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Final Report

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Neutral Buoyancy Testing of Architectural and Environmental Concepts of Space Vehicle Design

Approved by NASA

Prepared for
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

MARTIN MARIETTA CORPORATION

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FINAL REPORT
FOR

NEUTRAL BUOYANCY TESTING OF ARCHITECTURAL AND ENVIRONMENTAL CONCEPTS OF SPACE VEHICLE DESIGN

MARCH 1972

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FOREWORD

This report was prepared by the Martin Marietta Corporation under Contract NAS9-11947, DRL Line Item 4, "Neutral Buoyancy Testing of Architectural and Environmental Concepts for Space Vehicle Design", for the Manned Spacecraft Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Spacecraft Design Office with Mr. Clarence D. Council as the Technical Manager. This report documents and summarizes the results of the entire contract work, including recommendations and conclusions based on the experience and results obtained.

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I. INTRODUCTION

To create an optimum habitat for the "average" person on an extended space mission has not been considered a necessity on space missions to date. Past and present scheduled space missions, of limited crew size and mission duration, have only considered the physiological requirements of a very specialized person. However, as mission objectives become more sophisticated, the crew will consist of more scientific type persons rather than the highly trained astronaut of today with a significant increase in mission duration. This type of a crew must be provided a space environment in which they can work, eat, sleep, and relax comfortably and efficiently for the time in space.

For this reason, data must be generated to provide design guidelines for spacecraft. These guidelines can then be used to provide a habitat so that the average person can enjoy maximum comfort and thus maximize human reliability and behavioral efficiency.

The purpose of this contract was to generate design guidelines that are applicable to providing habitability areas and furniture elements for extended periods in a zero-gravity environment. This was accomplished by: (1) analyzing the existing A/E Handbook, habitability crew area requirements, mobility and restraint aids, cross cultural design, and establishing a man-model for zero gravity; (2) designing specific furniture elements, chair and table, and volumes for a stateroom, office, bathroom, galley, and wardroom; and (3) neutral buoyancy testing and evaluating these areas. The design criteria generated by these efforts are presented in a A/E Handbook Supplement specifically for zero-gravity environments. The rationale to substantiate the criteria in the A/E Handbook is presented in a rationale supplement. Both of these supplements are submitted as individual books but are to be considered as part of this final report.

II. ANALYSIS STUDIES

This section will define and discuss the analyses performed during the contract. The areas that were investigated were the A/E Handbook, mobility/restraint requirements analysis, crew areas habitability, cross-cultural design considerations, and man model for zero gravity. The following paragraphs give a summary of what data was collected during the contract.

A. A/E HANDBOOK FOR CONCEPT DATA

The data in the A/E Handbook was analyzed and found to be quite limited in the area of a zero-g environment. Some of the inadequacies are incomplete furniture dimensions, furniture access dimensions, space required to maneuver and patterns of traffic, mobility and restraint aids location and dimensions, specific criteria for a galley area, man-furniture interface relationship, and architectural designs of specific areas and equipment.

B. MOBILITY/RESTRAINTS REQUIREMENTS ANALYSIS

General considerations for restraints or mobility aids for zero-g locomotion and mass handling and transfer activities must be designed to enhance the following aspects of IVA maneuvering:

1. Locomotion - The ability to move from one point to another.

2. Orientation - The ability to determine body attitude with respect to some reference system.

3. Control - The ability to maintain a positive influence over rate, distance, and direction of travel.

4. Stability - The ability to maintain a desired orientation.

In addition to the general requirements of enhancing locomotion, orientation, control and stability, the development of specific mobility aid design concepts must consider:

1. Range of travel.

2. Frequency of travel.

3. Need to carry or transport equipment.

Specific criteria for restraints or mobility aids should incorporate the following:

1. Sharp edges and protuberances on restraints or mobility aids shall be eliminated (e.g., recessed handholds and handrails rather than protruding).

2. Designs of restraints and mobility aids should be functionally simple and easily used.

3. Mobility aids must facilitate access to all areas in a crew compartment.

4. Mobility aids must facilitate the tasks of mass handling and transfer.

5. Mobility aids must provide positive control over rate and direction of travel.

6. Mobility aids must provide orientation and stability during transit.

7. Mobility aids must provide personnel with the capability to move in the dark.

8. Mobility aids must permit the utilization of the crewman's physical capabilities for movement of the self and small packages.

9. Traffic flow routes and regulations for normal and emergency situations shall be established for safe and efficient movement of personnel and equipment.

   a. Consistent entrance and exit traffic flows should be established (e.g., in wardroom, entrance through food serving area - exit by food tray rack to avoid "jamups" and head-on collisions).

   b. Traffic route intersections should be avoided whenever possible.

10. Mobility aid devices and techniques for their use should be compatible with the task of transporting equipment.

11. Padded surfaces should be provided in crew compartments or other energy absorbing materials to prevent injury.

12. Passageways and hatches should be clearly marked as to clearance dimensions.

13. Traffic routes over tables and the serving area in the wardroom shall be prohibited.

For restraint devices, eighteen different restraint concepts were investigated and evaluated. These items were evaluated first by the area of application or the task to be performed and then for their merits of simplicity, maintenance ease, entry/exit ease, use fatigue, vertical area accessibility, horizontal area accessibility, directional orientation, stowability, stability, and adjustability. The restraints were for both standing and sitting tasks that may take from a few minutes to several hours.

Of all the restraints/mobility aids investigated or tested, the simple handrail/foot bar satisfied all the habitability requirements for maneuvering or performing tasks in a standing position. The foot bar also provided ample restraint for the feet when sitting in a chair restraint. For tasks that require a sitting position, a chair restraint with a lap belt provided the most satisfactory restraint. The chair design also incorporated mobility aids in the seat configuration and the foot restraint D-ring. This chair restraint is further defined in Section III.

C. CREW AREAS HABITABILITY ANALYSIS

The habitability functional requirements and task analyses were defined by crew area and the function performed in that area. The task analysis were for the commander's stateroom, office, bathroom, and the galley/wardroom functions. These tasks and the order of their performance dictated the traffic/locomotion patterns for each area and between each area. Also included in the analyses was the hardware and restraint aids required to satisfy the function of the area. These analyses also provided the basis for the test plans in the stateroom complex and galley/wardroom.

Table II-1 is presented to show the minimum acceptable dimensions for comfort in performing tasks in zero-g and one-g. The tasks analyzed are common habitability tasks which man encounters in both environments.

