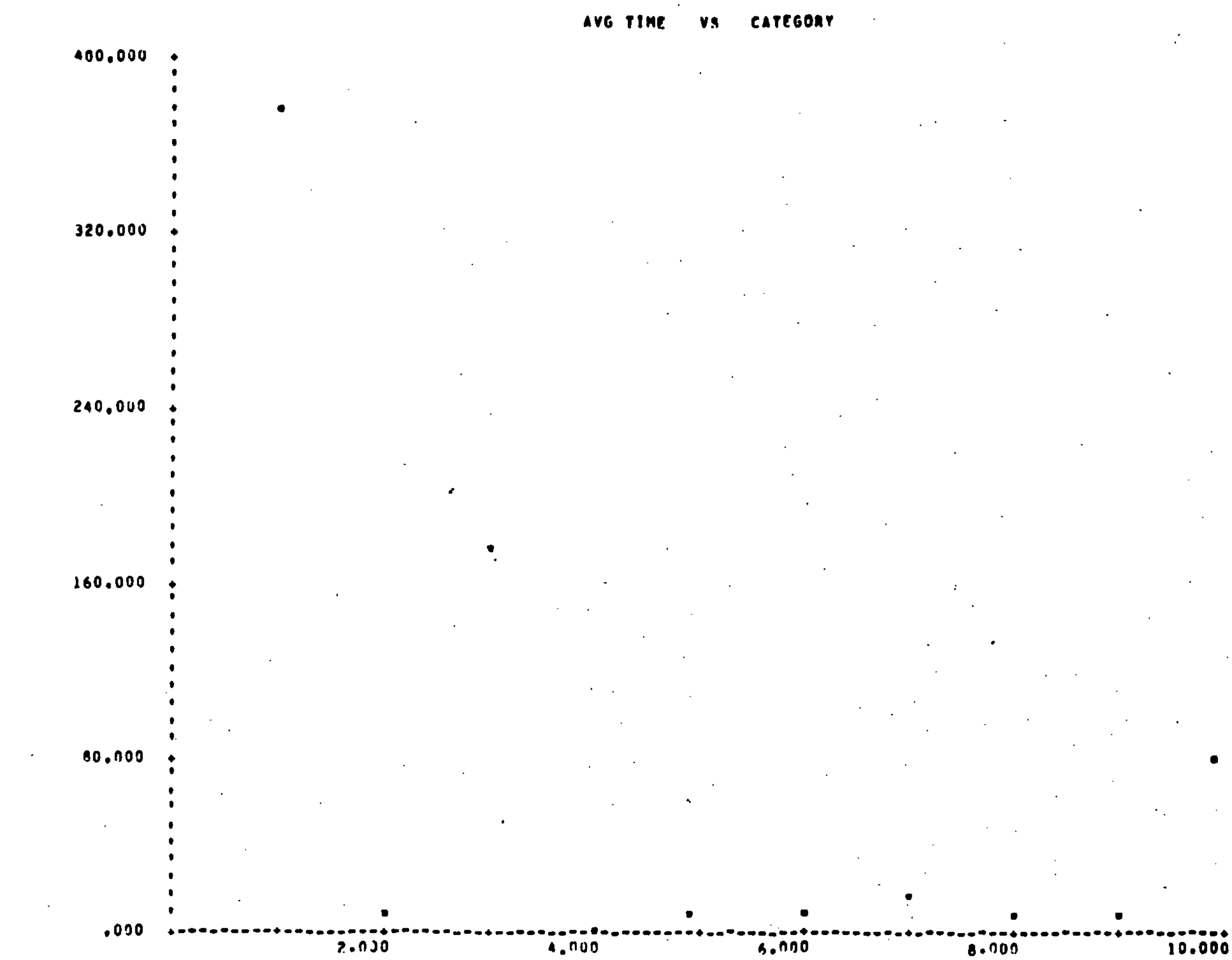


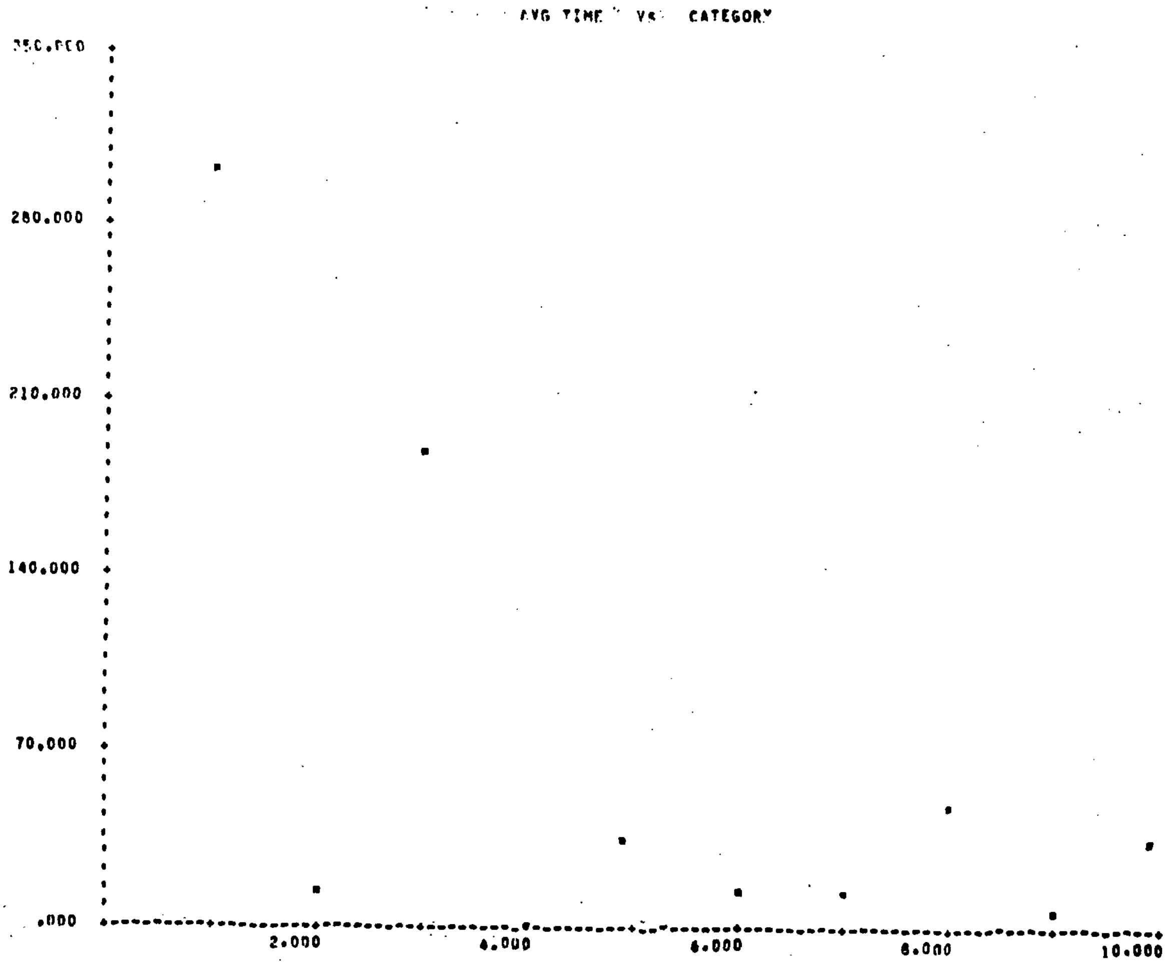
Figure 3-21. Case 5 - Schedule Slack vs Condition with 1/2-hr Average Interrupts of P (0.08, 0.02, 0.02, 0.5)



AVG TIME	CATEGORY
.37468E 03	.10000E 01
.11315E 02	.20000E 01
.17502E 03	.30000E 01
.00000E-80	.40000E 01
.88861E 01	.49990E 01
.74250E 01	.60000E 01
.14124E 02	.70000E 01
.76313E 01	.80000E 01
.63003E 01	.90000E 01
.78350E 02	.99990E 01

.7717E 01 .6023E 00 .2814E 01 .0000E-80 .1891E 01 .5220E 00 .2131E 01 .1498E 01 .5232E 00 .6111E 01

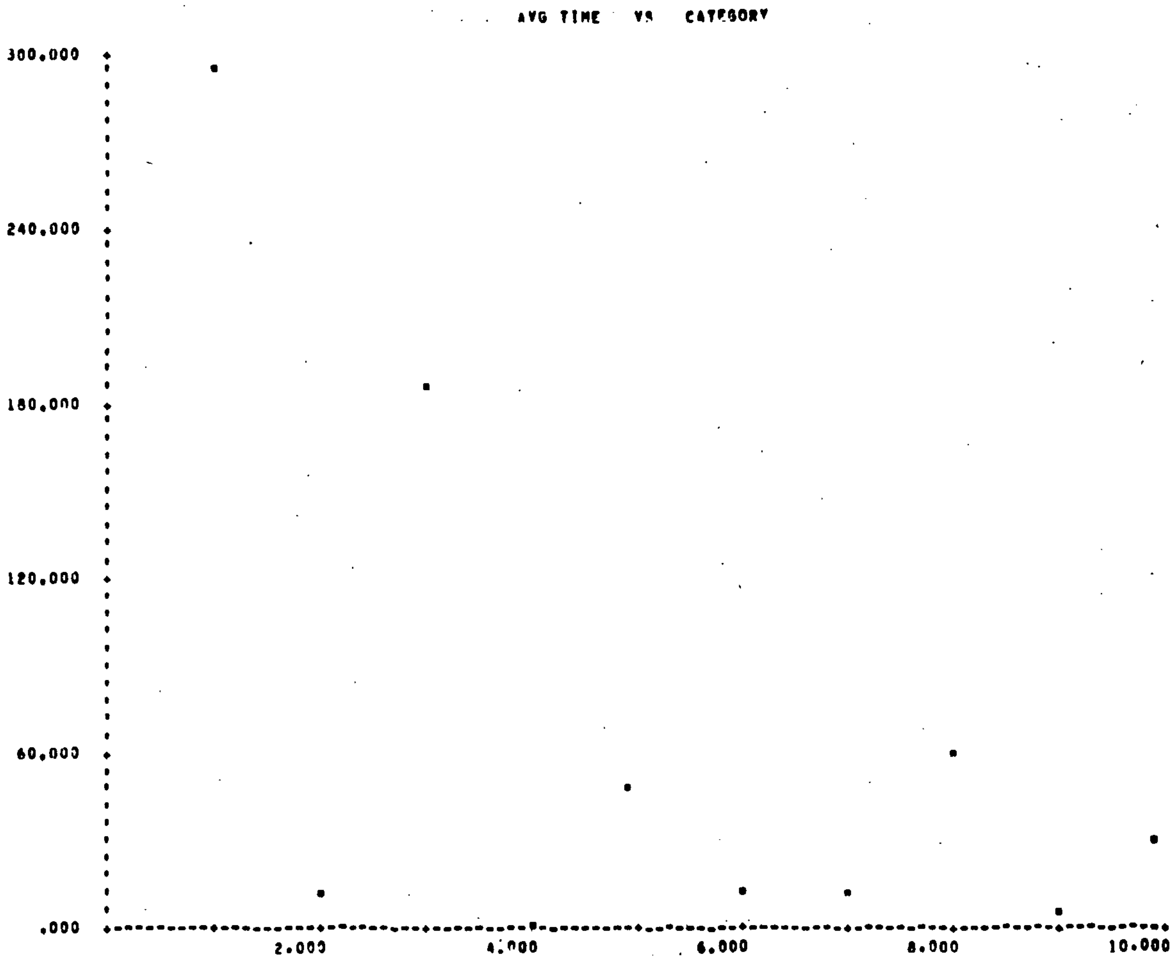
Figure 3-22. Case 5 - Seven Conditions Average Time vs Category. Condition I



AVG TIME	CATEGORY
.30195E 03	.10000E 01
.11753F 02	.20000E 01
.18937E 03	.30000E 01
.00000F-80	.40000E 01
.36215F 02	.49990E 01
.12550E 02	.60000E 01
.12387E 02	.70000E 01
.47457F 02	.80000E 01
.76315E 01	.90000E 01
.37667E 02	.99990E 01

.1195E 02 .7614E 00 .5478E 01 .0000E-80 .3262E 01 .1532E 01 .1340E 01 .5239E 01 .4127E 00 .3432E 01

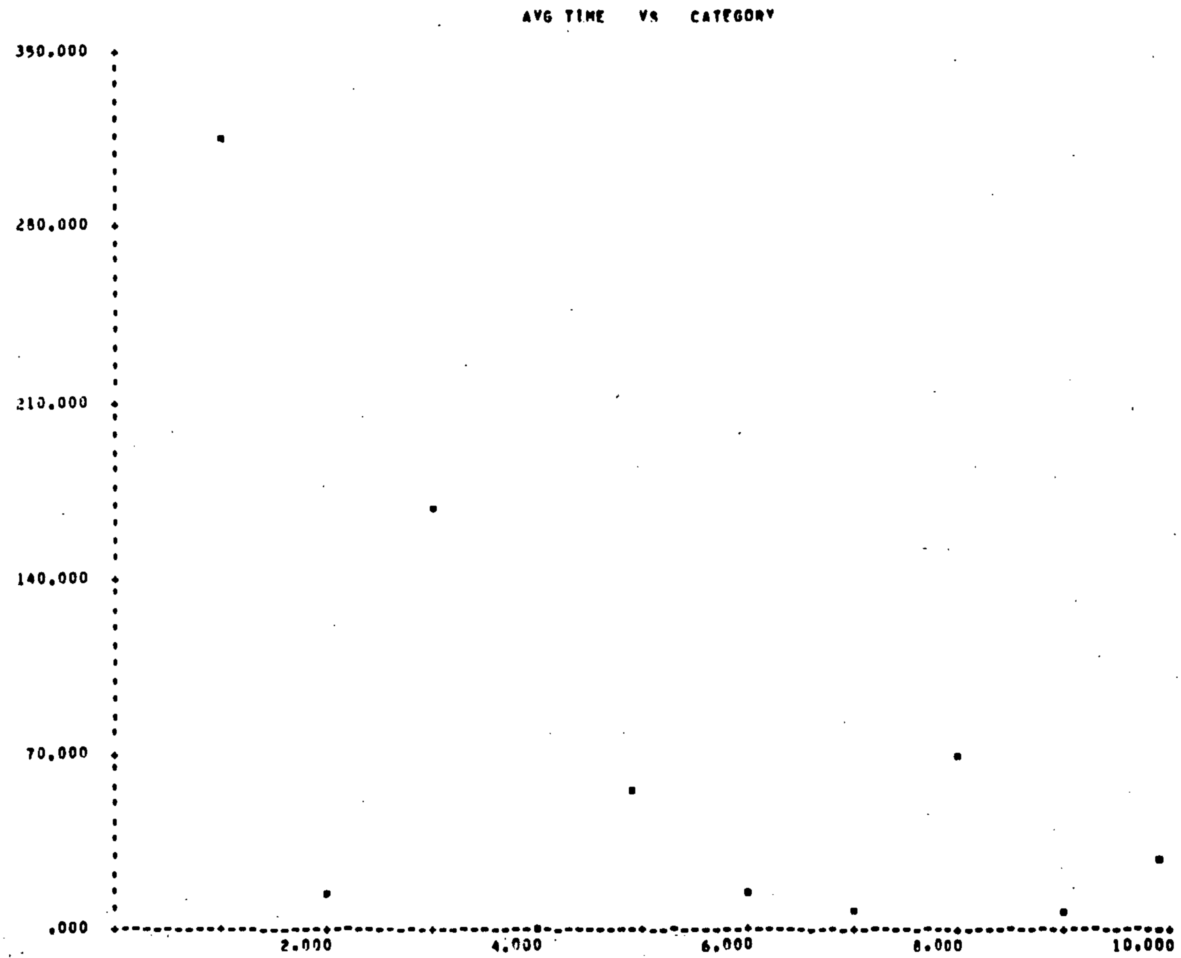
Figure 3-23. Case 5 - Seven Conditions Average Time vs Category. Condition 2



AVG TIME	CATEGORY
.29591E 03	.10000E 01
.11471E 02	.20000E 01
.18903E 03	.30000E 01
.00000E-80	.40000E 01
.50538E 02	.49990E 01
.14627E 02	.60000E 01
.10733E 02	.70000E 01
.61392E 02	.80000E 01
.74850E 01	.90000E 01
.28549E 02	.99990E 01

.1552E 02 .6540E 00 .7868E 01 .0000E-80 .6063E 01 .9064E 00 .9558E 00 .7038E 01 .5560E 00 .2095E 01

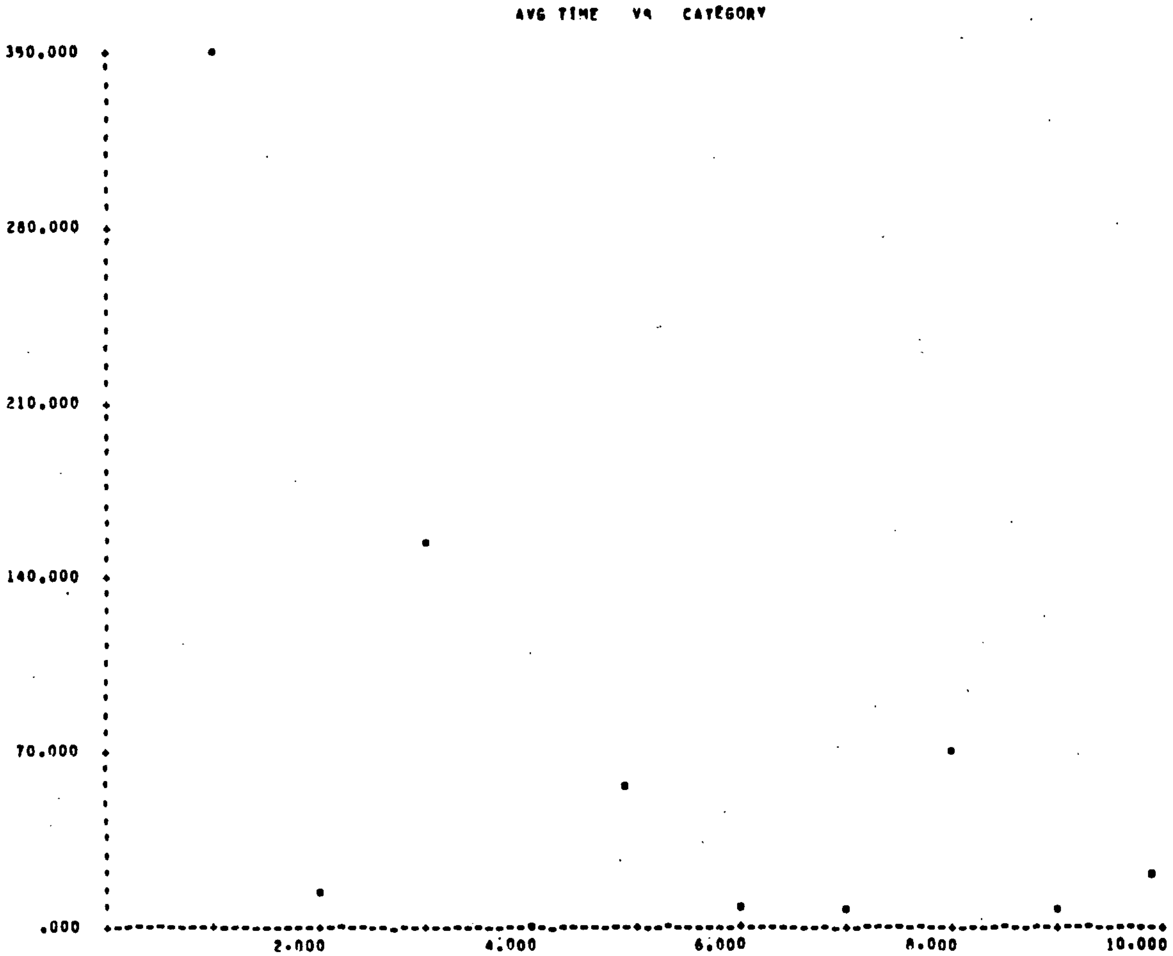
Figure 3-24. Case 5 - Seven Conditions Average Time vs Category. Condition 3



AVG TIME	CATEGORY
.31581E 03	.10000E 01
.11780E 02	.20000E 01
.16735E 03	.30000E 01
.00000E-80	.40000E 01
.57476E 02	.49990E 01
.12187E 02	.60000E 01
.96721E 01	.70000E 01
.68591E 02	.80000E 01
.70262E 01	.90000E 01
.25455E 02	.99990E 01

.1060E 02 .6470E 00 .5352E 01 .0000E-80 .4756E 01 .8729E 00 .8536E 00 .4801E 01 .4255E 00 .1884E 01

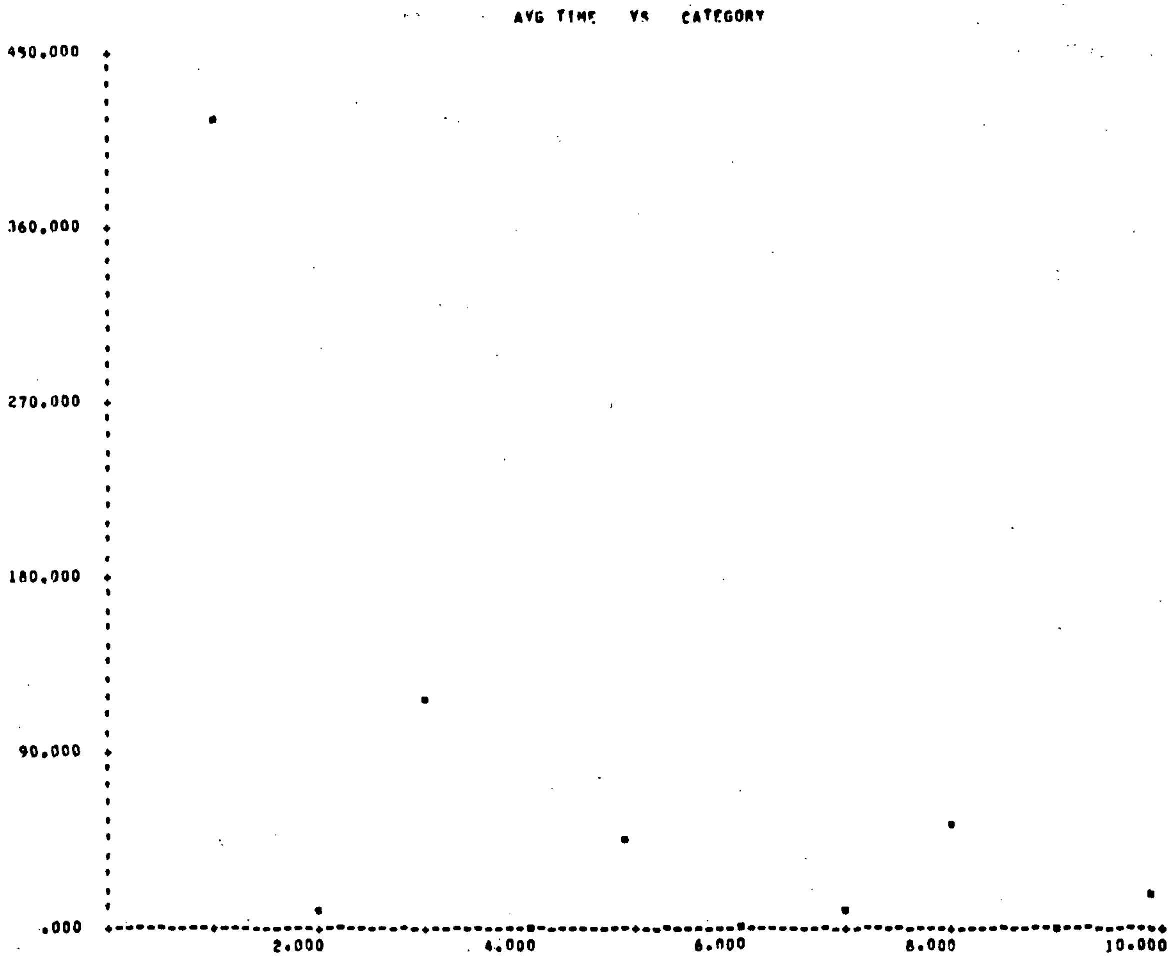
Figure 3-25. Case 5 - Seven Conditions Average Time vs Category. Condition 4



AVG TIME	CATEGORY
.35000E 03	.10000E 01
.11299E 02	.20000E 01
.15237E 03	.30000E 01
.00000E-80	.40000E 01
.57718E 02	.49990E 01
.56478E 01	.60000E 01
.79022E 01	.70000E 01
.69704E 02	.80000E 01
.51669E 01	.90000E 01
.22407E 02	.99990E 01

.1267E 02	.7454E 00	.7885E 01	.0000E-80	.4044E 01	.1901E 00	.7342E 00	.3793E 01	.3973E 00	.1838E 01

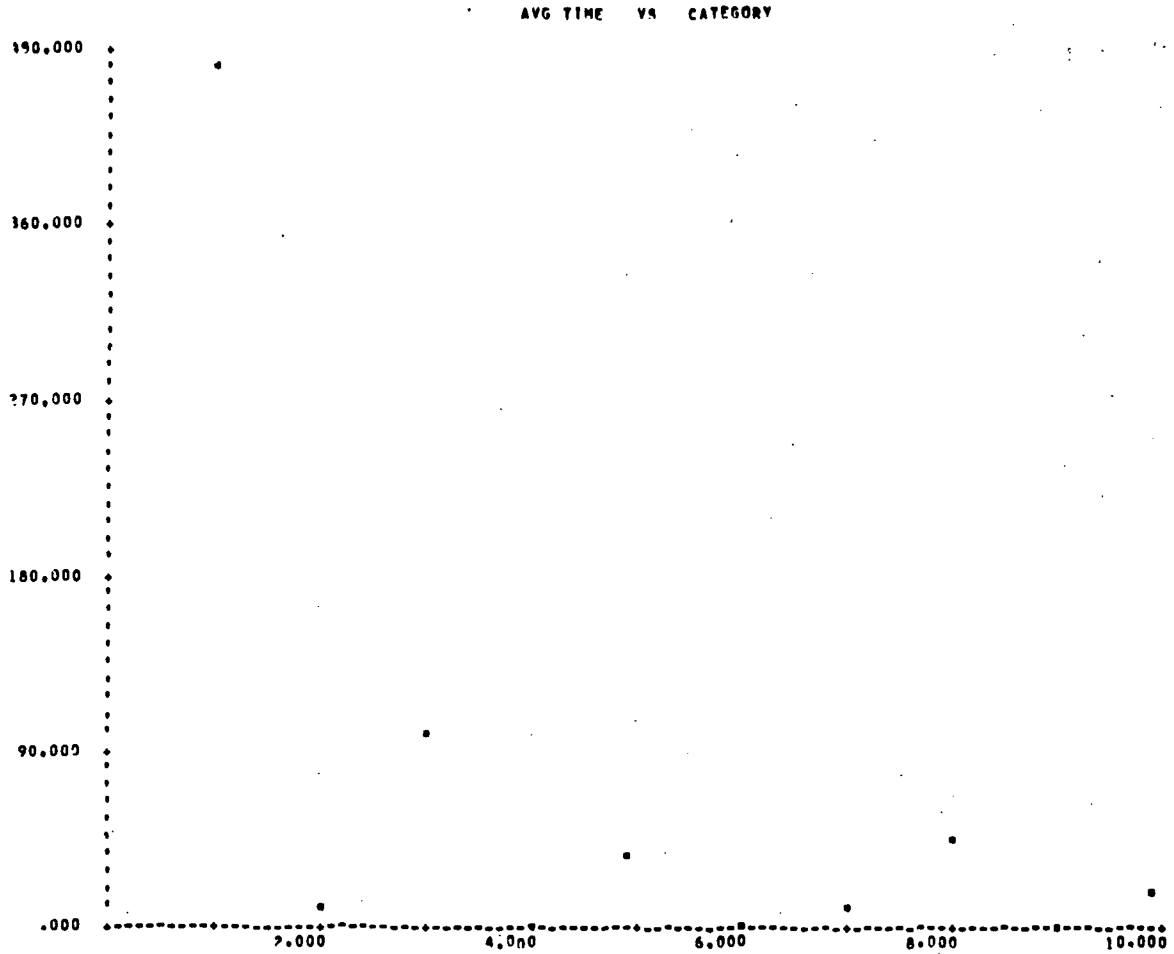
Figure 3-26. Case 5 - Seven Conditions Average Time vs Category. Condition 5



AVG TIME	CATEGORY
.41207E 03	.10000E 01
.88757E 01	.20000E 01
.11671E 03	.30000E 01
.00000E-80	.40000E 01
.45134E 02	.49990E 01
.34042E 01	.60000E 01
.62024E 01	.70000E 01
.55490E 02	.80000E 01
.38564E 01	.90000E 01
.17754E 02	.99990E 01

.1192E 02 .6352E 00 .7553E 01 .0000E-80 .5223E 01 .1702E 00 .7972E 00 .4193E 01 .2740E 00 .2329E 01

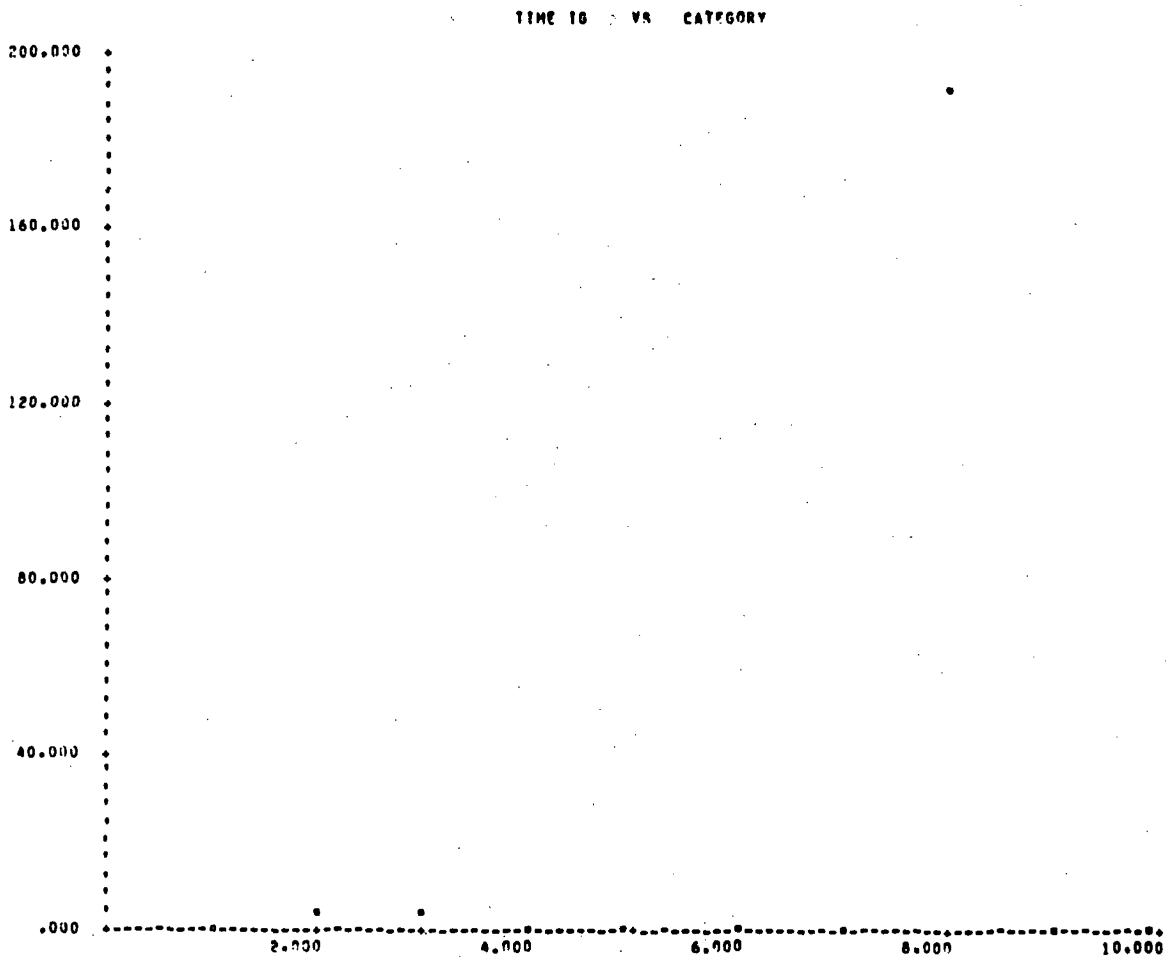
Figure 3-27. Case 5 - Seven Conditions Average Time vs Category. Condition 6



AVG TIME	CATEGORY
.43883E 03	.10000E 01
.76242E 01	.20000E 01
.99610E 02	.30000E 01
.00000E-50	.40000E 01
.40298E 02	.49990E 01
.26525E 01	.60000E 01
.52592E 01	.70000E 01
.49398E 02	.80000E 01
.33185E 01	.90000E 01
.15420E 02	.99990E 01

.1357E 02 .6005E 00 .6940E 01 .0000E-80 .3738E 01 .4887E-01 .3760E 00 .3624E 01 .2639E 00 .2045E 01

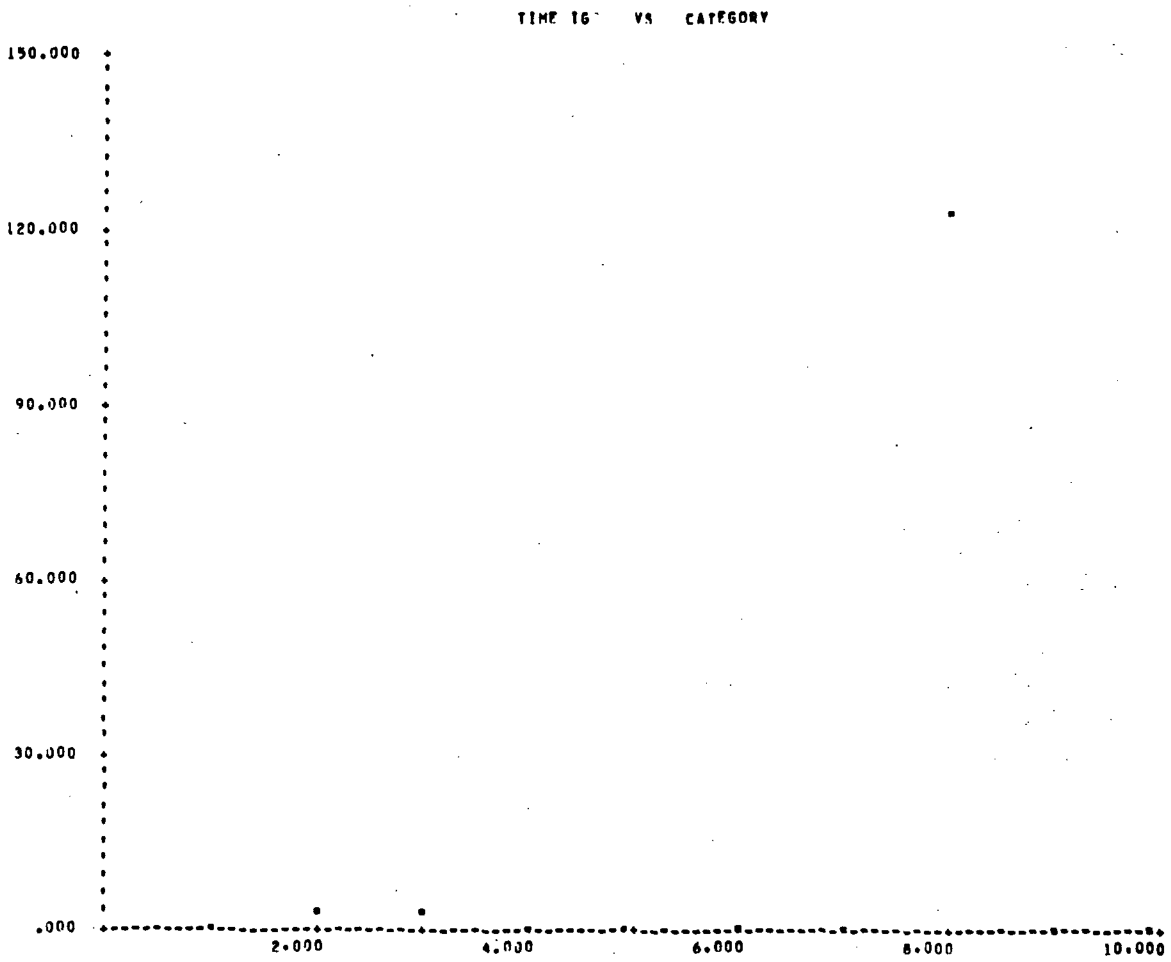
Figure 3-28. Case 5 - Seven Conditions Average Time vs Category. Condition 7