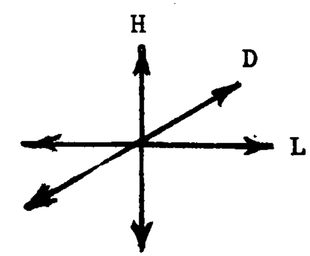
Table II-1 Envelope Dimensions for Habitability Tasks

Function	Zero-Gravity		One-Gravity	
	Description	Envelope* (H x L x D), in.	Description	Envelope* (H x L x D), in.
Sitting - Working	Feet must be restrained, hands free, eyes on horizontal or vertical surface	53 x 29 x 44 H does not include chair ht.	Feet and/or hands provide stability for reaching, eyes on horiz. or vert. surface	53 x 29 x 44 H does not include chair ht.
Sitting - Relaxing	Hands must be free, variable foot positions should be available, head movement unrestricted	53 x 36 x 24 H does not include chair ht.	Same as zero-g	53 x 36 x 24 H does not include chair ht.
Standing - Working	Eyes generally straight ahead, hands or feet provide restraint, one or both hands always free		Feet maintain balance, hands free, eyes straight ahead	
Standing - Relaxing	Eyes straight ahead, hands or feet provide restraint	75 x 18 x 24	Same as above	75 x 18 x 24
Sleeping	Although restraint within a specific volume is required, body should be free to assume any position	78 x 36 x 36	No restraints, essentially a two-dimensional envelope	78 x 36 x 36
Walking	---------	-----	Hands free, feet maintain balance, eyes straight ahead	70 x 34 x 24
Soaring	Hands and/or feet provide guidance, head turned for proper view, anticipation required	84 x 29 x 30	-----------	-------
Hand-Propelled	Hands must be free, feet used for guidance, reaction surfaces must be convenient, head free	84 x 29 x 35	-----------	-------

Table II-1 Envelope Dimensions for Habitability Tasks (continued)

Function	Zero-Gravity		One-Gravity	
	Description	Envelope* (H x L x D), in.	Description	Envelope* (H x L x D), in.
Personal Hygiene	Hands and/or feet provide restraint, otherwise free	75 x 30 x 24	Hands free, feet used for balance	75 x 30 x 24
Writing	Feet restrained	53 x 36 x 24 Does not include chair height	Same as zero-g	53 x 36 x 24 Does not include chair height
Reading	Different foot positions must be available, hands free	53 x 36 x 24 Does not include chair height	Same as zero-g	53 x 36 x 24 Does not include chair height
Eating	One-hand entry, hands free while eating, feet restrained	53 x 36 x 24 Does not include chair height	Hands not required for entry, free for eating, foot position variable	53 x 36 x 24 Does not include chair height
Donning & Doffing	No restraint required, legs pulled in toward torso, walls can be used for guidance	75 x 30 x 30 48" x 48" Required for tumbling	Feet used alternately for balance	70 x 30 x 30

*Reference Axis:



All dimensions given for line of sight along positive L axis

D. CROSS-CULTURAL DESIGN CONSIDERATIONS

An examination of Eastern (Oriental) as opposed to Western (Occidental) architectural design approaches reveals several points in Japanese architecture which may be specifically applicable to space vehicle design and which should be considerations in such design. Principal among these is the degree of flexibility in the Japanese home; this factor has the greatest relevance to the design of a spacecraft interior. The manner in which the Japanese have been able to achieve flexible use of internal space and structural elasticity without creating a confused mess has direct applicability to the spacecraft with its imposed dual-room usage requirements. A spacecraft interior design approach providing movable wall partitions (fusumas) and associated grooves in the floor and ceiling to provide structural support and to limit the boundaries of various room configurations has distinct advantages in terms of crew work and time requirements for interior reconfiguration tasks.

Several other traditional Japanese architectural design approaches which have possible applicability to spacecraft interior designs are:

1. Japanese rooms are traditionally much smaller than those of a similar class of American homes. However, the rooms usually appear larger because of the absence of furniture. The Japanese have evolved a design approach which maximizes visual space. A predominant aspect of this effect is the hidden storage areas for furniture items when they are not in use. A similar design approach for storage and a procedure for storing furniture items when not in use could be used in spacecraft interior areas to maximize the visual effect of existing space.

2. The use of shojis (paper windows) rather than glass windows in Japanese homes creates a unique visual interior effect. Shojis give a uniform, diffuser lighting effect and tend to soften the visual effect inside a room. Since window space will be practically non-existant inside a spacecraft, shoji-type screens could be used to similate the effects of windows in various crew areas. Shoji-type screens could also be placed over illumination sources to create a soft visual illumination effect.

3. The traditional Japanese home does not have a bedroom per se; there is no circumscribed area upon which a bed is placed. The whole floor, indeed the whole house, can be used for sleeping. A similar approach could be used in designing spacecraft interiors especially the interior arrangement of a commander's stateroom. The isolation of a specific sub-area within a stateroom for sleep could possibly be wasteful of existing space. An alternative approach would be to provide a means of attaching a sleep restraint anywhere inside the stateroom area and to remove and store the sleep restraint when it is not in use.

4. The Japanese have mastered the art of maximizing visual space in very small confined area. This effect is especially evident in their design of gardens, which are remarkable in the attempt to create an illusion of distance in a comparatively small space. Some of the techniques used to create this effect include: the use of dwarf plants; a highly developed sense of scaling; leaving plenty of empty spaces so nothing seems crowded. The principles of Japanese garden design could be used to create similar effects in spacecraft interiors.

E. MAN MODEL FOR ZERO GRAVITY

In the design of habitable areas, researchers have often found it useful to model the mechanical systems of the human body. By analysis and test, they have developed design guides based on the models. These guides suggest proper shapes of chairs, locations of foot pedals, keyboard designs, etc. Other models have been suggested for the non-mechanical aspects of the man. These models are usually less formal and include signal processing, transfer functions, esthetic values, etc. These models of normal gravity man have been developed after extended testing, observation, and analysis. Testing in a neutral buoyancy environment has yielded sufficient pertinent data so that a zero-gravity man model can be defined. The differences between a true zero-gravity environment and the neutral buoyancy test environment include the following factors: 1) viscous effects of the water produce an increased drag on both the subject's body and any object he carries or attempts to move, 2) the buoyancy of various parts of the subject's body varies; for example, the legs and feet are difficult to keep neutrally buoyant and a large face mask, because of its buoyant effect, tends to force the head upward with respect to gravity. Despite these deviations from true zero gravity, the simulation is sufficiently accurate to produce a reasonable man model envelope for various habitability tasks. The advantages of such models are: 1) they provide a guide for design which is better than no guide, and 2) they provide for an identification of variables for testing.

Since there is no prior reason to assume that zero gravity directly changes the psychological social esthetic models of man, data concerning human requirements in these areas can be taken directly from the normal gravity models. There are no formal models for the special case of men in isolation and men in prolonged stress that can be readily translated into design of habitable quarters but the general consensus is that minor annoyances under normal conditions can become major disturbances under these kinds of special conditions. The changes from the mechanical systems models have been summarized in Table II-2. Figures II-1 thru II-5 illustrate the relaxed positions and the functional reach using restraint devices.