TIME IG	CATEGORY
.17145E 01	.10000E 01
.22675F 01	.20000E 01
.36943E 01	.30000E 01
.00000F-80	.40000E 01
.00000F-80	.49990E 01
.00000F-80	.60000E 01
.14467F 01	.70000E 01
.19093F 03	.80000F 01
.69197F-11	.90000E 01
.00000F-80	.99990E 01

.1487E 01 .3943E 00 .1444E 01 .0000E-80 .0000E-80 .0000E-80 .2064E 01 .3036E-01 .1657E-11 .0000E-80

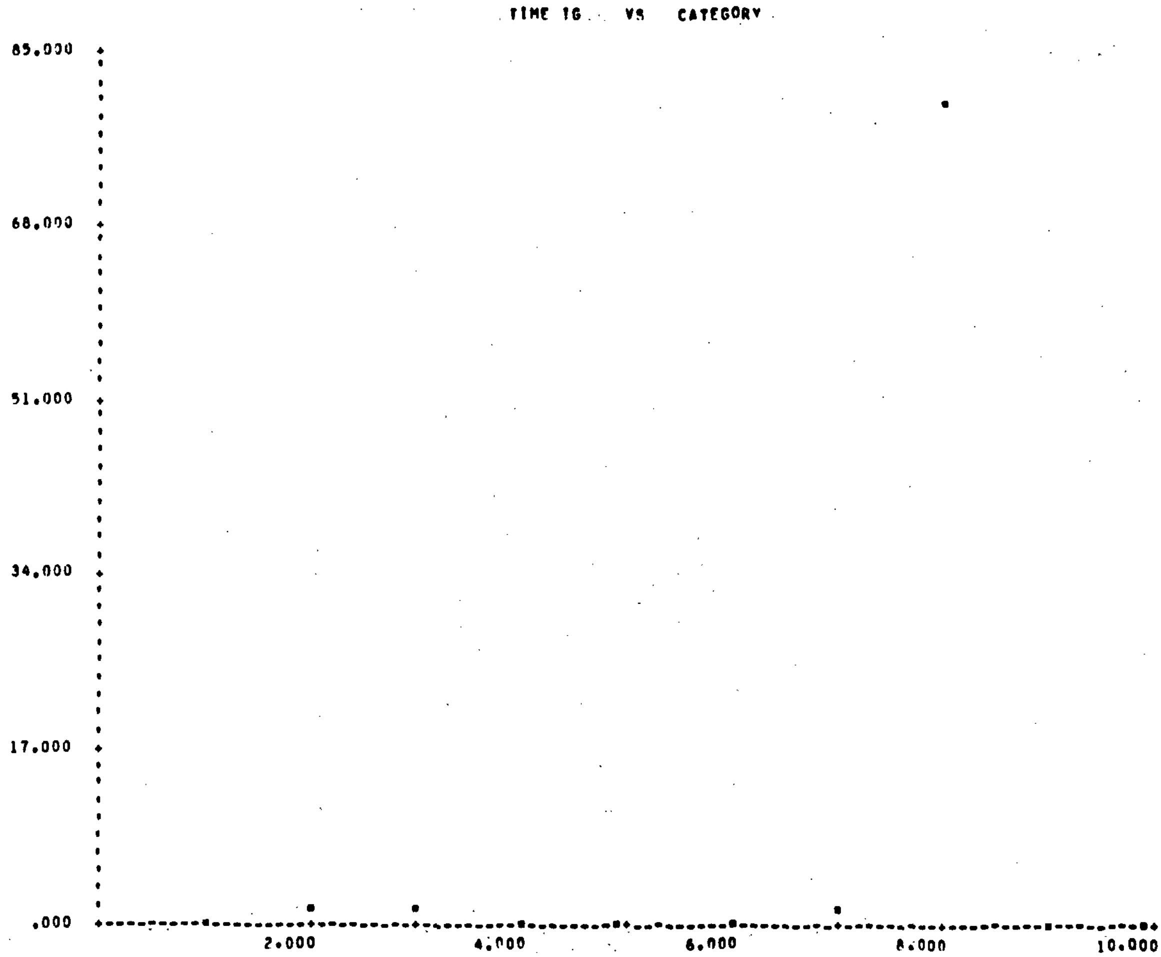
Figure 3-29. Case 5 - Seven Conditions Time Ignored vs Category.. Condition I



TIME IG	CATEGORY
.83295E 00	.10000E 01
.20000E 01	.20000E 01
.23973F 01	.30000E 01
.00000E-80	.40000E 01
.00000E-80	.49990E 01
.00000E-80	.60000E 01
.10400E 01	.70000E 01
.12323F 03	.80000E 01
.65635E-11	.90000E 01
.00000E-80	.99990E 01

.9700E 00 .3823E 00 .1273E 01 .0000E-80 .0000E-80 .0000E-80 .1592E 01 .1037E 02 .1957E-11 .0000E-80

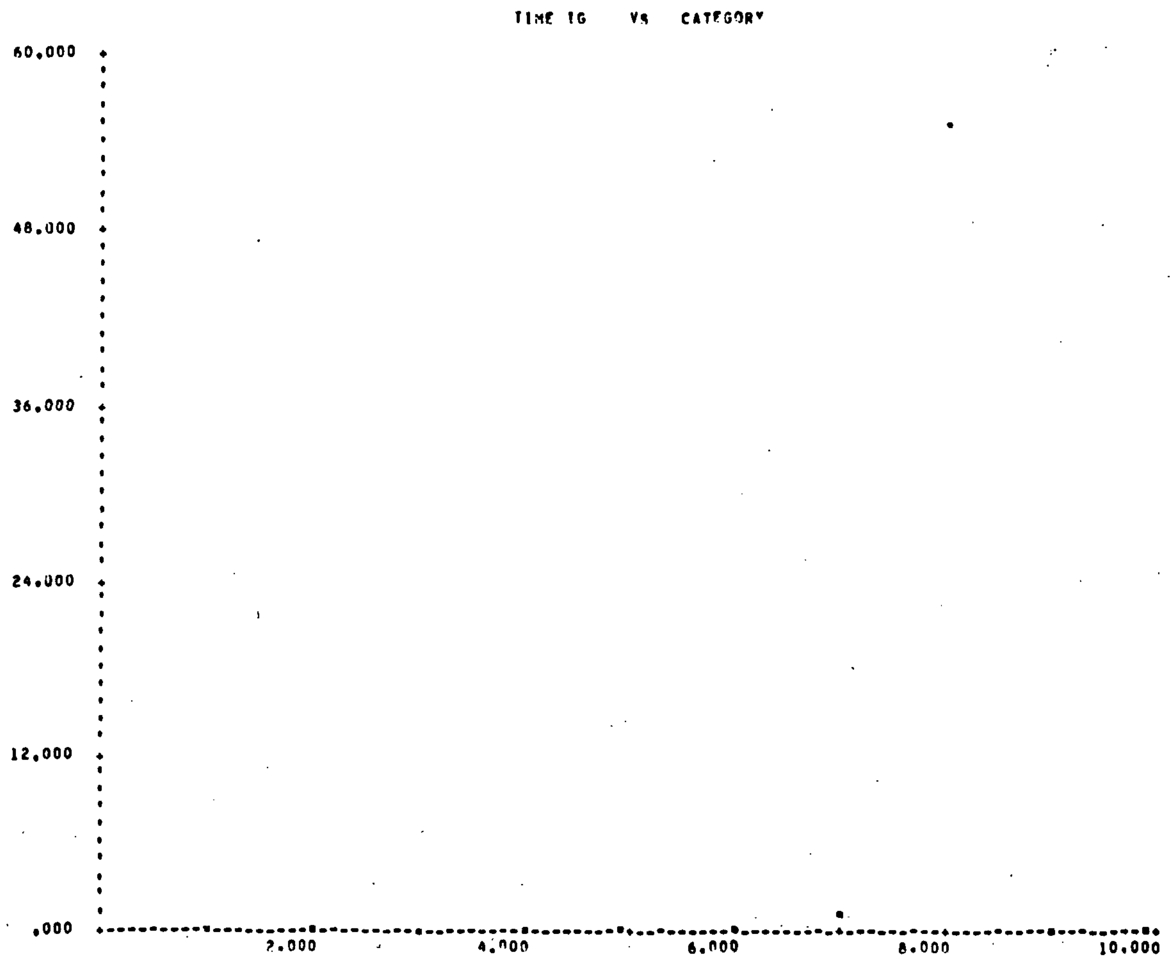
Figure 3-30. Case 5 - Seven Conditions Time Ignored vs Category. Condition 2



TIME IG	CATEGORY
.11303E 00	.10000E 01
.15120E 01	.20000E 01
.12536E 01	.30000E 01
.00000E-80	.40000E 01
.00000E-80	.49990E 01
.00000E-80	.60000E 01
.10433E 01	.70000E 01
.80354E 02	.80000E 01
.56351E-11	.90000E 01
.00000E-80	.99990E 01

.3427E 00	.1079E-04	.6784E 00	.0000E-80	.0000E-80	.0000E-80	.1914E 01	.1372E 02	.1996E-11	.0000E-80

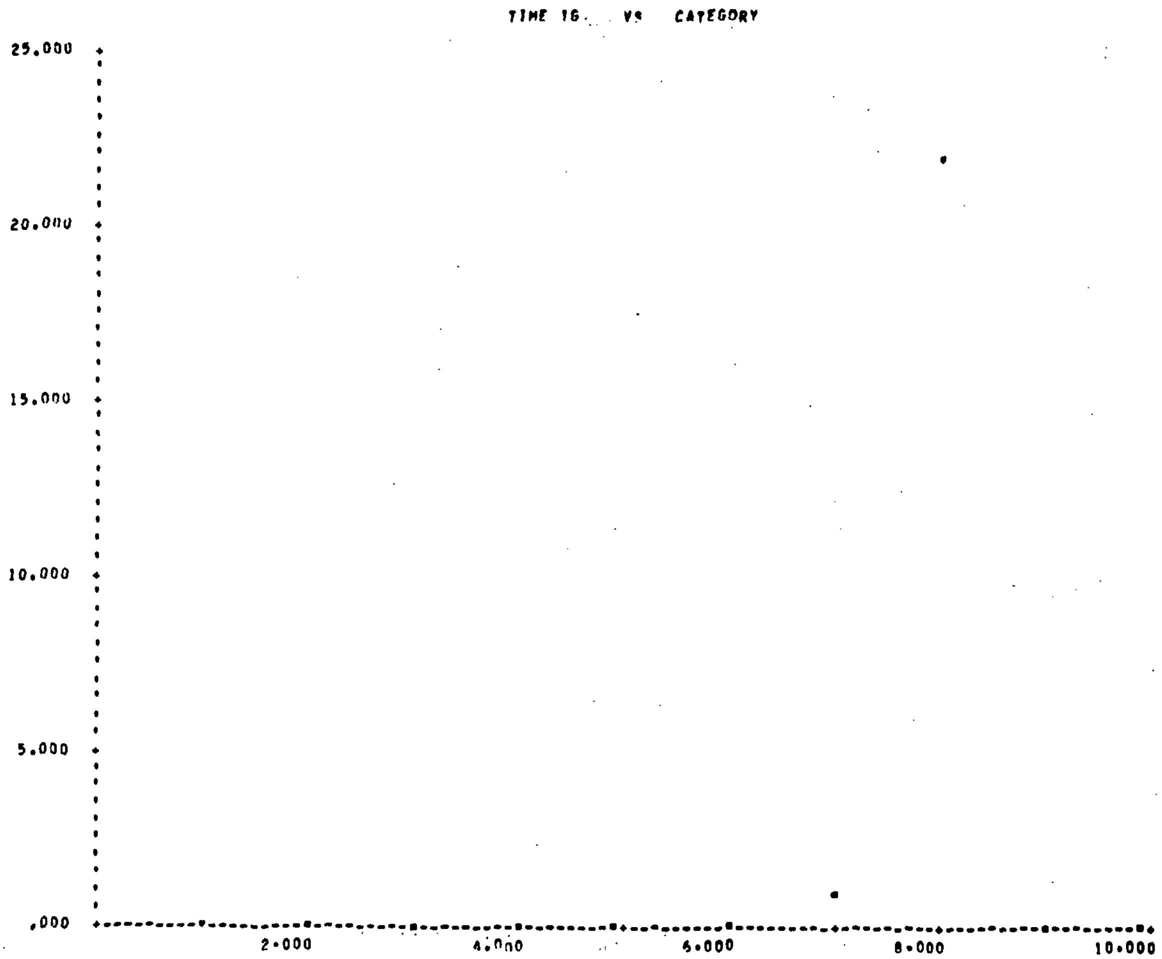
Figure 3-31. Case 5 - Seven Conditions Time Ignored vs Category. Condition 3



TIME IG	CATEGORY
.52868E-02	.10000E 01
.66829E-01	.20000E 01
.42926E 00	.30000E 01
.00000E-80	.40000E 01
.00000E-80	.49990E 01
.00000E-80	.60000E 01
.91333E 00	.70000E 01
.55324E 02	.80000E 01
.35432E-11	.90000E 01
.00000E-80	.99990E 01

.2847E-01 .2587E 00 .5098E 00 .0000E-80 .0000E-80 .0000E-80 .1485E 01 .1069E 02 .1671E-11 .0000E-80

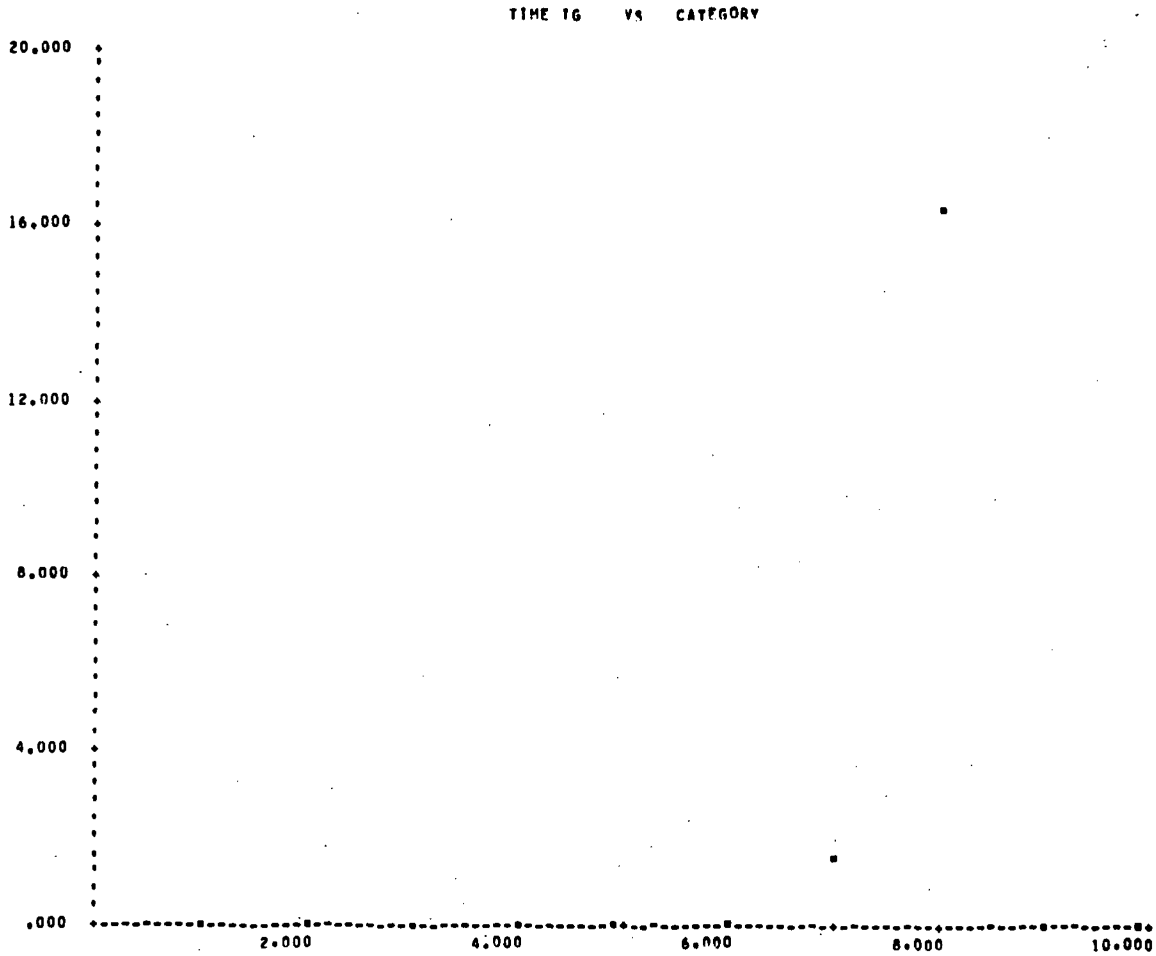
Figure 3-32. Case 5 - Seven Conditions Time Ignored vs Category. Condition 4



TIME IG	CATEGORY
.00000E-80	.10000E 01
.98438E-01	.20000E 01
.19886F 00	.30000E 01
.00000E-80	.40000E 01
.00000E-80	.49990E 01
.00000E-80	.60000E 01
.11333F 01	.70000E 01
.22136F 02	.80000E 01
.19384E-11	.90000E 01
.00000E-80	.99990E 01

.0000E-80 .2546E 00 .3327E 00 .0000E-80 .0000E-80 .0000E-80 .1833E 01 .8789E 01 .1344E-11 .0000E-80

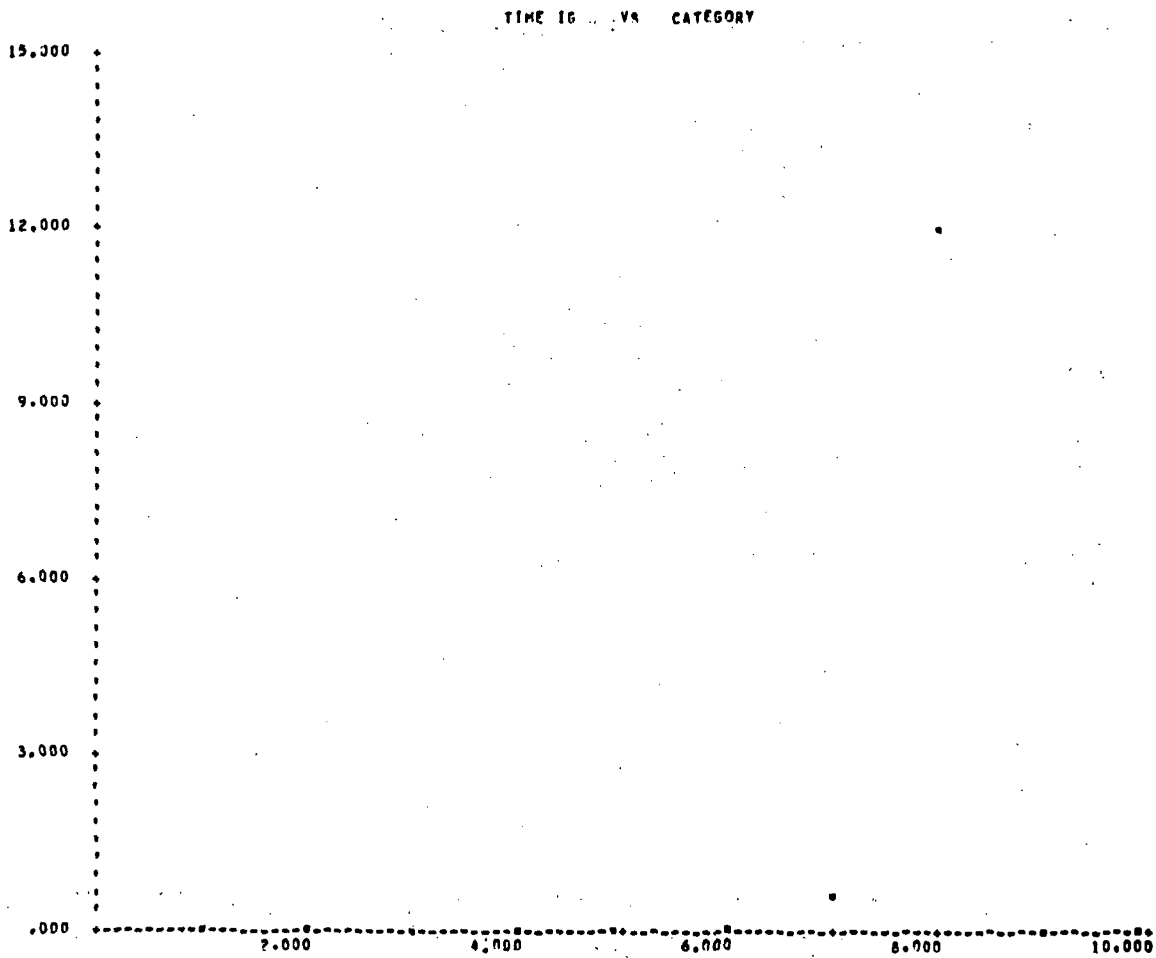
Figure 3-33. Case 5 - Seven Conditions Time Ignored vs Category. Condition 5



TIME IG	CATEGORY
.00000E-80	.10000E 01
.00000F-80	.20000E 01
.10810E 00	.30000E 01
.00000E-80	.40000E 01
.00000E-50	.49990E 01
.00000E-80	.60000E 01
.14833F 01	.70000E 01
.16583F 02	.80000E 01
.76170E-12	.90000E 01
.00000E-80	.99990E 01

.0000E-80	.0000E-90	.1892E 00	.0000E-80	.0000E-80	.0000E-80	.1978E 01	.1316E 02	.9802E-12	.0000E-80

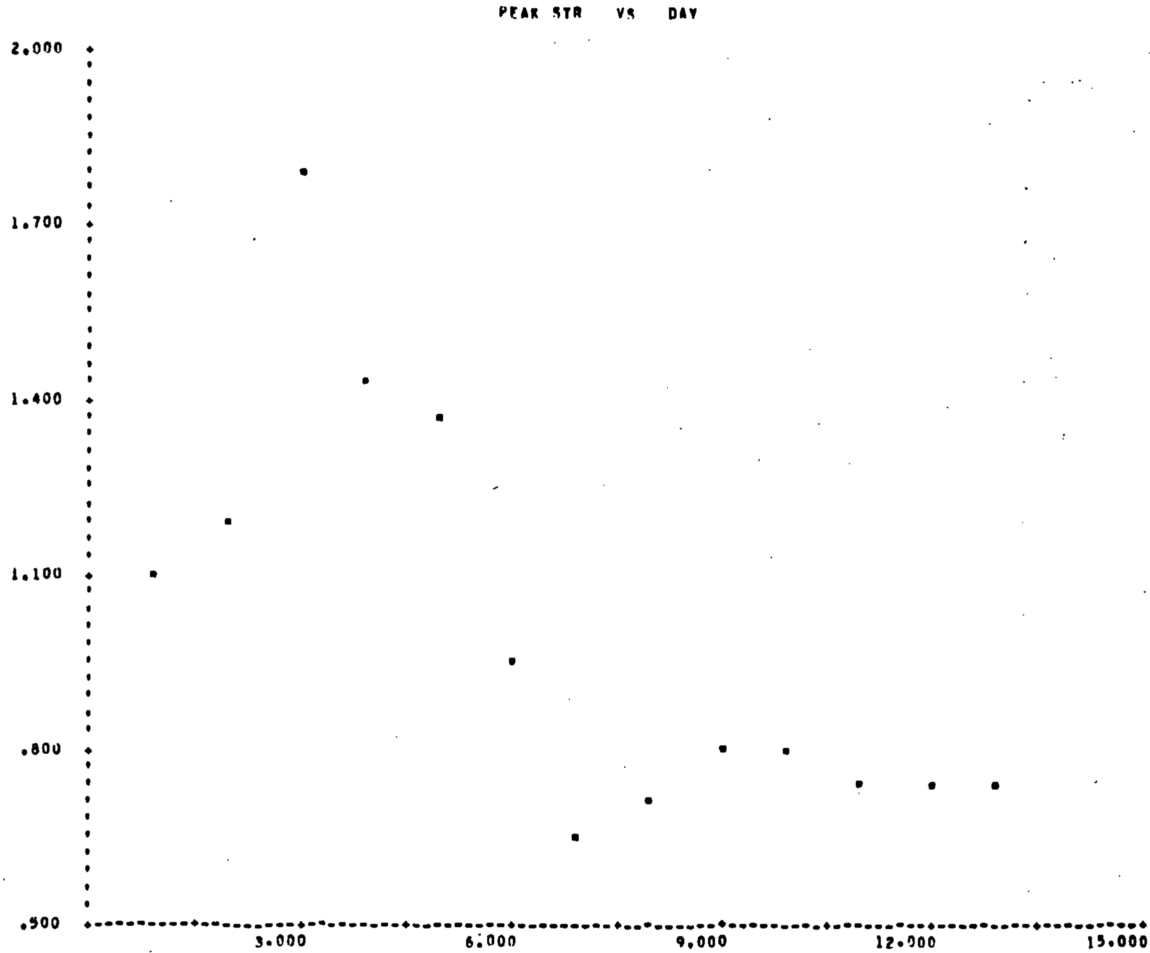
Figure 3-34. Case 5 - Seven Conditions Time Ignored vs Category. Condition 6



TIME IG	CATEGORY
.00000E-80	.10000E 01
.00000E-80	.20000E 01
.45334E-01	.30000E 01
.00000E-80	.40000E 01
.00000E-80	.49990E 01
.00000F-90	.69000E 01
.73667E 00	.70000E 01
.11961E 02	.80030E 01
.64612E-12	.90000E 01
.00000E-80	.99990E 01

.0000E-80	.0000E-40	.1041E 00	.0000E-80	.0000E-80	.0000E-80	.1733E 01	.1178E 02	.8263E-12	.0000E-80

Figure 3-35. Case 5 - Seven Conditions Time Ignored vs Category. Condition 7

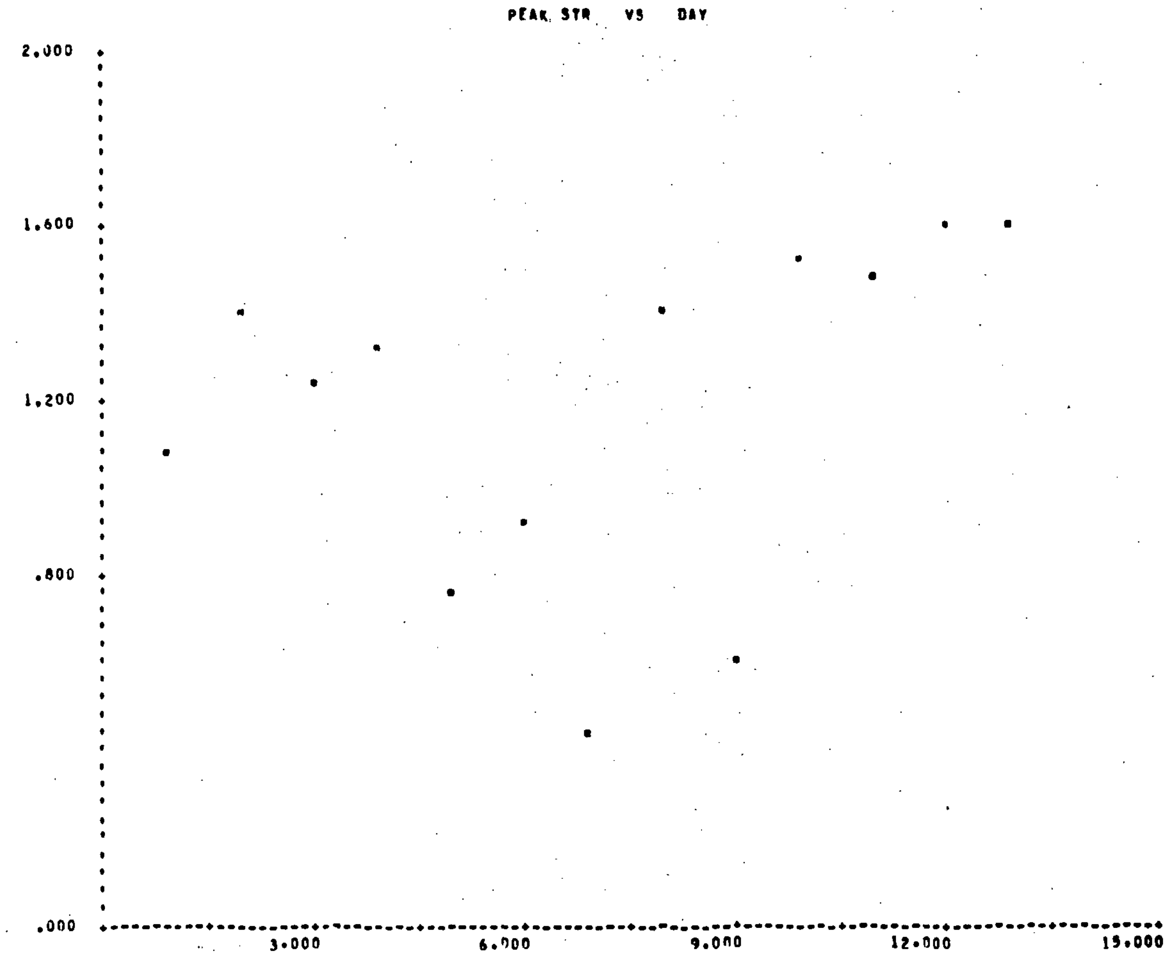


PEAK STR	DAY
.10931E 01	.10000E 01
.12043E 01	.20000E 01
.17829E 01	.30000E 01
.14301E 01	.40000E 01
.13608E 01	.49990E 01
.94544E 00	.60000E 01
.66438F 00	.70000E 01
.70937F 00	.80000E 01
.78962E 00	.90000E 01
.79383F 00	.99990E 01
.74335F 00	.11000E 02
.75093E 00	.12000E 02
.73363E 00	.13000E 02

.4560E-01 .6028E-01 .9930E-01 .7380E-01 .2174E-01 .8429E-01 .3272E-01 .2844E-01 .7510E-02 .1868E-01

.9710E-02 .9783E-02 .4837E-02

Figure 3-36. Case 5 - Seven Conditions Peak Stress vs Day Condition. Condition I

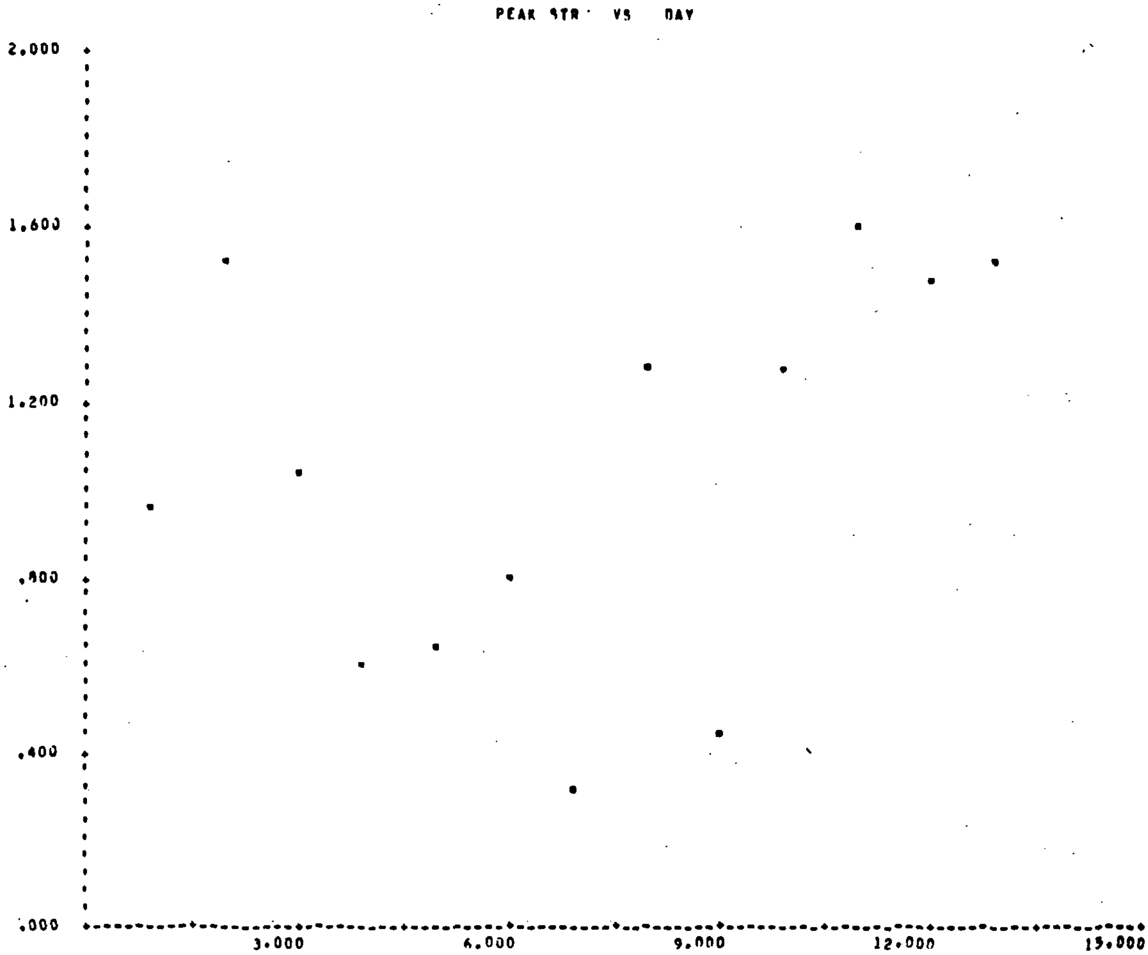


PEAK STR	DAY
.10867E 01	.10000E 01
.14064E 01	.20000E 01
.12267E 01	.30000E 01
.13241E 01	.40000E 01
.75058E 00	.49990E 01
.90213E 00	.60000E 01
.43509E 00	.70000E 01
.13832E 01	.80000E 01
.58090E 00	.90000E 01
.15386E 01	.99990E 01
.14681E 01	.11000E 02
.16163E 01	.12000E 02
.16071E 01	.13000E 02

.5442E-01 .4374E-01 .1215E 00 .2369E 00 .5365E-01 .7627E-01 .1644E-01 .9605E-01 .2250E-01 .1909E-01

.3420E 00 .3658E-01 .5684E-01

Figure 3-37. Case 5 - Seven Conditions Peak Stress vs Day. Condition 2

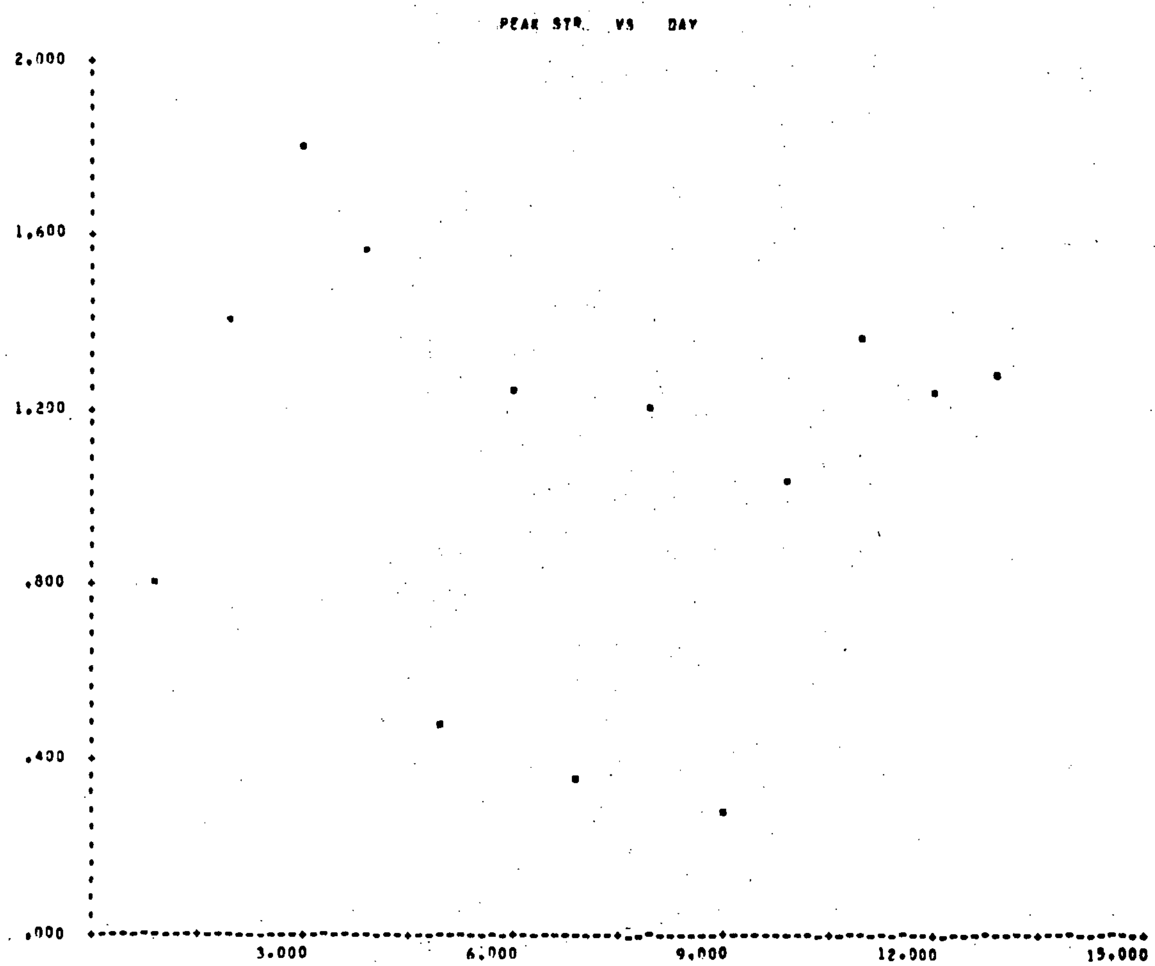


PEAK STR	DAY
.94246F 00	.10000E 01
.15249E 01	.20000E 01
.10364F 01	.30000E 01
.59412F 00	.40000E 01
.62442F 00	.49990E 01
.80567F 00	.60000E 01
.30633F 00	.70000E 01
.12969E 01	.80000E 01
.44285E 00	.90000E 01
.12897F 01	.99990E 01
.15998F 01	.11000E 02
.14881E 01	.12000E 02
.15050F 01	.13000E 02