Table II-2 Adjustments of Models to Zero Gravity

Zero Gravity Adjustment	Design Implication
1. Posture - The need to align the body to meet gravity requirements is eliminated so all normal postural restrictions (hip support, keeping elbows down, supporting the knees, etc) are relieved.	1. Posture - The man can work in a variety of attitudes and maintain a cantilever orientation indefinitely. New concepts in locations of displays and stowage areas are needed.
2. Surface Contact - While there is no steady contact due to gravity, contacts will be made in the form of minor impacts and use of surfaces for a base from which force is applied.	2. Surface Contact - (a) Surface areas to support the trunk, arms, and legs can be substantially reduced in size (b) all surfaces which the man can contact must be designed to meet low speed impacts. Particular attention must be paid to the "underside" of work surfaces, cabinet corners, etc.
3. Application of Force - (a) Heavy or sustained force: the mechanics for the normal application of force by restraint of the feet similar to gravity-induced friction must be maintained. Even forces which are applied with the arms require foot restraint to prevent rotation effects.	3. Application of Force - (a) Foot restraints or comfortable toe holds must be provided at work stations which require heavy or sustained application of force, (b) occasional switch operations or tethering can be accomplished with very light holds or positioning aids.

Table II-2 Adjustments of Models to Zero Gravity (continued)

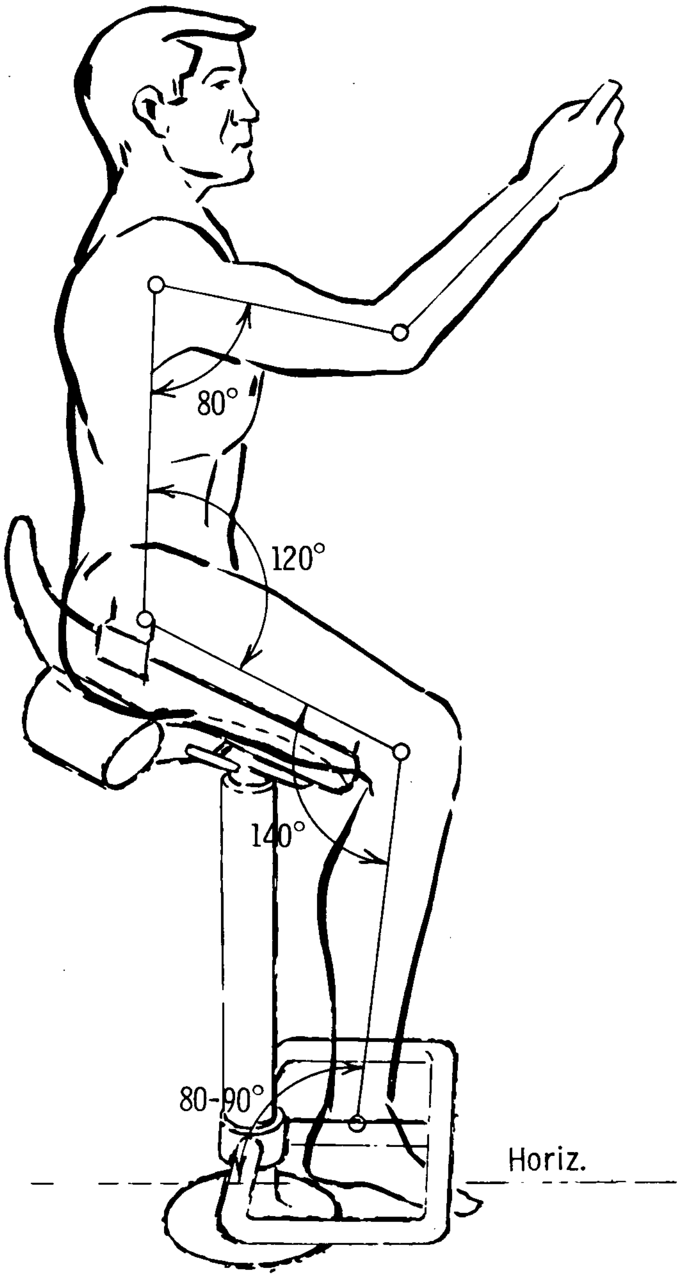
Zero Gravity Adjustment	Design Implication
4. Orientation - The man can assume a number of orientations relative to work stations. For the short term, the novelty of being able to work in all positions is positive. The long term effects of multiple orientation within a room are not known. The crew needs to establish a method of relating to key directions such as earthward or forward relative to flight path. Time orientation is important not only for local events but for earth events. Efforts should be made to control feelings at isolation and noninvolvement in earth activities. When not in contact with a surface, the man can control attitude but cannot translate.	4. Orientation - Operations which can be accomplished from a variety of orientations should be designed to allow this variety without increase of errors. Labels should be read from any orientation, shape and color coding should be used. Work areas and sleeping quarters should be designed so that the orientation of the room can be immediately determined. This is especially true for sleeping areas. Clocks, calendars, and earth event schedules should be provided. Related tasks in the same room should be of the same orientation. Unrelated tasks may be of a different orientation as long as there is room to maneuver to the different positions.
5. Movement to New Station - The man will initially use hands, then hands and feet, and then primarily feet unless specifically trained. Major problem is to control speeds and acceleration.	5. Movement to New Station - Provide light weight holds that can be used for either hands or feet. Limit size of passages to allow contact with surfaces if the man desires or to allow "soaring".
6. Carrying Objects - There is no limit on size or center-of-gravity but mass and center-of-gravity should be known. Estimates of mass must be twice as great as weight differences to be judged as different when man is inexperienced in zero gravity. No data on learning.	6. Carrying Objects - Handles in line with the center of mass should be provided. When center of mass is not at the geometric center, the center should be identified.

Table II-2 Adjustments of Models to Zero Gravity (continued)

Zero Gravity Adjustment	Design Implication
7. <u>Toilets</u> - Methods to remove and secure clothing and to provide visual feedback are needed. Some indication of increase in frequency of urination for zero gravity. Diarrhea is a likely event for a long flight.	7. <u>Toilets</u> - A major design problem is to be able to dispose of any product the human body is capable of producing. Should be isolated from other areas.
8. <u>Hygiene</u> - Methods to clean and groom the body are important to health and outlook.	8. <u>Hygiene</u> - Need to provide facilities which do not require elaborate training.
9. <u>Sleep</u> - Sleeping comfort is very subjective with a wide variety of taste and requirements among individuals.	9. <u>Sleep</u> - Provide bed which maintains orientation. Need to have option of close or loose restraint. Also option for pillow or other earth oriented features to be used at option of user.
10. <u>Meals</u> - Should be as close to earth normal as possible. Should be associated with social activity rather than a refueling. Positioning of the tray relative to the table and individual to take advantage of zero gravity.	10. <u>Meals</u> - Allow options and provide an eating place rather than a tray. Design table and restraint devices to accommodate man in the zero gravity posture.
11. <u>Dressing</u> - Greater options to allow putting pants on both legs at once. Man should maintain orientation by normal contact with walls or foot restraint device.	11. <u>Dressing</u> - Provide small semi-closed area or a toe bar for stability with method to secure garments in a convenient location.
12. <u>Mounting Chair</u> - Could be mounted from above, behind, side as well as front. In some cases, a "no-hands" technique from any angle can be used.	12. <u>Mounting Chair</u> - Chair should have rounded edges which can be easily grasped.