.1322E 00 .3059E 00 .1383E 00 .7710E-01 .4157E-05 .5413E-02 .2906E-02 .1833E 00 .1478E-01 .6881E-01

.3605E-02 .1829E-04 .1321E-04

Figure 3-38. Case 5 - Seven Conditions Peak Stress vs Day. Condition 3

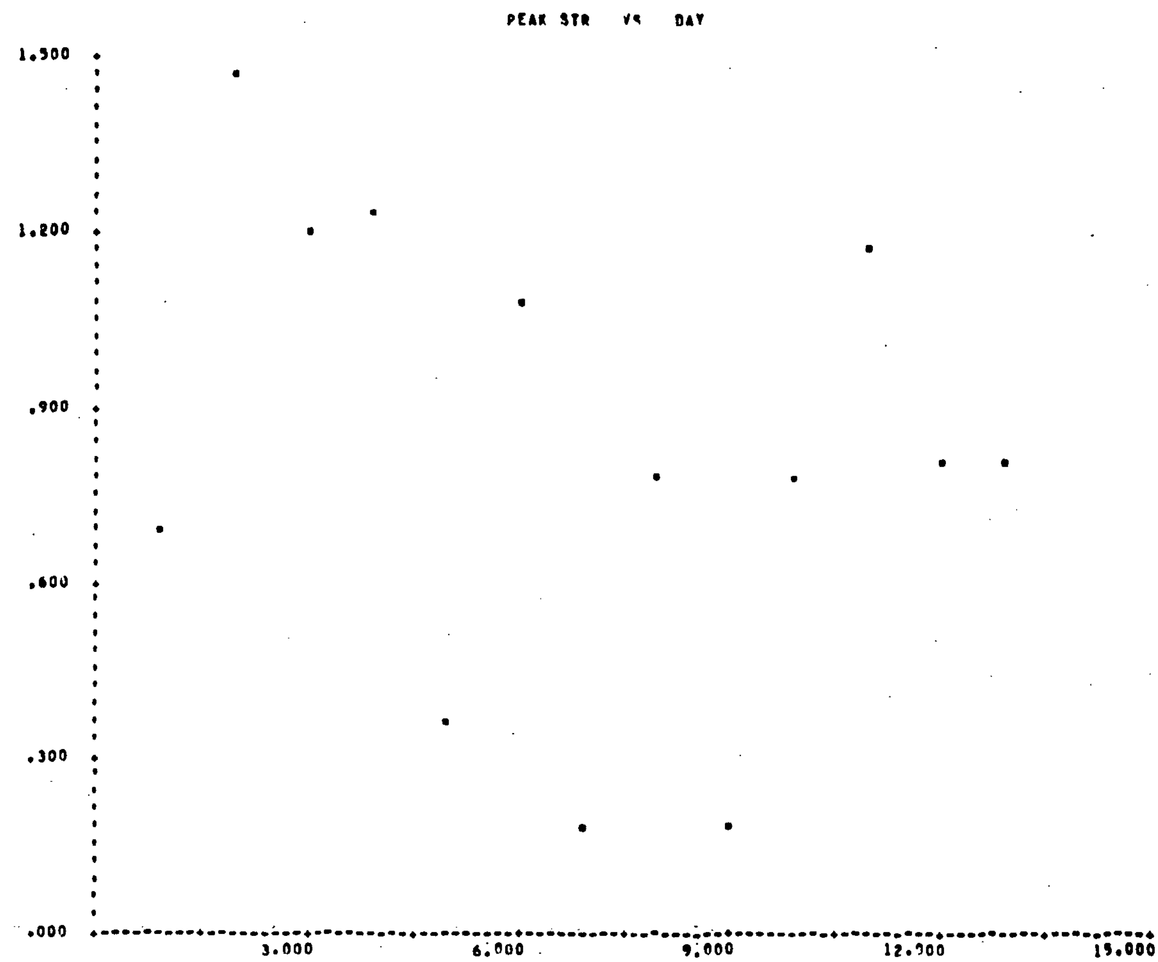


PEAK STR	DAY
.79425E 00	.10000E 01
.14038E 01	.20000E 01
.17981E 01	.30000E 01
.15541E 01	.40000E 01
.46488E 00	.49990E 01
.12412E 01	.60000E 01
.35172E 00	.70000E 01
.12117E 01	.80000E 01
.28810E 00	.90000E 01
.10323E 01	.99990E 01
.13420E 01	.11000E 02
.12425E 01	.12000E 02
.12665E 01	.13000E 02

.9325E-01 .3447E 00 .1634E-01 .1365E 00 .1545E-01 .2198E-01 .8220E-01 .4226E-01 .4650E-01 .6849E-01

.3748E-01 .1331E-01 .4100E-01

Figure 3-39. Case 5 - Seven Conditions Peak Stress vs Day. Condition 4

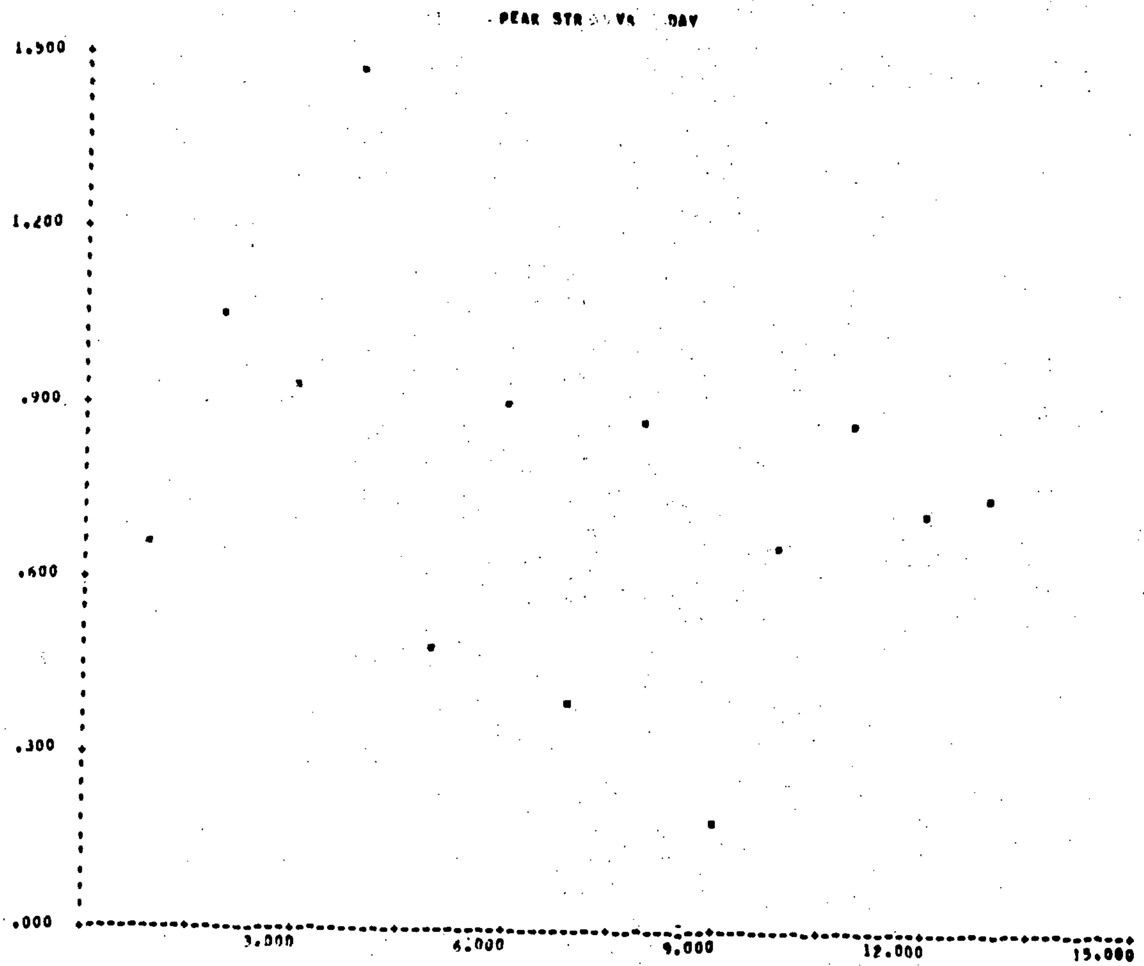


PEAK STR	DAY
.68477E 00	.10000E 01
.14588E 01	.20000E 01
.11981E 01	.30000E 01
.12419E 01	.40000E 01
.36611E 00	.49990E 01
.10719E 01	.60000E 01
.17956E 00	.70000E 01
.76649E 00	.80000E 01
.18412E 00	.90000E 01
.79148E 00	.99990E 01
.11601E 01	.11000E 02
.81850E 00	.12000E 02
.82335E 00	.13000E 02

.1069E 00 .1328E 00 .2196E 00 .3972E-01 .2892E-01 .5296E-01 .1101E-01 .1685E-01 .1032E-01 .5021E-01

.5897E-01 .2365E-01 .5051E-02

Figure 3-40. Case 5 - Seven Conditions Peak Stress vs Day. Condition 5

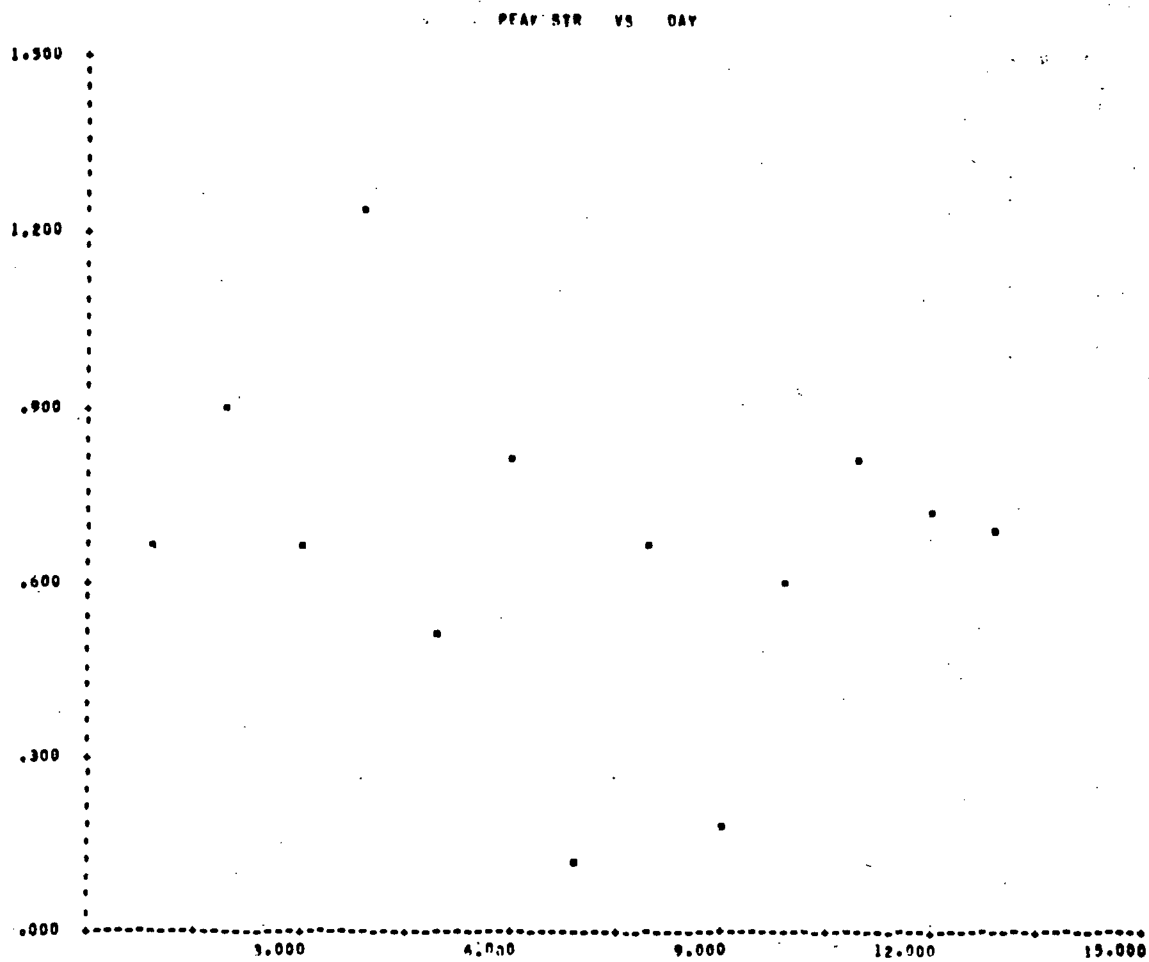


PEAK STR	DAY
.67017E 00	.10000E 01
.10548E 01	.20000E 01
.92555E 00	.30000E 01
.14636E 01	.40000E 01
.47213E 00	.49990E 01
.89194E 00	.60000E 01
.39776E 00	.70000E 01
.87852E 00	.80000E 01
.19098E 00	.90000E 01
.67228E 00	.99990E 01
.87464E 00	.11000E 02
.72578E 00	.12000E 02
.73753E 00	.13000E 02

.1267E 00 .8125E-01 .1084E 00 .4051E 00 .1638E 00 .4664E-01 .1664E 00 .2093E 00 .2006E-01 .3503E-01

.3583E-01 .2217E-01 .3757E-01

Figure 3-41. Case 5 - Seven Conditions Peak Stress vs Day. Condition 6

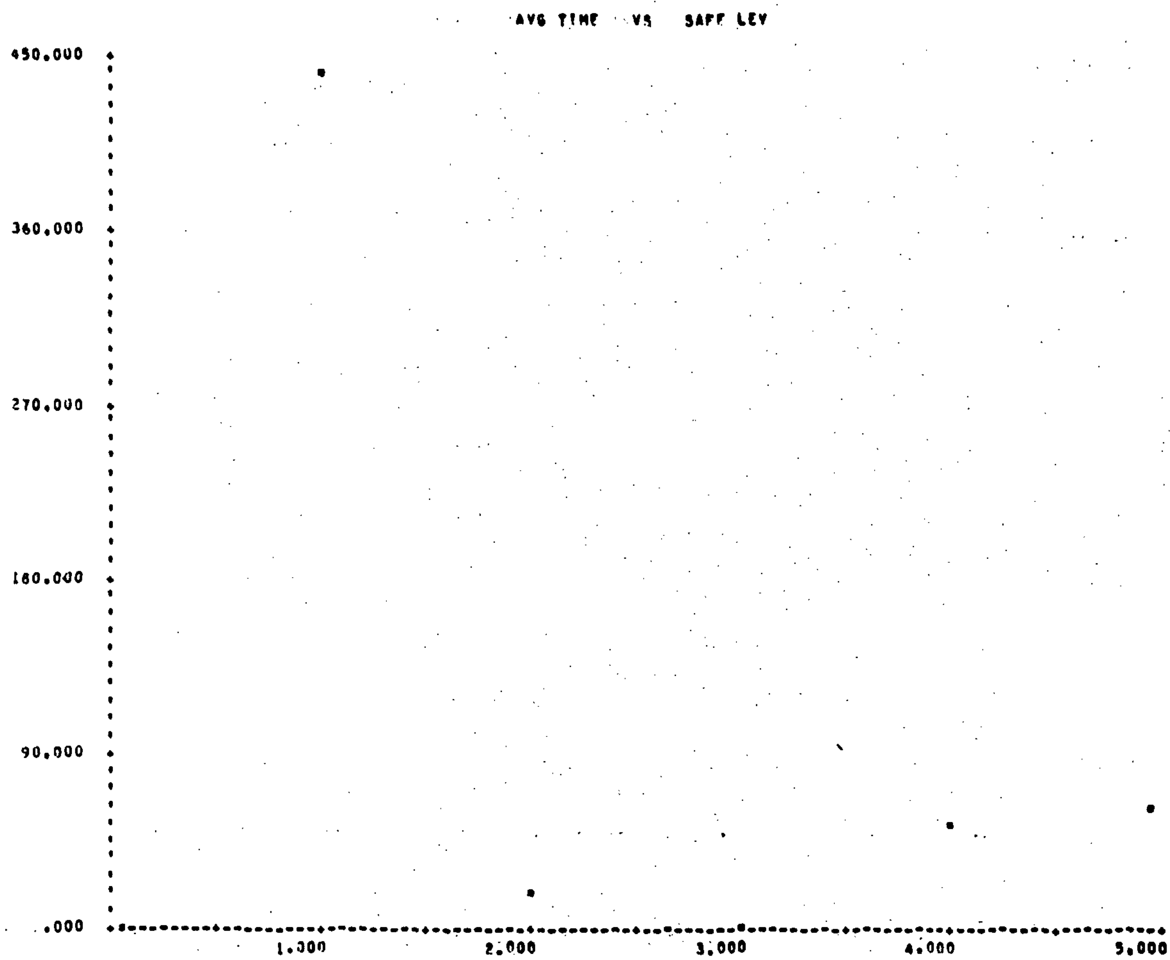


PEAK STR	DAY
.66467E 00	.10000E 01
.89567E 00	.20000E 01
.65913E 00	.30000E 01
.12179E 01	.40000E 01
.50749E 00	.49990E 01
.80086E 00	.60000E 01
.13480E 00	.70000E 01
.67038E 00	.80000E 01
.18555E 00	.90000E 01
.60350E 00	.99990E 01
.80904E 00	.11000E 02
.72853E 00	.12000E 02
.69941E 00	.13000E 02

.1267E 00 .9628E-01 .6787E-01 .2921E 00 .2317E 00 .2171E-01 .3608E-01 .3309E-01 .4416E-01 .2119E-01

.3176E-01 .6599E-01 .4779E-01

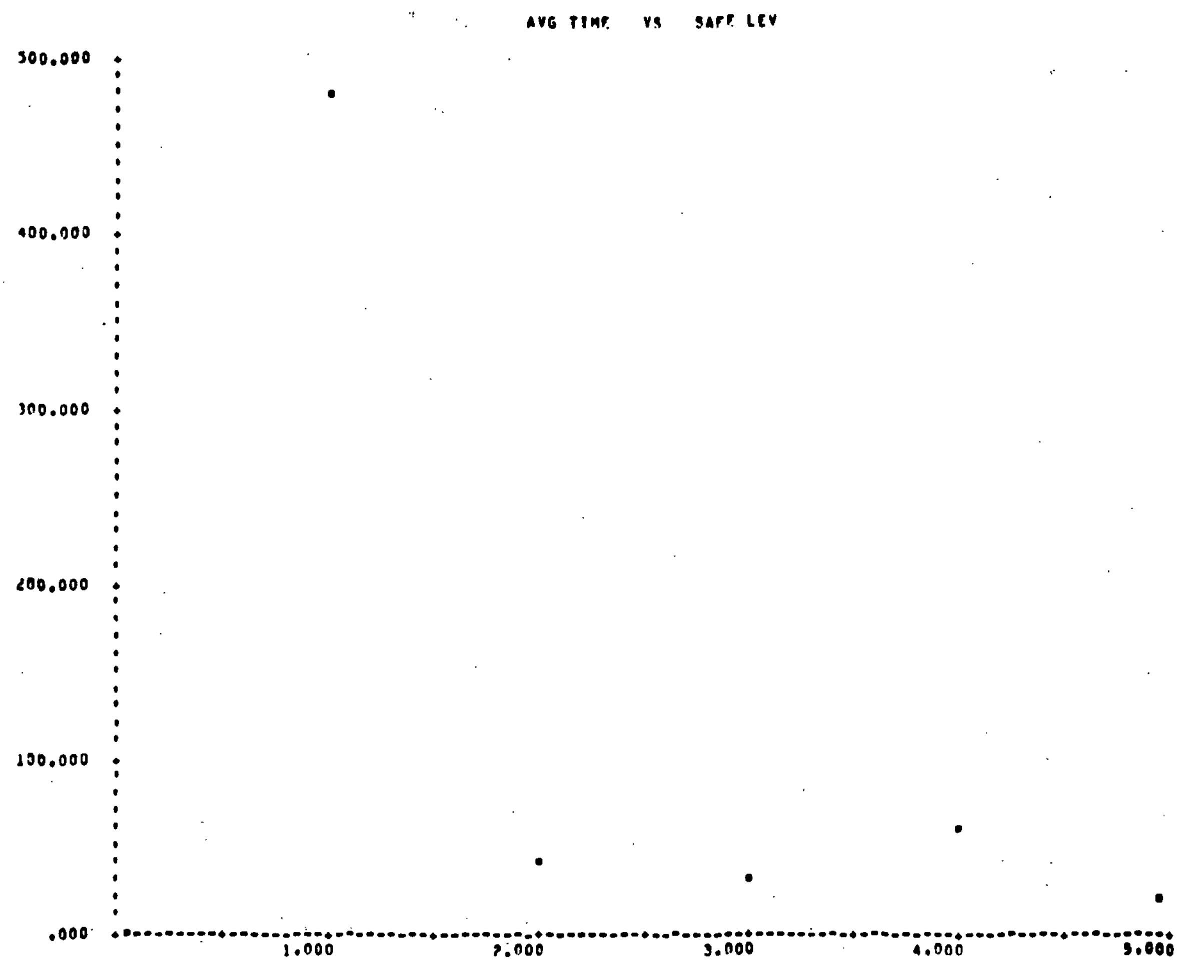
Figure 3-42. Case 5 - Seven Conditions Peak Stress vs Day. Condition 7



AVG TIME	SAFE LEV
.44237E 03	.10000E 01
.13942E 02	.20000E 01
.16606E 01	.30000E 01
.54898E 02	.40000E 01
.64068E 02	.49990E 01
.00000E-80	.10000E-02

.1328E 02 .4123E 01 .9471E 00 .3567E 01 .6666E 01

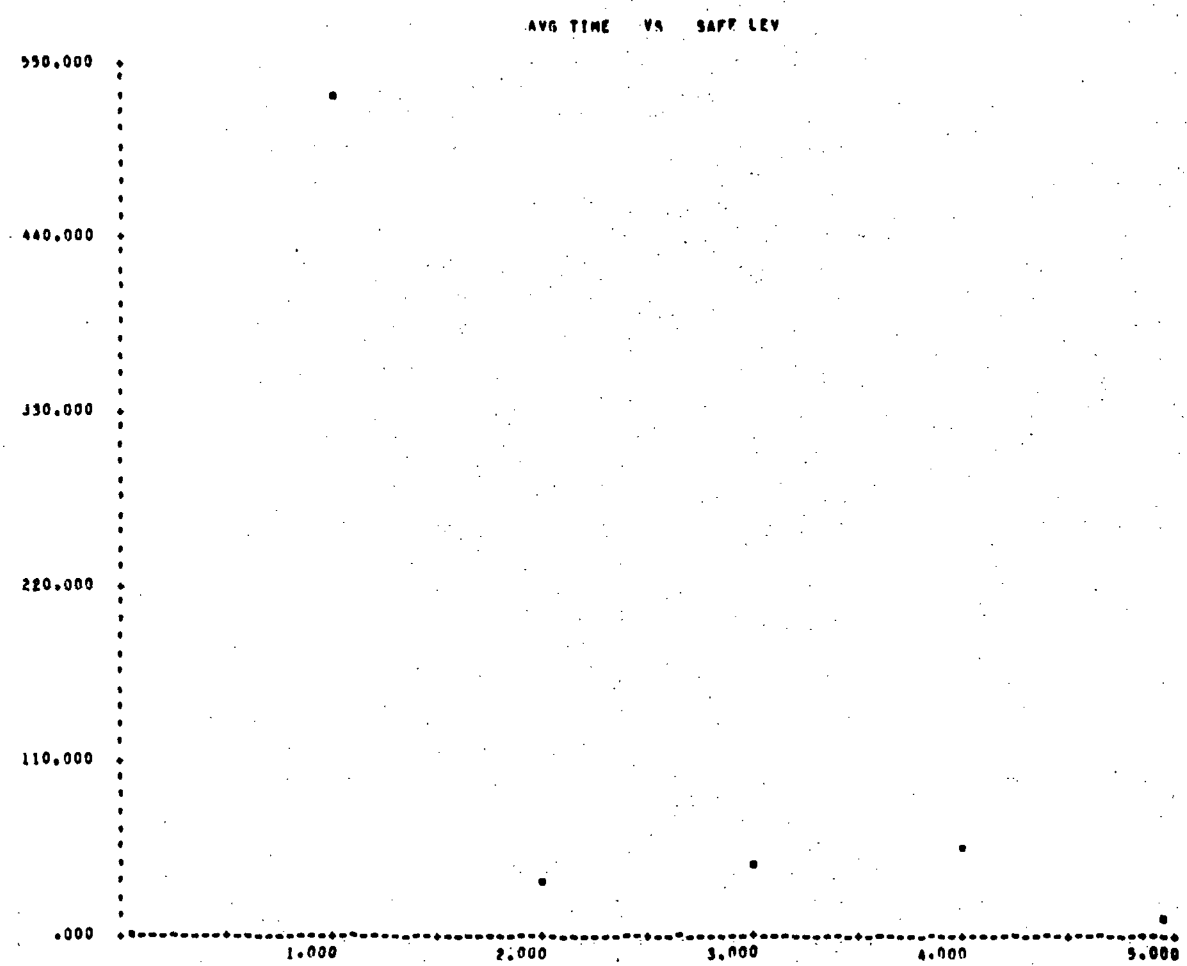
Figure 3-43. Case 5 - Seven Conditions Average Time vs Safety Level. Condition I



AVG TIME	SAFE LEV
.48339E 03	.10000E 01
.38932E 02	.20000E 01
.28946E 02	.30000E 01
.61005E 02	.40000E 01
.22944E 02	.49990E 01
.00000E-00	.10000E-02

.1540E 02 .4896E 01 .4734E 01 .5713E 01 .4034E 01

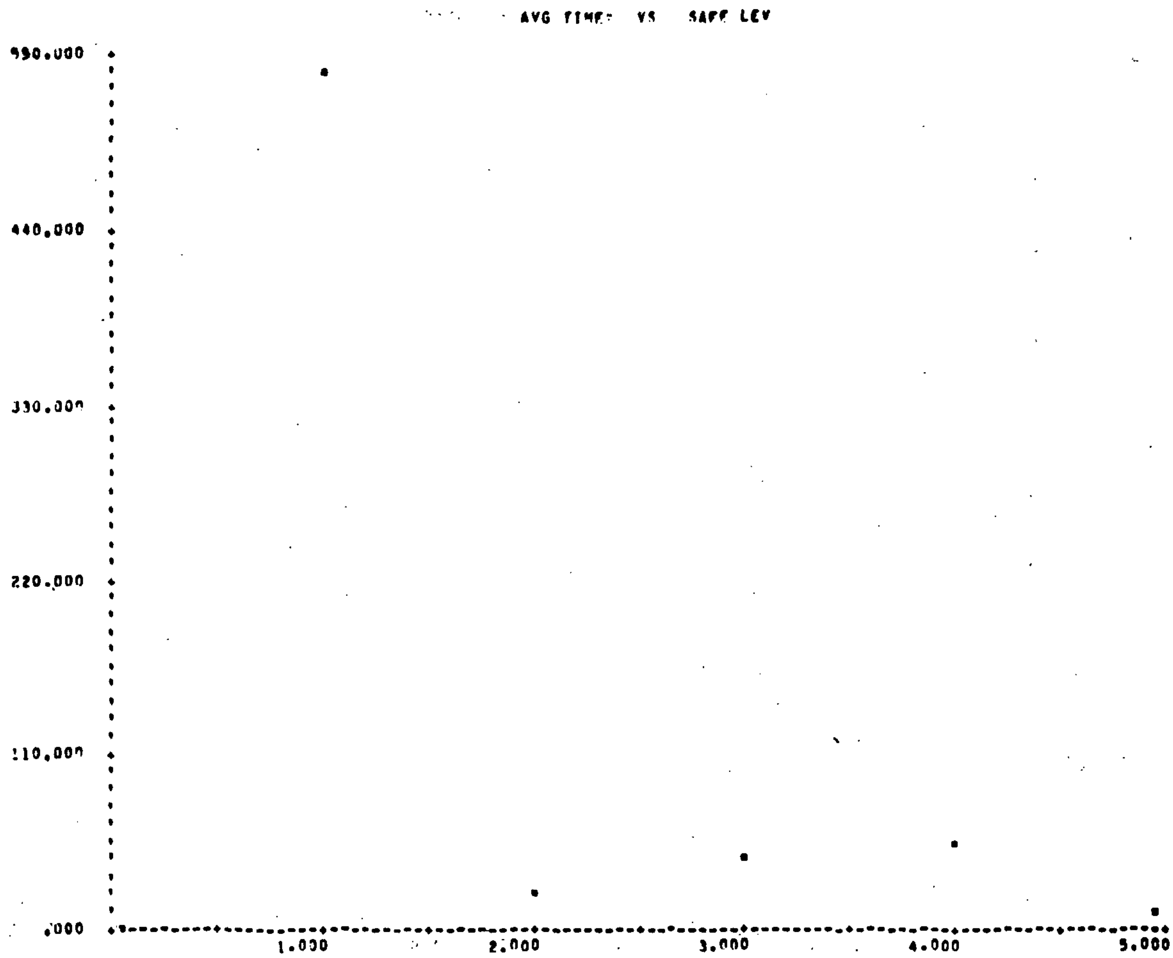
Figure 3-44. Case 5 - Seven Conditions Average Time vs Safety Level. Condition 2



AVG TIME	SAFE LEV
.52329E 03	.10000E 01
.33380E 02	.20000E 01
.47279E 02	.30000E 01
.91749E 02	.40000E 01
.11717E 02	.49990E 01
.00000E-80	.10000E-02

.9105E 01   .4738E 01   .6843E 01   .2326E 01   .2644E 01

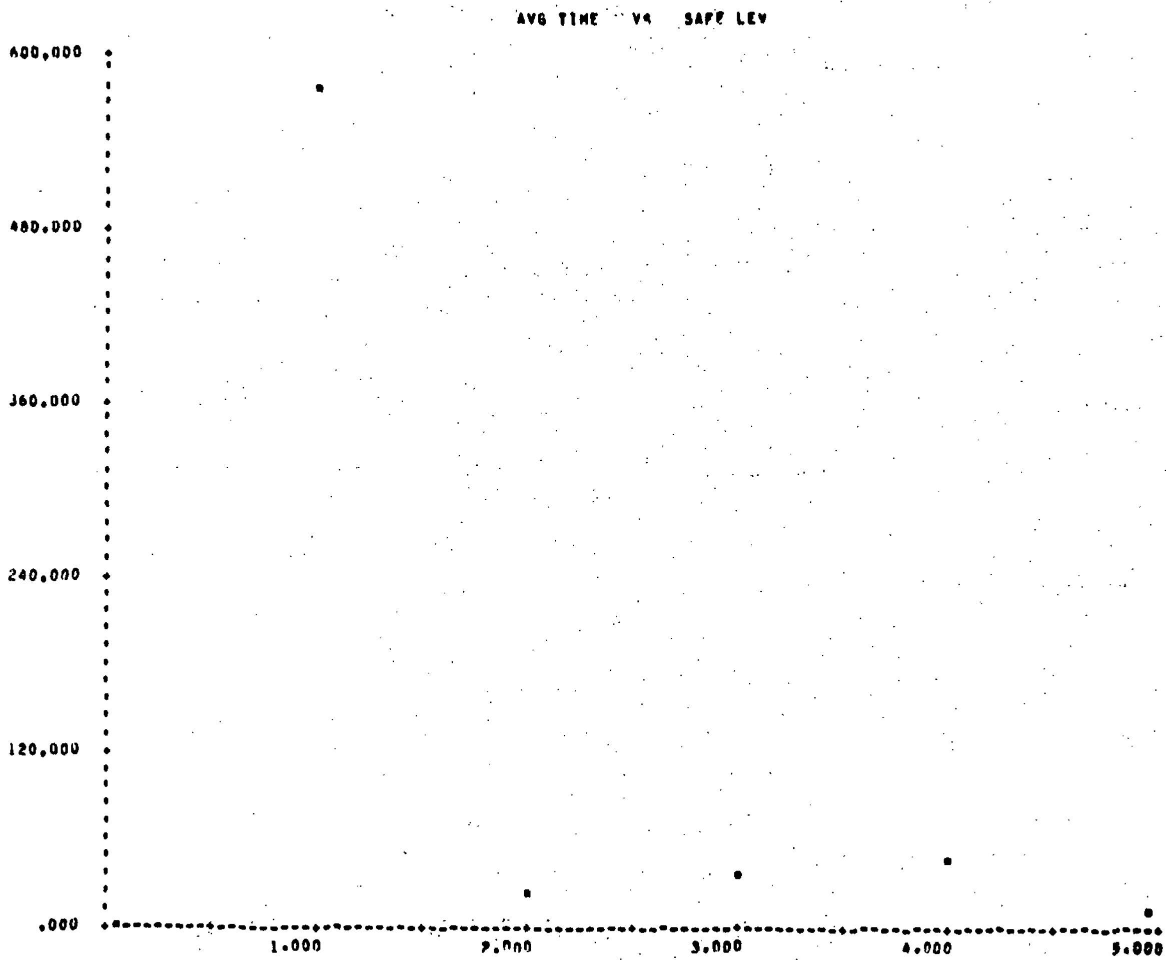
Figure 3-45. Case 5 - Seven Conditions Average Time vs Safety Level. Condition 3



AVG TIME	SAFE LEV
.53934E 03	.10000E 01
.27430E 02	.20000E 01
.47724E 02	.30000E 01
.52648E 02	.40000E 01
.12162E 02	.49990E 01
.00000E-30	.10000E-02

.7337E 01 .2785E 01 .3425E 01 .3507E 01 .5044E 01

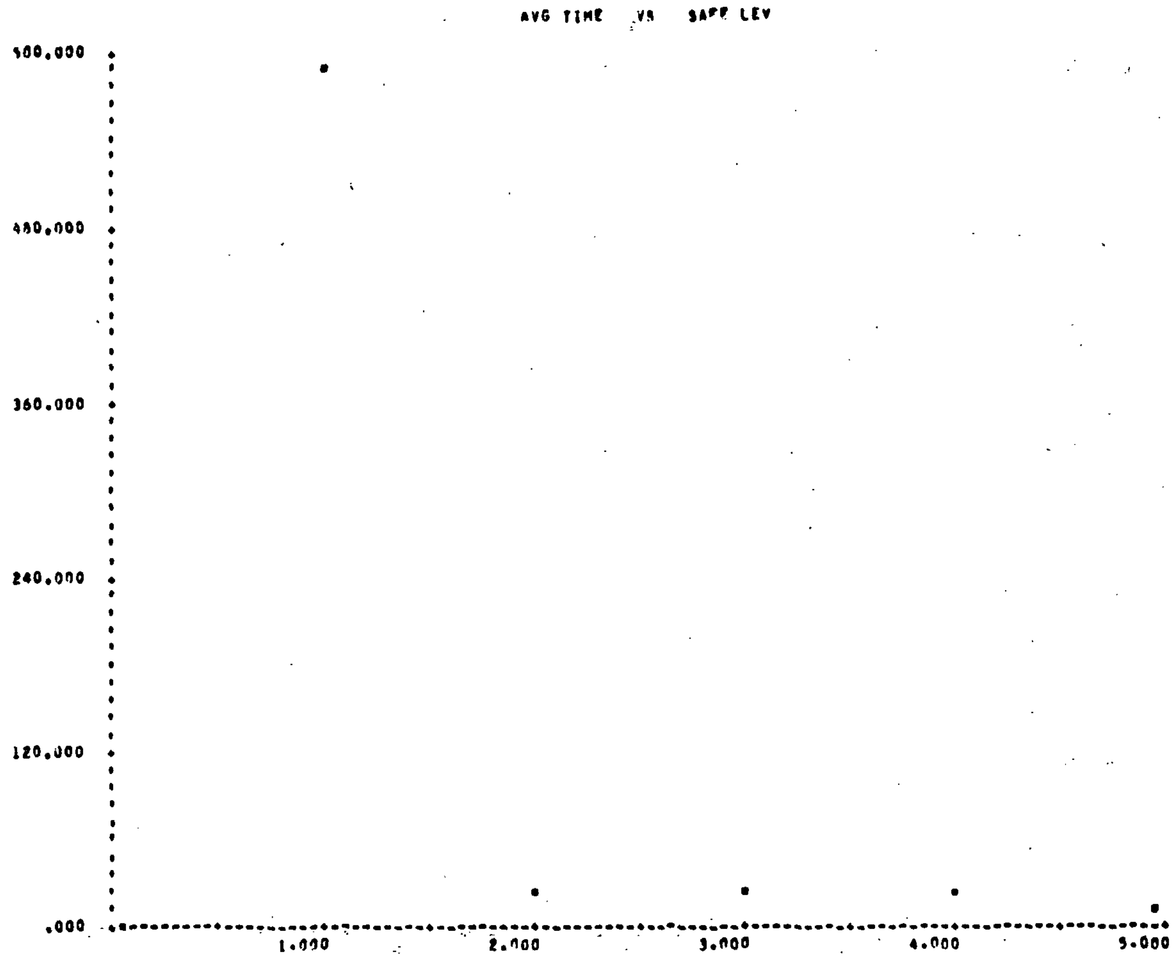
Figure 3-46. Case 5 - Seven Conditions Average Time vs Safety Level - Condition 4