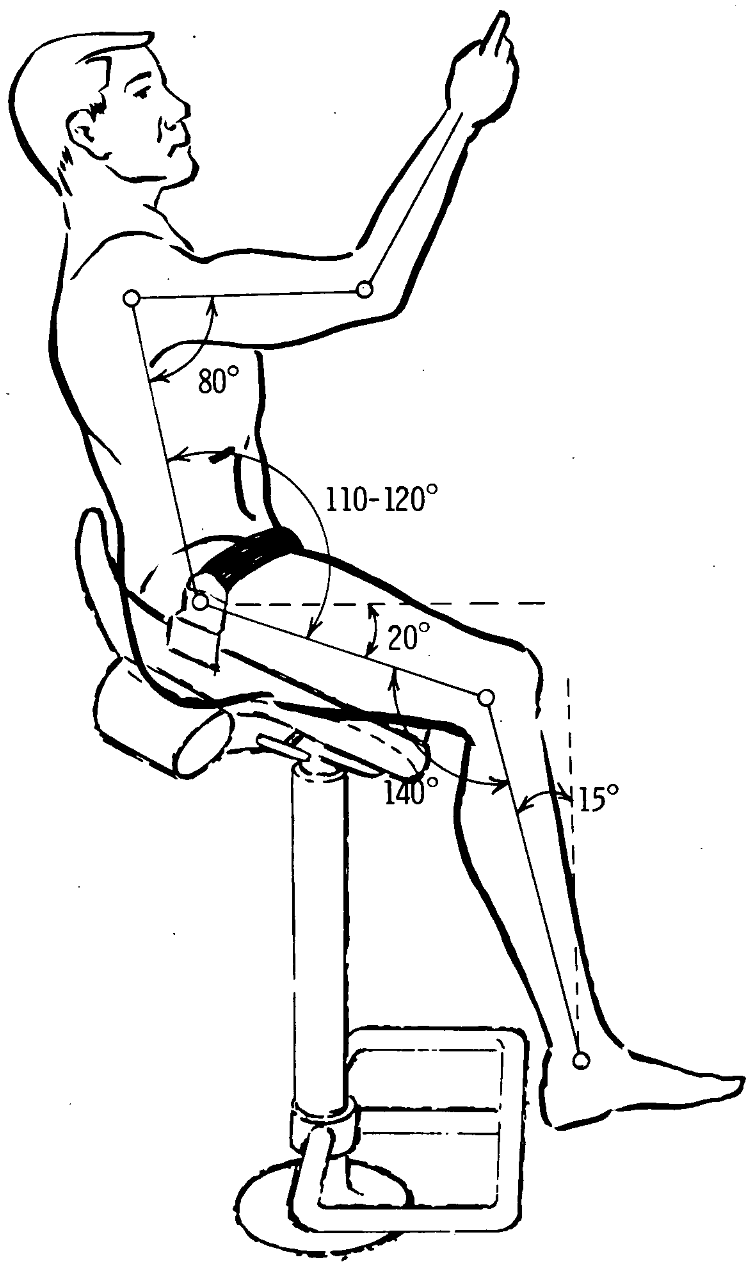
Table II-2 Adjustments of Models to Zero Gravity (concluded)

Zero Gravity Adjustment	Design Implication
13. Use of all Surfaces - Subjects tend to use any and all available surfaces for mobility aid, control, etc.	13. Use of all Surfaces - Handholds, furniture items, etc. could be placed on any surface, easily adapted to.
14. Room-to-Room Orientation - Different orientations very quickly adapted to; only minimal cue needed to obtain proper orientation in different rooms.	14. Room-to-Room Orientation - Separate but connecting rooms can be placed in different orientations, traffic/locomotion patterns between rooms only limiting factor in a series of more than two rooms. Equipment placement becomes major factor in determining traffic patterns.
15. Safety - Use of all surfaces and full room volume creates greater safety hazards.	15. Safety - Desks, chairs, etc. should have rounded edges which can be safely used as mobility aids, etc.



- Minimum Impact on "No-Contact" Relaxed Position
- Top of Toes Establish Contact - Point of Force with Reaction on Soles of Feet
- Angle Between Lower Leg and Vertical Remains Nearly Normal at All Times
- Upper Body Position Unchanged from Free Relaxed Position

Figure II-1 Toe Rail - Relaxed Position



- Lap Belt Establishes Point of Contact with Seat Providing Reacting Surface
- Angle Between Vertical & Lower Leg Increases to 15°
- Other Body Angles Remain Unchanged
- Angle Between Upper Leg & Horizontal is ≈ 20°