AVG TIME	SAFE LEV
.57038F 03	.10000E 01
.27656E 02	.20000E 01
.35314F 02	.30000E 01
.42676F 02	.40000E 01
.96393E 01	.49990E 01
.00000E-80	.10000E-02

.4853E 01 .3152E 01 .3085E 01 .2900E 01 .2118E 01

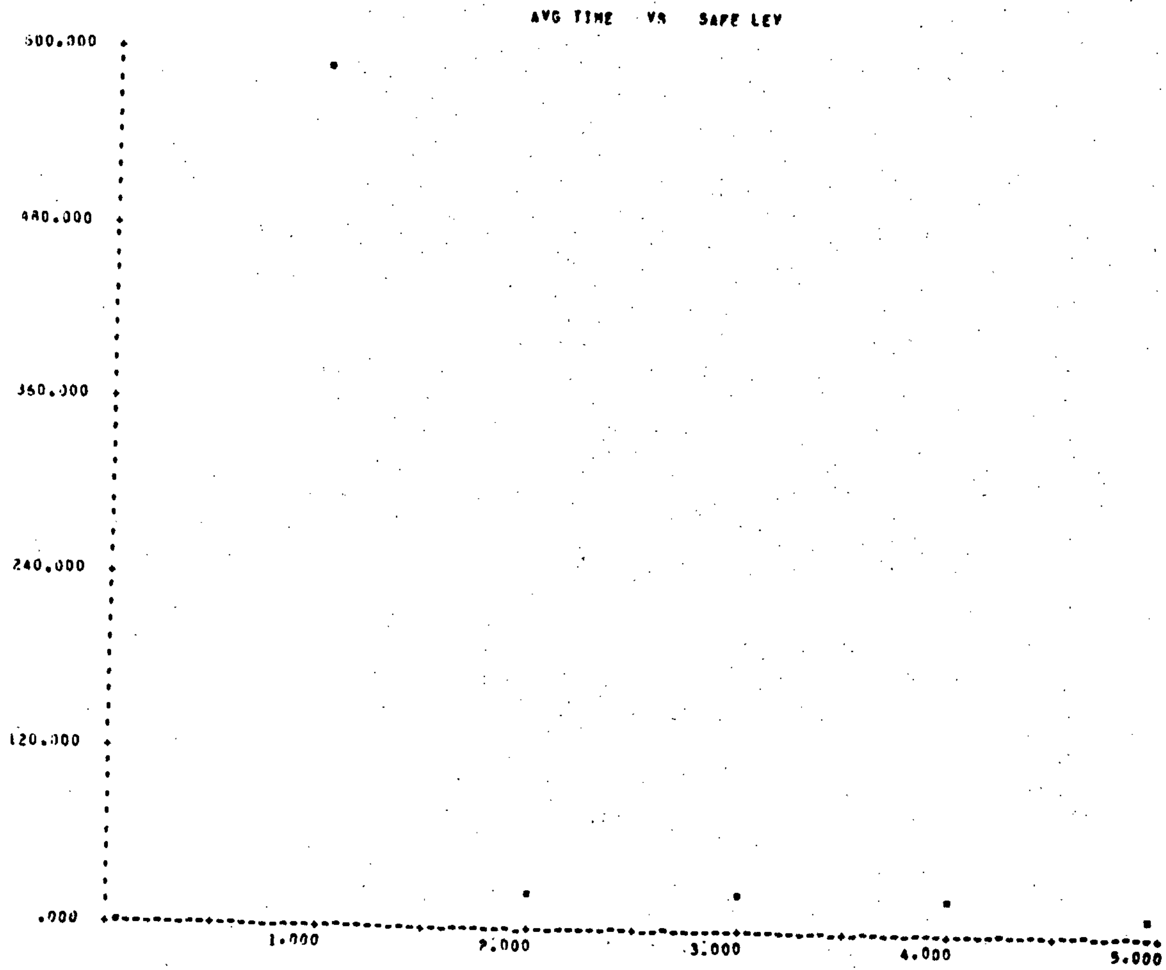
Figure 3-47. Case 5 - Seven Conditions Average Time vs Safety Level. Condition 5



AVG TIME	SAFE LEV
.98540E 03	.10000E 01
.23577E 02	.20000E 01
.29529E 02	.30000E 01
.28045E 02	.40000E 01
.83480E 01	.49990E 01
.00000E-89	.10000E-02

.7088E 01 .2357E 01 .4363E 01 .2638E 01 .3173E 01

Figure 3-48. Case 5 - Seven Conditions Average Time vs Safety Level. Condition 6



AVG TIME	SAFE LEV
.59025E 03	.10000E 01
.19727E 02	.20000E 01
.28481E 02	.30000E 01
.27952E 02	.40000E 01
.80593E 01	.49990E 01
.00000E-80	.10000E-02

.6062E 01 .1723E 01 .2705E 01 .2585E 01 .2911E 01

Figure 3-49. Case 5 - Seven Conditions Average Time vs Safety Level. Condition 7

CASE 6 - EFFECT OF INCREASED SCHEDULE INTERRUPT

General Conditions

Vehicle Speeds	2, 4.33, 6, 15 and 30 km/hr
Astronaut Speeds	0.6, 1.0, and 1.4 x nominal
Interrupt Conditions	P_1, P_2, P_3

Specific Conditions (Case 6A)

Nominal Vehicle (6 km/hr), nominal astronaut

Interrupt Conditions P_1, P_2, P_3

Discussion (Case 6A)

Table 3-2 is a summary of the data related to changing interrupt conditions. Figure 3-50 is a summary of scientific accomplishment related to P_1, P_2, and P_3, when the nominal design point is considered a 100-percent achievement of activities.

Conclusion (Case 6A)

Under nominal conditions, the proposed schedule is most sensitive to small interruptions in schedule and tends to increase in its variance with increased interruptions. Crew safety levels and astronaut stress are not adversely affected by the schedule interruptions.

Specific Conditions (Case 6B)

Vehicle Speeds	2, 4.33, 6, 15 and 30 km/hr
Astronaut Speed	Nominal
Interrupt Condition	P_1, P_2 and P_3

Discussion (Case 6B)

Figure 3-51 is a summary of scientific accomplishment for varying vehicle speeds under three conditions of interrupt. Figure 3-52 is a summary of the Task 8 nonpriority "science" tasks which are omitted under the same conditions. Figure 3-53 indicates the total amount of time spent in travel under the various conditions. Variation in astronaut stress and time in more dangerous safety levels was not appreciably affected.

TABLE 3-2

SUMMARY: NOMINAL VEHICLE AND ASTRONAUT P_1, P_2, P_3

		Mean Interrupt, hr		
		1/2, P_1	1, P_2	3, P_3
Average Time	Cat. 1	279.4	269.0	247.7
	Cat. 2	14.1	13.8	12.38
	Cat. 3	184.9	183.8	164.8
	Cat. 4	0.0	0.0	0.0
	Cat. 5	73.2	71.98	63.0
	Cat. 6	12.2	11.95	11.04
	Cat. 7	13.2	12.40	10.82
	Cat. 8	84.8	83.00	72.78
	Cat. 9	6.4	6.38	6.01
	Cat. 10	23.7	24.5	22.50
Time 1g	Cat. 7	1.28	0.77	1.57
	Cat. 8	47.00	47.70	56.72
Time in Safe Level	Cat. 2	10.48	10.27	14.19
	Cat. 3	75.94	74.39	61.57
	Cat. 4	52.34	51.15	46.80
	Int.	8.03	15.38	45.17
Percent Science Tasks		64.7	63.7	56.8
Average Safety Level		1.46	1.46	1.45

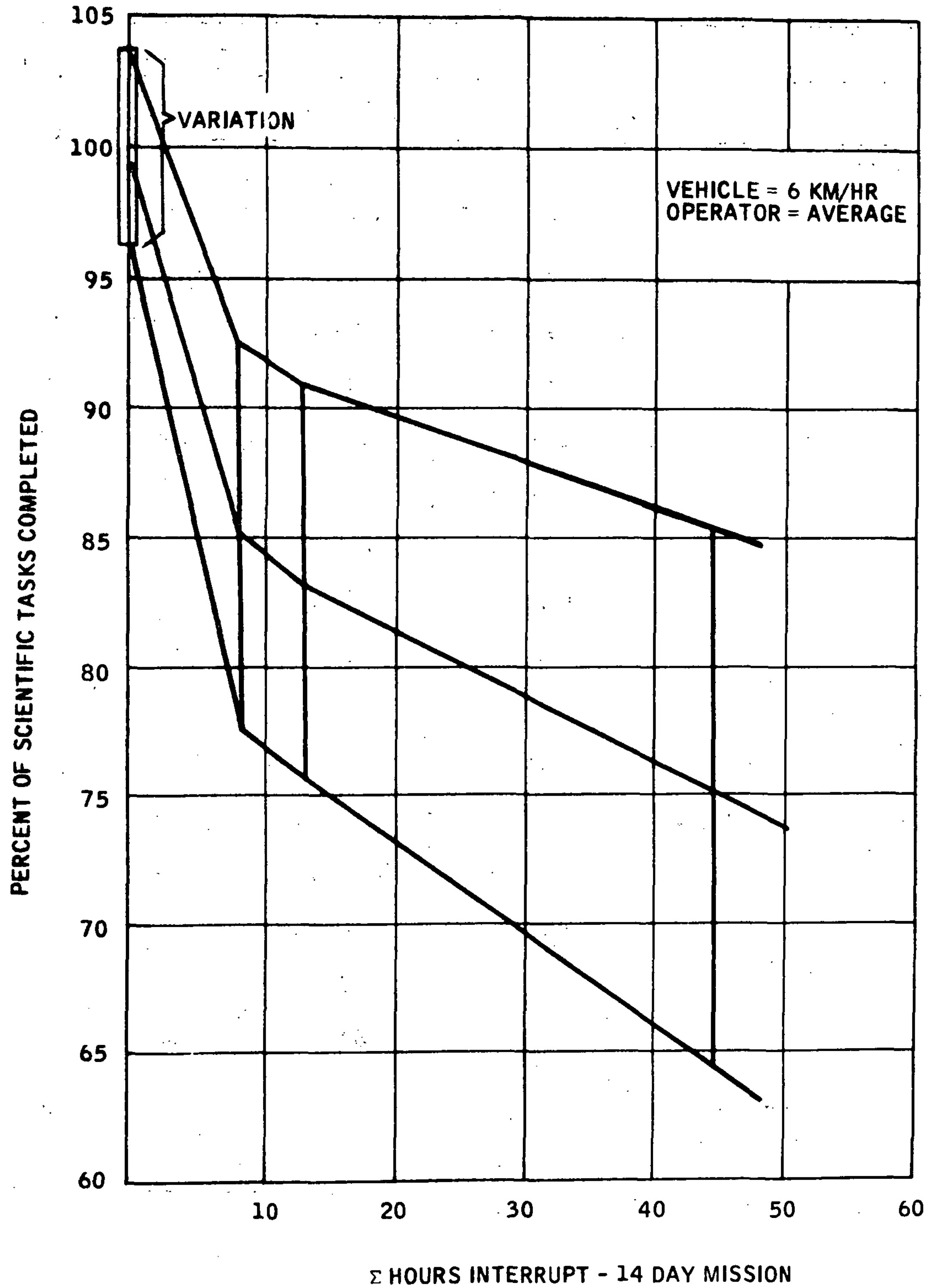


Figure 3-50. Case 6A - Effect of Increased Interrupt on Nominal Mission Omitted

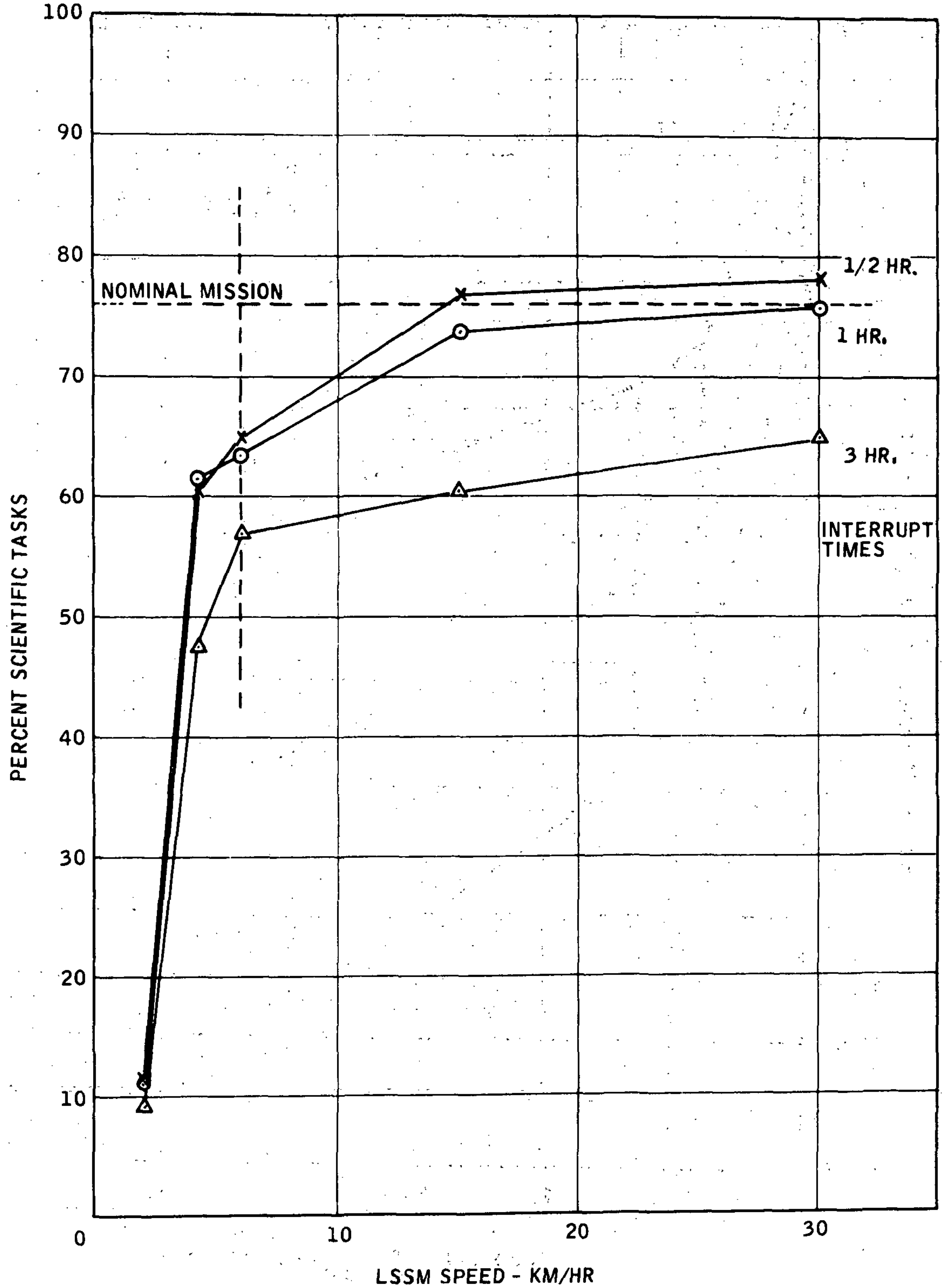


Figure 3-51. Case 6B - Percent Scientific Tasks vs LSSM Speed (Interruptions P_1, P_2, P_3)

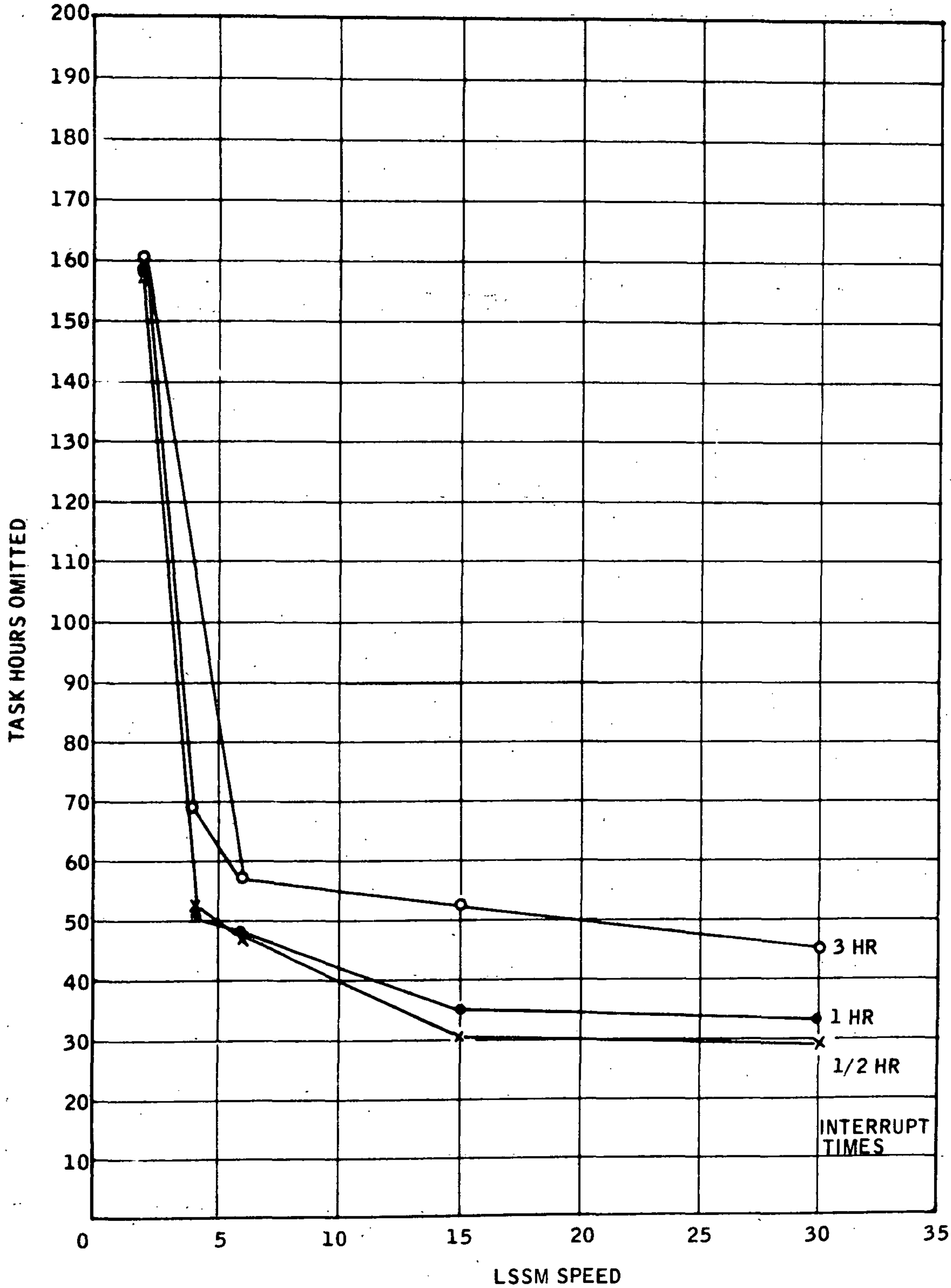


Figure 3-52. Case 6B - Hours Task 8 Omitted for Three Interrupt Times vs LSSM Speed

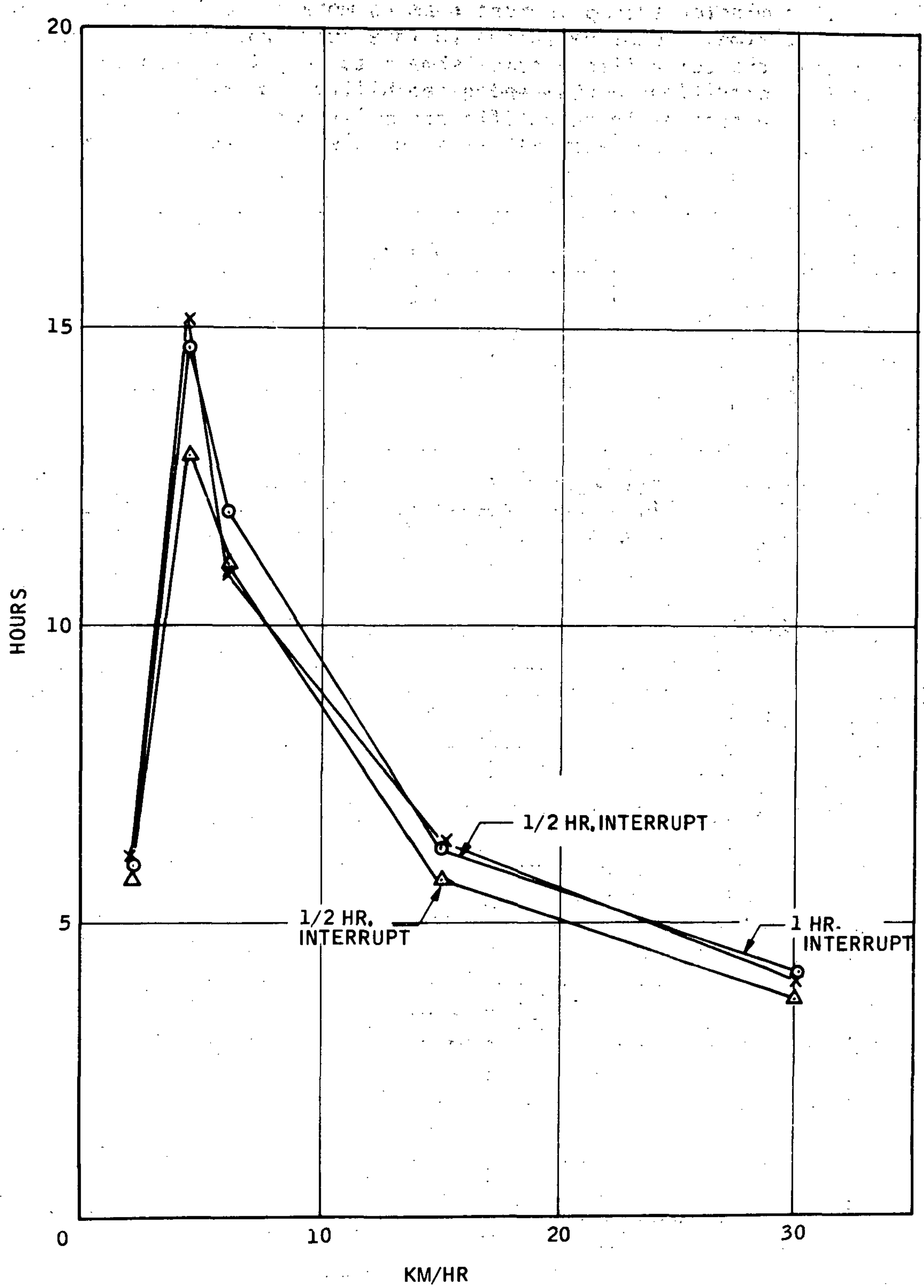


Figure 3-53. Case 6B - Travel Time vs LSSM Speed for Three Interrupts

Conclusion (Case 6B)

Scientific mission accomplishment depends more on vehicle speed than on total interrupt time. Total variation in interrupt, which could exceed 47 hr of time, causes the scientific accomplishment to vary less than 25 percent under nominal vehicle conditions. LSSM speed capability reduction can cause more than 50-percent decreases in scientific accomplishment. Higher vehicle speed capability appears to produce small gains in scientific accomplishment.

Specific Conditions (Case 6C)

Vehicle Speed	Nominal 6 km/hr
Astronaut Speeds	0.6, 1.0 and 1.4 x nominal
Interrupt Conditions	P_1, P_2, P_3

Discussion (Case 6C)

Figure 3-54 is a summary of total scientific accomplishment versus total hours of interrupt for three astronaut speeds. Figure 3-55 is a summary of time spent at the most hazardous safety level for various cases of interrupt and astronaut speed.

Conclusion (Case 6C)

Astronaut speed variations produce large variations in scientific accomplishment and safety levels that are larger than those produced by variations in schedule interrupt.

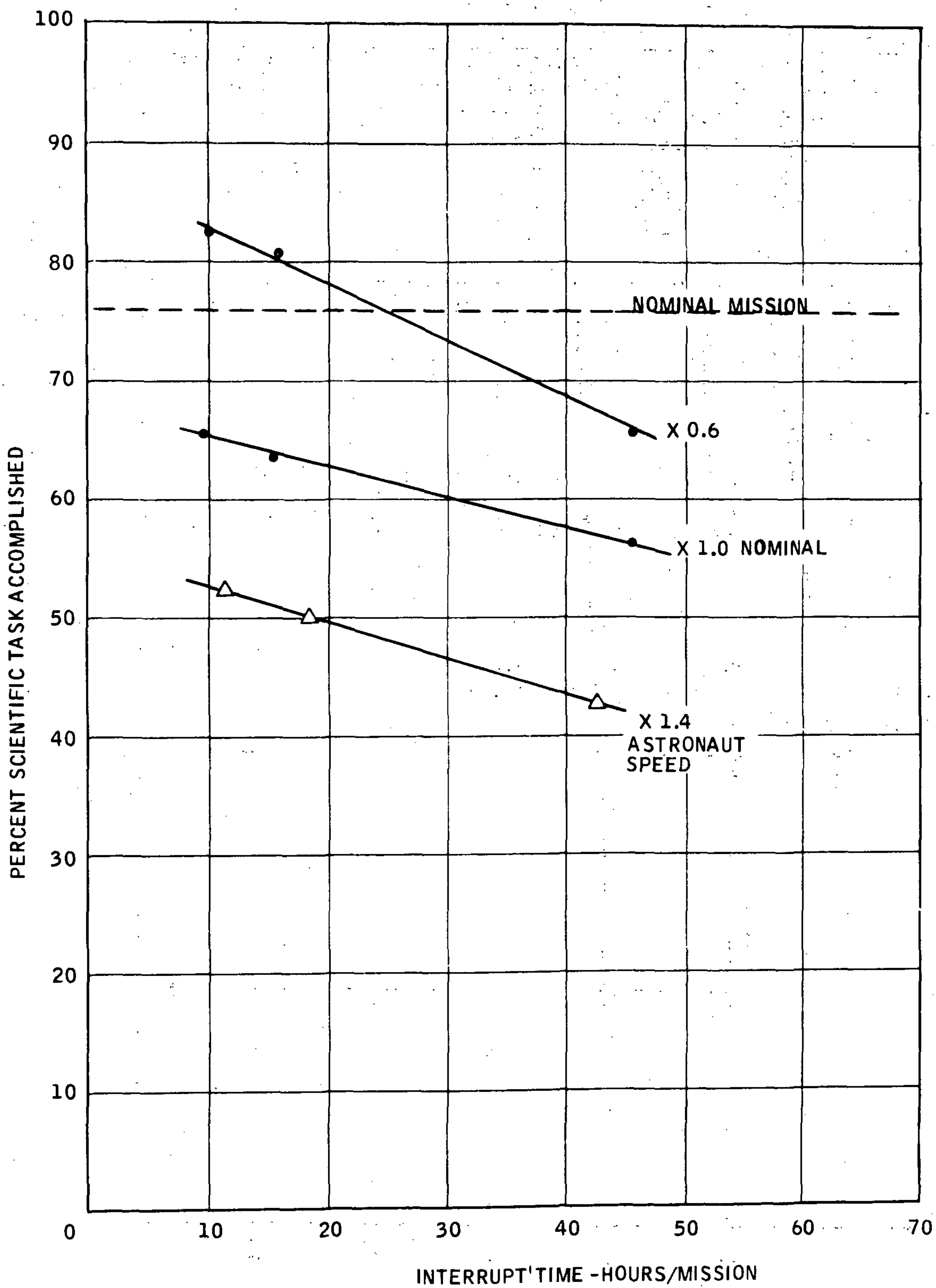


Figure 3-54. Case 6C - Scientific Task Accomplishment vs Total Interrupt for Three Astronaut Speeds

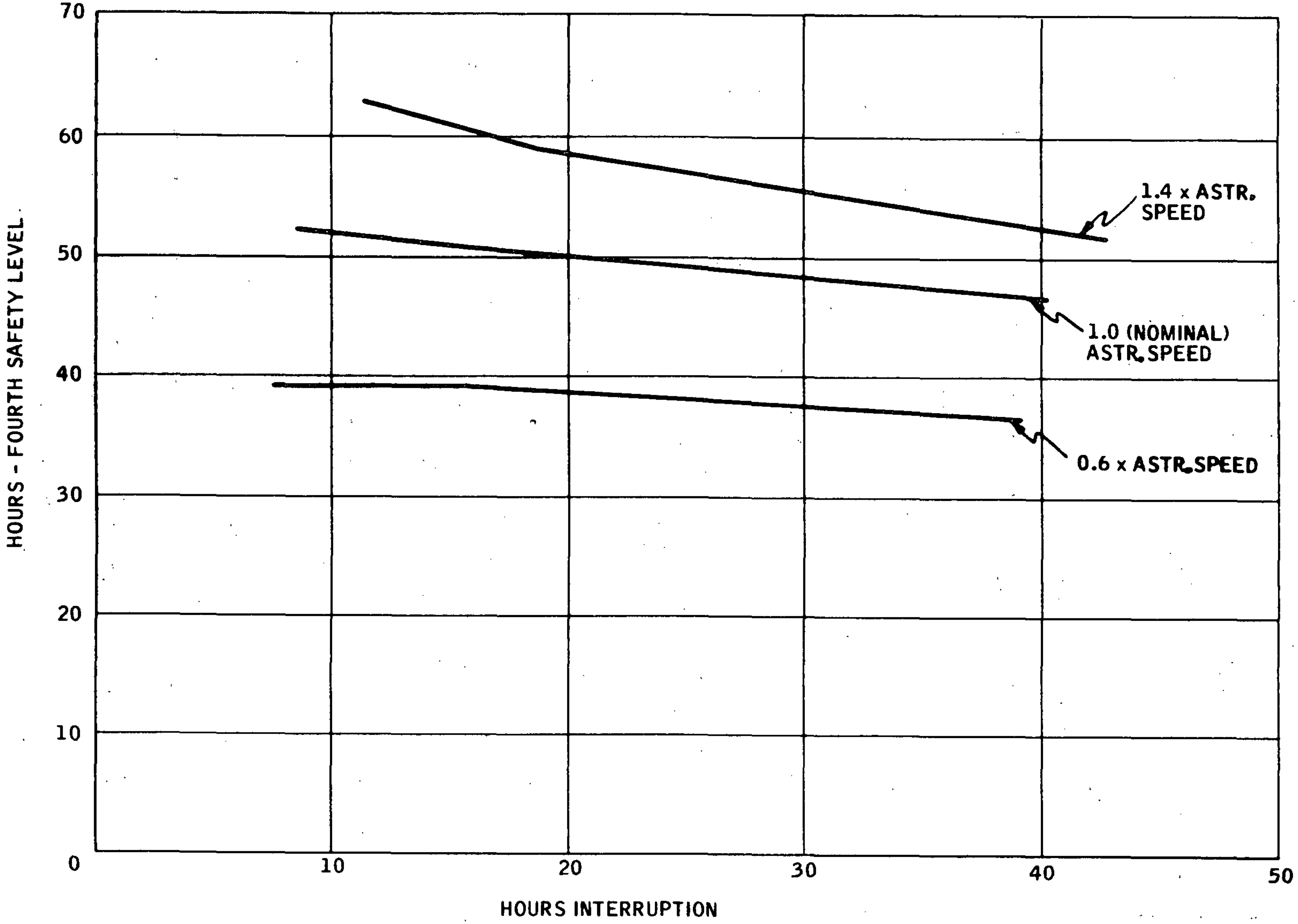


Figure 3-55. Case 6C - Hours in Most Dangerous Safety Level vs Interrupts for Three Astronaut Speeds

SECTION 4

SUGGESTED HASSLE IMPROVEMENTS

GENERAL

Areas in which work to improve existing capability for evaluation of mission schedules are briefly described below. The suggested improvements are designed to evaluate the effect of the equipment used on the success of the mission. This requires an objective definition of mission success and an understanding of how the specific equipment affects each task in the mission. To take full advantage of the suggested improvements, a program of equal magnitude should be carried out to supply the data required by improved methods.

LEVEL OF SUCCESS

Task Success

The desire to measure objectively a given completed task simulation presents difficult problems in the present HASSLE. A useful compromise is to require levels of success only for scientific tasks. The possible outcomes of each such task in the simulation must then be enumerated to decide whether the nature of the task permits a continuous distribution of success levels about 1.0, the desired outcome, or only a few discrete values.

Mission Success

The mission success level should be treated as an average of the individual task success levels selected by HASSLE. The selection of the task success will be based on a draw from a population of numbers distributed as specified by the statistical description of the detailed task simulation. Consequently, no other introduction of task-performance-related parameters into HASSLE will be necessary.

The success level of each task and the time of completion should be stored in memory so that both task success and total current mission success may be displayed as a function of mission time.

DETAILED TASK SIMULATION

Many of the results desired from the simulation of Lunar Surface Operations would be more efficiently found by a detailed simulation of particular tasks than of the whole mission. In this way, the repeated simulation of unrelated or routine tasks cannot suppress the effect of a special equipment parameter on the particular tasks to which it is relevant. The simulation can also be specially designed for the task in question and may include an appropriate mathematical model of the object upon which the task is being performed. In many cases, the input data required for HASSLE can be more properly specified, using the output of a detailed task simulation than by relying on previous experience.

OUTPUT PLOTS VERSUS MISSION TIME

A method for specifying task time spent in each category in the entire mission would permit the effect of parametric changes to be evaluated throughout the mission. Problem areas at specific times during the mission could then be identified with the specific tasks and parametric variables to which they correspond.

Several output variables are suggested for this treatment, although others may ultimately be desired. Current values of safety level, interrupt probability, interrupt occurrence, task success, mission success, power requirement, human energy requirement, oxygen consumed, accumulated time in task category, accumulated equipment operating time, and total and effective stresses could be made available for observation during the mission. The number of hours ahead or behind schedule, plotted against mission time, would also be of value in assessing the value of the combination of parameters characterizing the particular run.

SAFETY LEVEL/INTERRUPT PROBABILITY

These aspects of the HASSLE program should be based on analysis similar to that used in reliability work. Two separate systems are involved; the safety level need be concerned only with the reliability of equipment that is critical for life support times the probability of astronaut failure unrelated to equipment failure. The interrupt probability should be based on the reliability of all equipment, life support included, whose failure could delay the mission. The total length of time each piece of equipment is used must be recorded for use in the reliability computations.

IMPROVED INPUT SCHEDULE PRIORITIES AND FLEXIBILITY

The present program tends to contain input schedule restrictions which are not representative of operational procedures. Simple logic, such as contained in scheduling type programs, should be introduced into HASSLE. An improved or expanded priority listing would help the program seek a better solution than is presently available. Task time requirements which are more nearly equal to facilitate re-scheduling of such activity are desirable. In addition, schedule elements that are obviously somewhat flexible, such as rest and eating, should be simplified to provide more computer memory for crucial output parameters and to simplify data handling.

QUALITY OF INPUT DATA

Objective information on average times, time deviations, touch-up times, percent essential, oxygen consumption, and operator work load should be obtained for all routine daily tasks. If pertinent data are not available in the literature, experimental studies with human subjects should be carried out. This would provide an accurate basis for constructing the 24-hr timelines for basic schedules.

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