Figure II-2 Chair Restraint - Relaxed Position

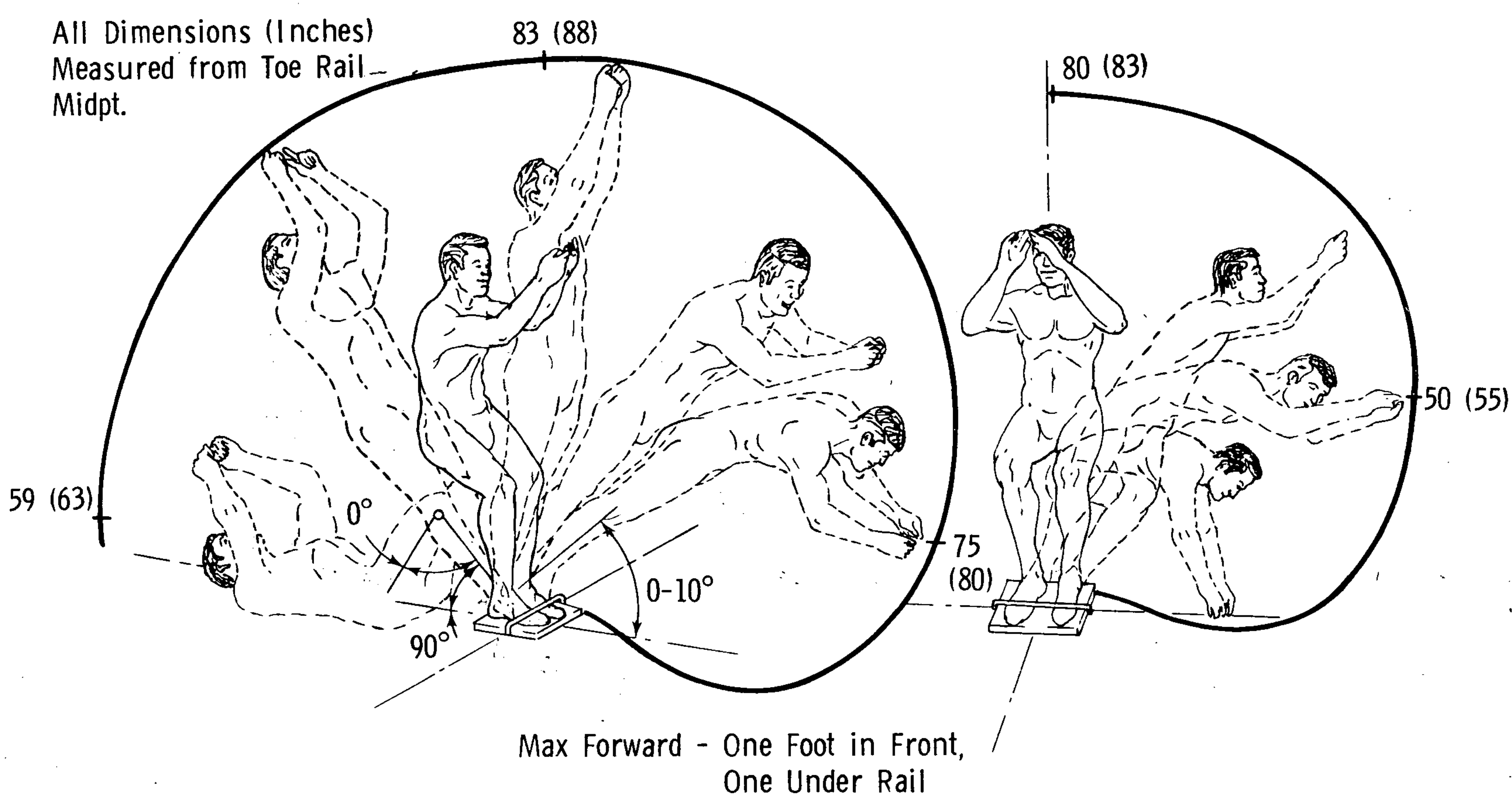


Figure II-3 Toe Rail Functional Reach - 50th (95th) Percentile Man

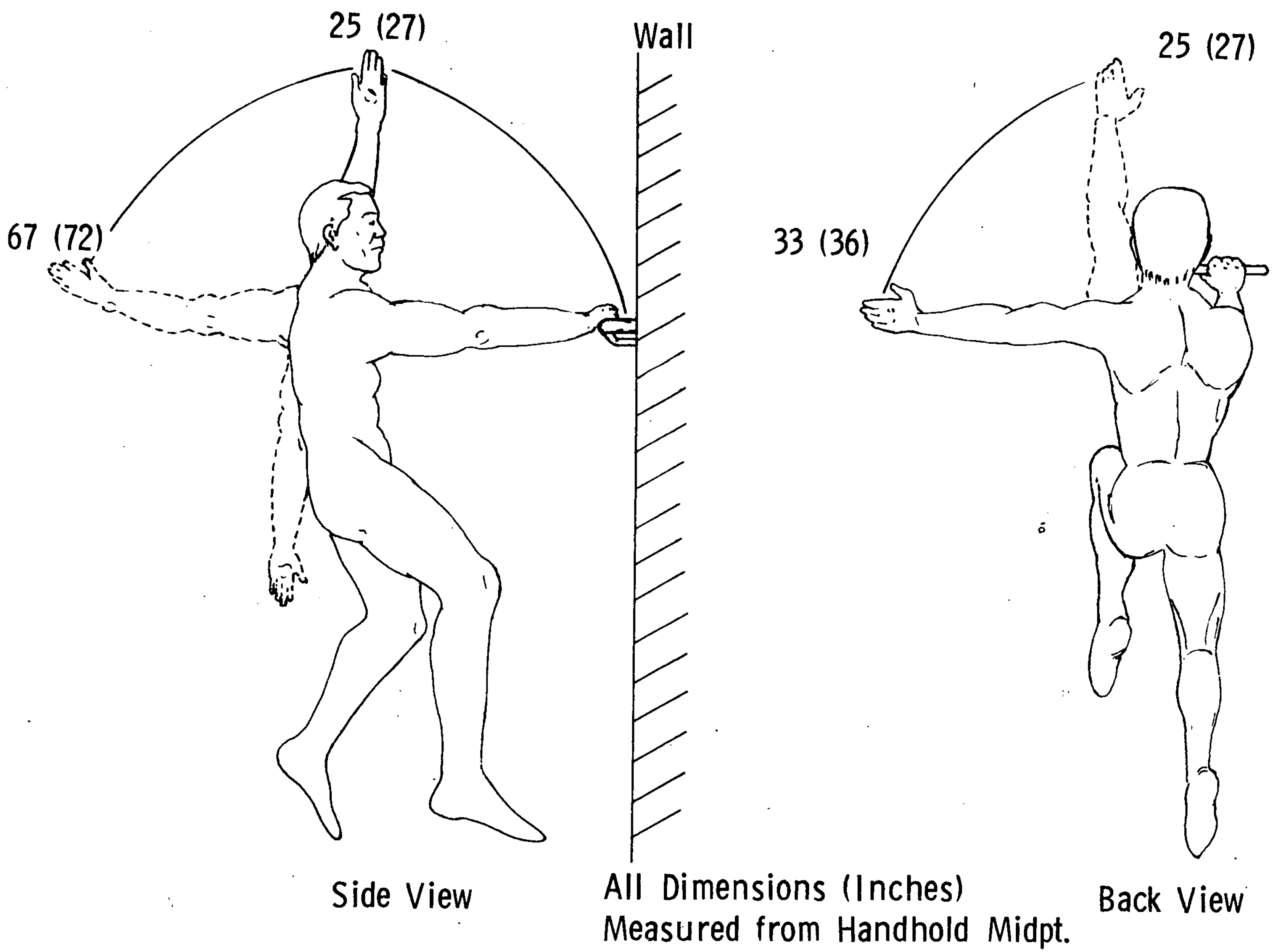


Figure II-4 Handhold Functional Reach - 50th (95th) Percentile Man

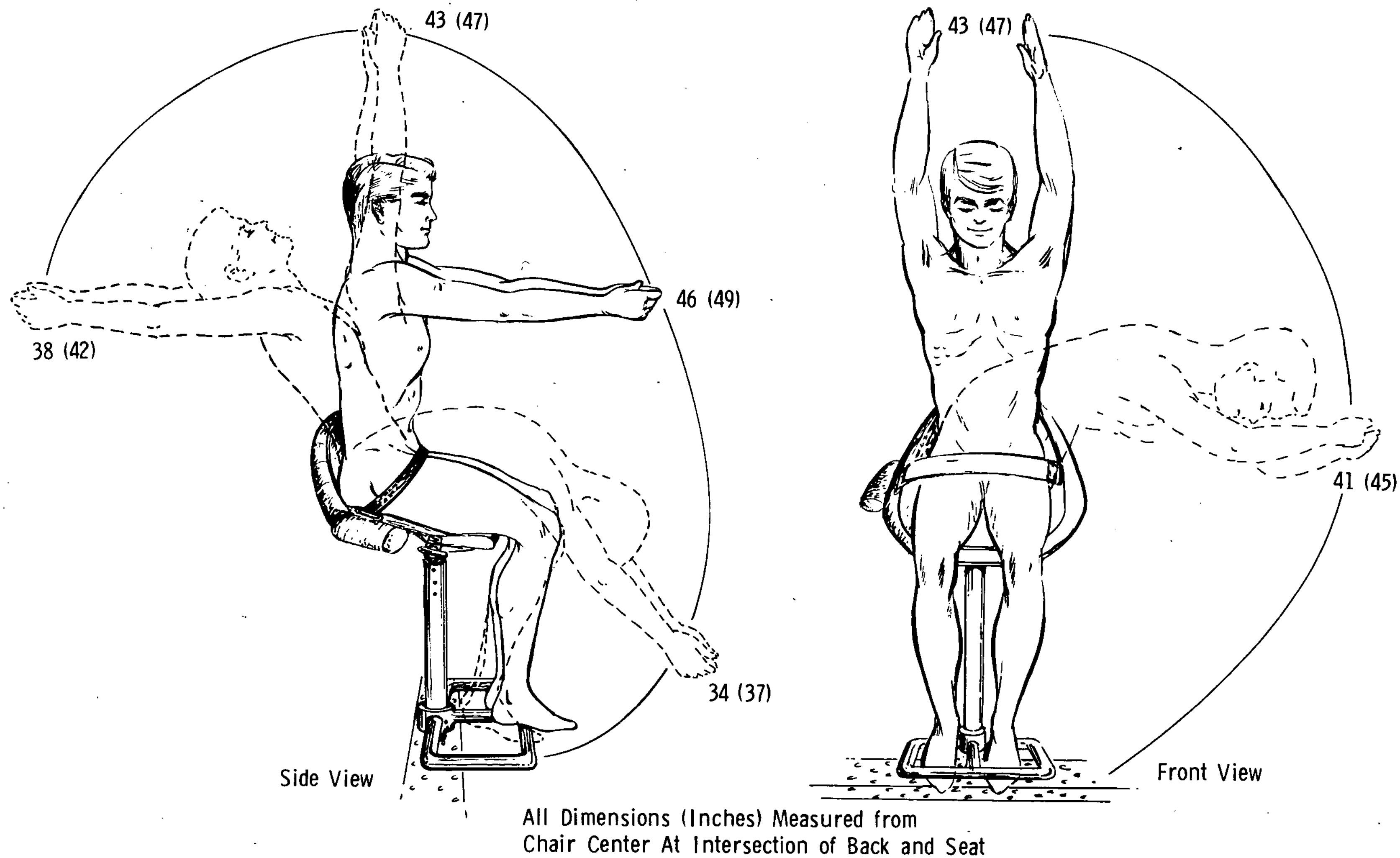


Figure II-5 Chair Restraint Functional Reach - 50th (95th) Percentile Man

Analysis of post-flight debriefings has not been done as a part of the contract. Data based on the Apollo VII review, 27 November 1968, are of direct interest, however, and are provided for comparison with the neutral buoyancy results.

The crew views can be reduced to two main points:

1. For extended missions, life should be as close to life on earth as possible as far as creature comforts are concerned.

2. The spacecraft should be designed for zero-g living with no up-down orientation forced on the crew.

The following points summarize the crew opinions presented at the discussion:

1. Suited operations and shirtsleeve operations are totally different.

2. All restraints should be light.

3. There is a very fast adaptation to body control in zero-g. The primary rule is to keep velocities low. No psychological problems in being unrestrained.

4. Sleep presents psychological problems which are resolved in a few days. Initially, the crew wanted restraints and later wanted a large cocoon-type of sleeping arrangement.

5. Windows are very important for recreation and "home movies" of the flight.

III. CONCEPT DESIGNS

Specific recommendations and rationales are presented here for a chair/table design, a stateroom complex, and the galley/wardroom design. It should be noted, however, that individual criteria can be utilized non-specifically. For example, volumetric requirements defined for the three-man office could be used in the design of a small lounge. Access dimensions for furniture items are independent of the rooms where the items are used. With proper room design and furniture orientation, overall volume requirements can be reduced by, for example, usage of the same access volume for two furniture items. Visual space of individual rooms can be greatly expanded by opening hatches onto hallways or to other rooms.

A. CHAIR/TABLE DESIGN CONCEPT

The chair and table developed for neutral buoyancy testing met the functional requirements and provided maneuvering mobility and restraint aid to complement the basic requirement. The chair design incorporated a retracting lap belt restraint, chair seat swivel, vertical height adjustment while seated, moveable foot restraint ring, and mobility/restraint aids. The table has several features, such as vertical height and lateral adjustment, that probably will not be required in a spacecraft but were required to obtain the optimum dimensions to make firm recommendations. The angle adjustment may be a desirable option since it is very probable that the individual desk/table will be of the fold-away type. Table III-1 and III-2 gives the details of the chair and table tested and the design to be delivered. The tested design is also depicted by Figure III-1 and the delivered item in Figures III-2 and III-3.

1. Chair Design Rationale

A restraint device for a zero-g environment must satisfy the functional requirements and be pleasing to the user. The primary functions of the device must be to provide the stability of controlling the body and maintaining body position while performing tasks in a particular place. The restraint must also provide the stability without placing undue stress on any muscle of the body. Another point that must be considered is that the body takes a certain amount of envelope volume, which is little changed whether he is standing or sitting. Therefore, the restraint device must satisfy many requirements and make maximum use of the available volume.

Table III-1 Chair Prototype Design

PARAMETERS	CONFIGURATION TESTED	DELIVERABLE DESIGN
SEAT DESIGN		
DIMENSIONS	18" WIDE BY 10" DEEP	18" WIDE BY 10" DEEP
SLOPE	GRADUATED 8° TO 20° BACK TO FRONT	GRADUATED 8° TO 20° BACK TO FRONT
BACK HEIGHT	5 INCHES	5 INCHES
CHAIR FEATURES		
HEIGHT	20" TO 24" IN 1" INCREMENTS	20" TO 24" IN 1" INCREMENTS
ADJUSTMENT	UP - MANUAL DOWN - SPRING LOADED 1/4" MOVEMENT AGAINST 8 LB FORCE 5" BELOW CHAIR LIP	UP - MANUAL DOWN - MANUAL RELEASE SPRING LOADED (NOTE: REDESIGN OPERATING LEVER) TRAVEL - 1/4" AGAINST 8 LB FORCE LOCATION - 2" BELOW CHAIR LIP
SWIVEL CAPABILITY	SPRING LOADED BALL (12 LB), 30° INCREMENTS	SPRING LOADED BALL (30 LB SPRING) IN 30° INCREMENTS
SUPPORT	3" TO 4" OD TUBE ON 7" SQUARE PAD	1.625" TO 2.0" ON 7" ROUND PAD
MOBILITY/RESTRAINT AIDS		
UPPER TORSO	NONE	NONE
LAP	RETRACTABLE BELT	RETRACTABLE BELT
HAND	3/4" RADIUS LIP AROUND SEAT	3/4" RADIUS LIP AROUND SEAT
FEET	D-RING 10" R x 8" TO D, 1" BAR, 5" OFF FLOOR	RECTANGULAR 8" x 18" TO SWIVEL WITH SEAT, 1" TUBE, 4-1/2" OFF FLOOR
WEIGHT	18 POUNDS	14.8 POUNDS

Table III-2 Table Prototype Design

PARAMETERS	CONFIGURATION TESTED	DELIVERABLE DESIGN
TABLE DESIGN		
TOP DIMENSIONS	24" x 36"	18" x 27"
ANGLE	0 TO 60^{o}	25 ± 5^{o} FIXED
TABLE FEATURES		
VERTICAL HEIGHT	38" TO 44" IN 1" INCREMENTS	42" ADJUSTABLE
HORIZONTAL MOVEMENT	MANUAL ± 3" SLIDING BASE	± 3" SLIDING BASE - MANUAL
ADJUSTMENT	± 3" BY SLIDING FOOT OPERATED LOCKING LEVER	FOOT OPERATED LOCKING LEVER ± 3" HORIZONTAL SLIDING
MOBILITY/RESTRAINT AIDS		
HAND	1" LIP AROUND TABLE	1" LIP AROUND TABLE TOP
FEET	3/4" BAR, 18" LONG, 8" OFF FLOOR	3/4" DIAMETER TUBE 18" LONG, 6" ABOVE BASE

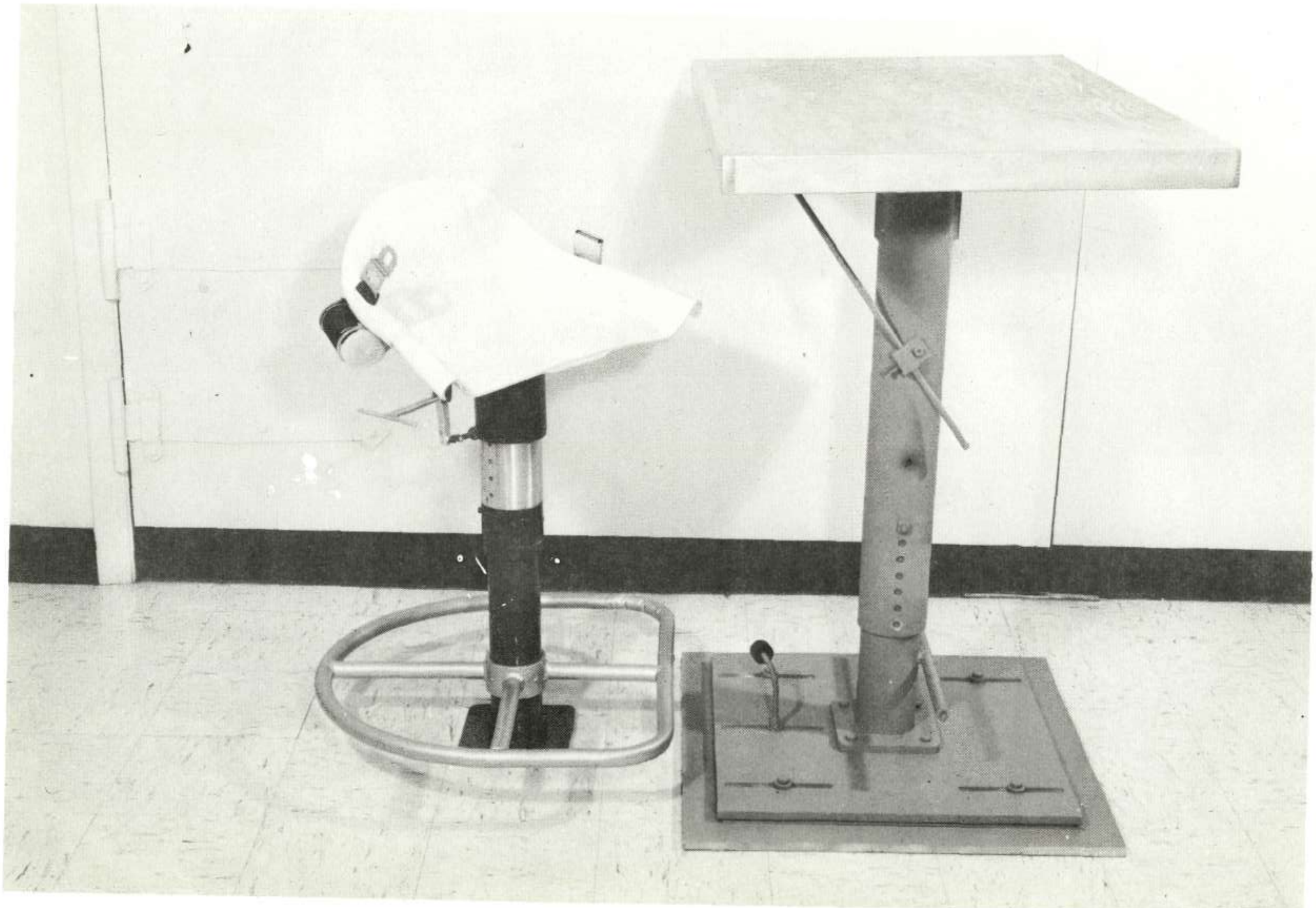
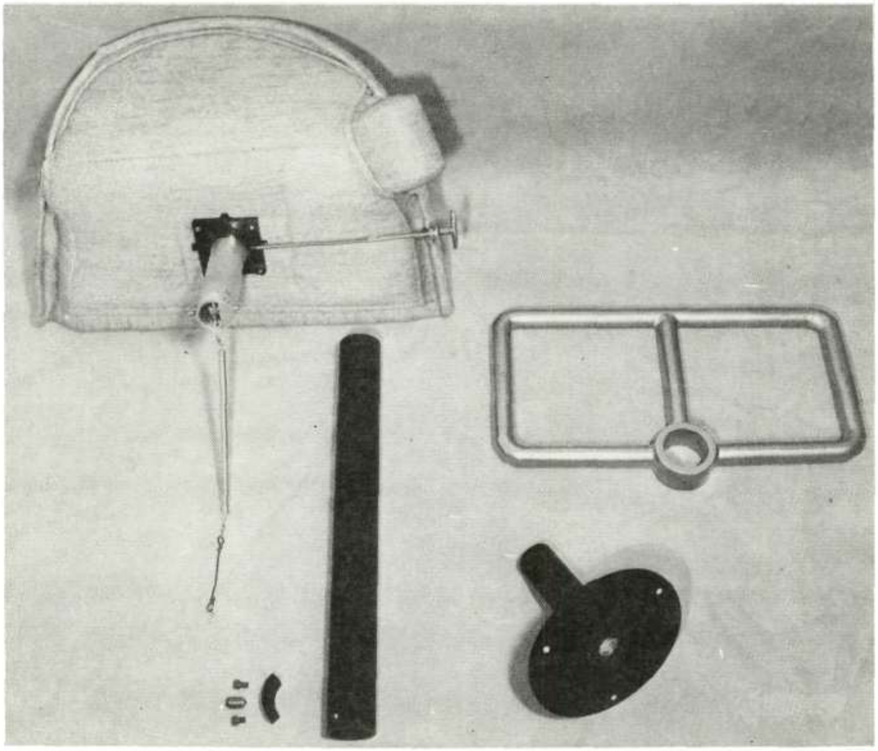


Figure III-1 Prototype Chair and Table Tested



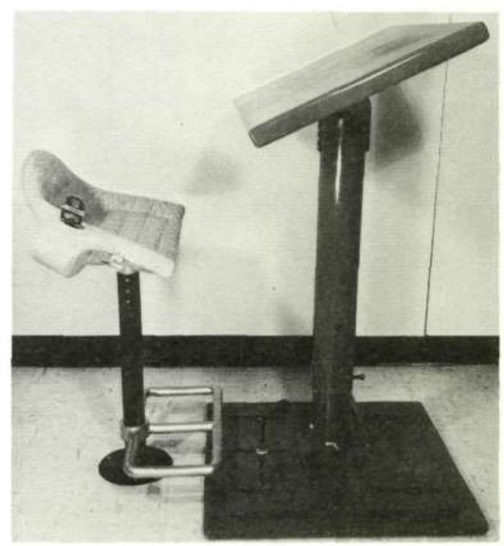
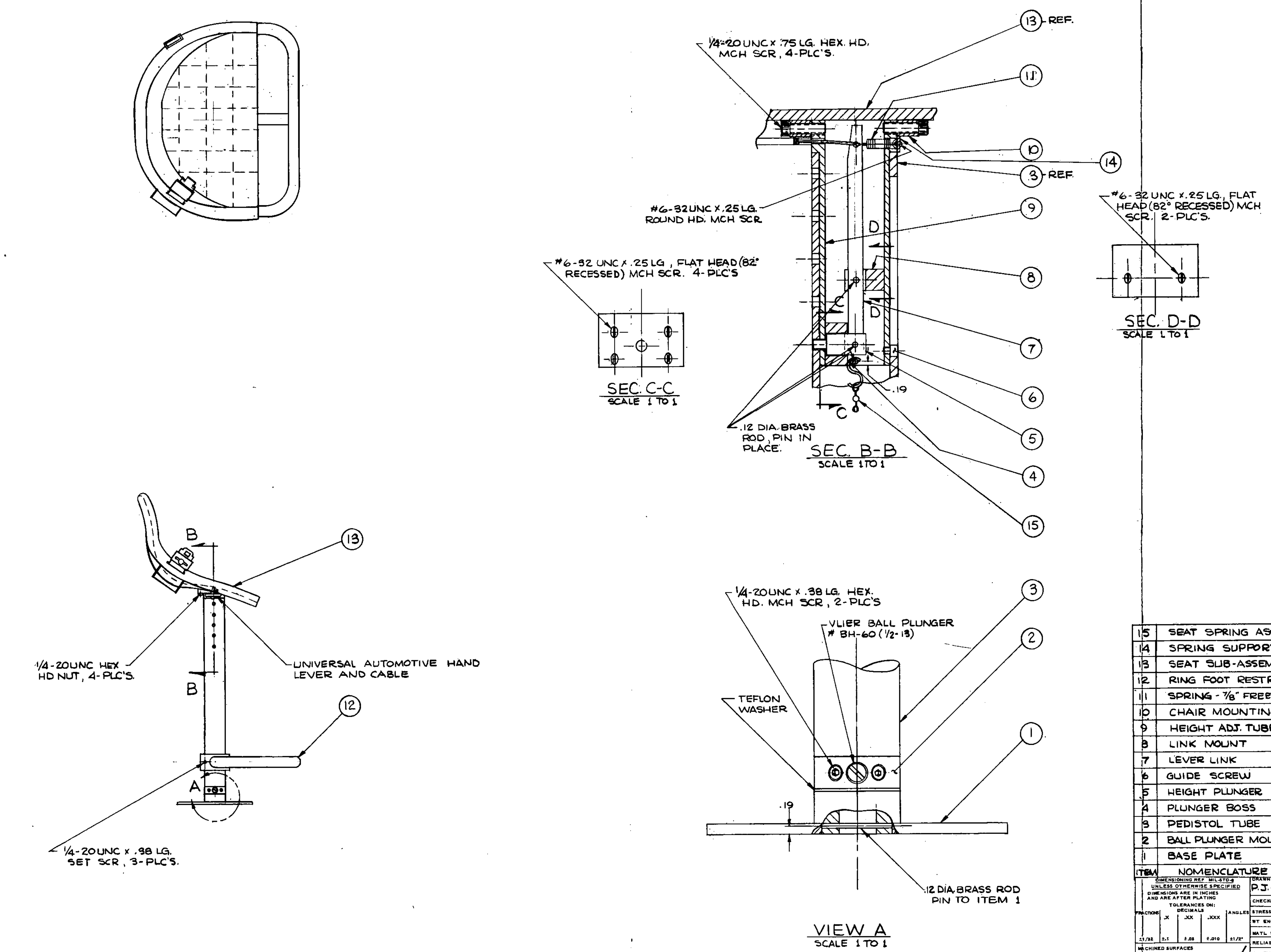


Figure III-2 Prototype Chair and Table Delivered

FOLDOUT FRAME 1

FOLDOUT FRAME 2



ITEM	NOMENCLATURE	PART NO.
15	SEAT SPRING ASS'Y	-014
14	SPRING SUPPORT	-013
13	SEAT SUB-ASSEMBLY	-009
12	RING FOOT RESTRAINT	-012
11	SPRING - 7/8" FREE LG. x 1/4" DIA.	
10	CHAIR MOUNTING PLATE	-011
9	HEIGHT ADJ. TUBE	-010
8	LINK MOUNT	-008
7	LEVER LINK	-007
6	GUIDE SCREW	-006
5	HEIGHT PLUNGER	-005
4	PLUNGER BOSS	-004
3	PEDISTOL TUBE	-003
2	BALL PLUNGER MOUNT	-002
1	BASE PLATE	NAS911947-001-

DRAWN BY P.J. GARBER 1642 2/85

MARTIN MARIETTA CORPORATION, POST OFFICE BOX 179, DENVER, COLORADO

ZERO-G CHAIR ASSEMBLY

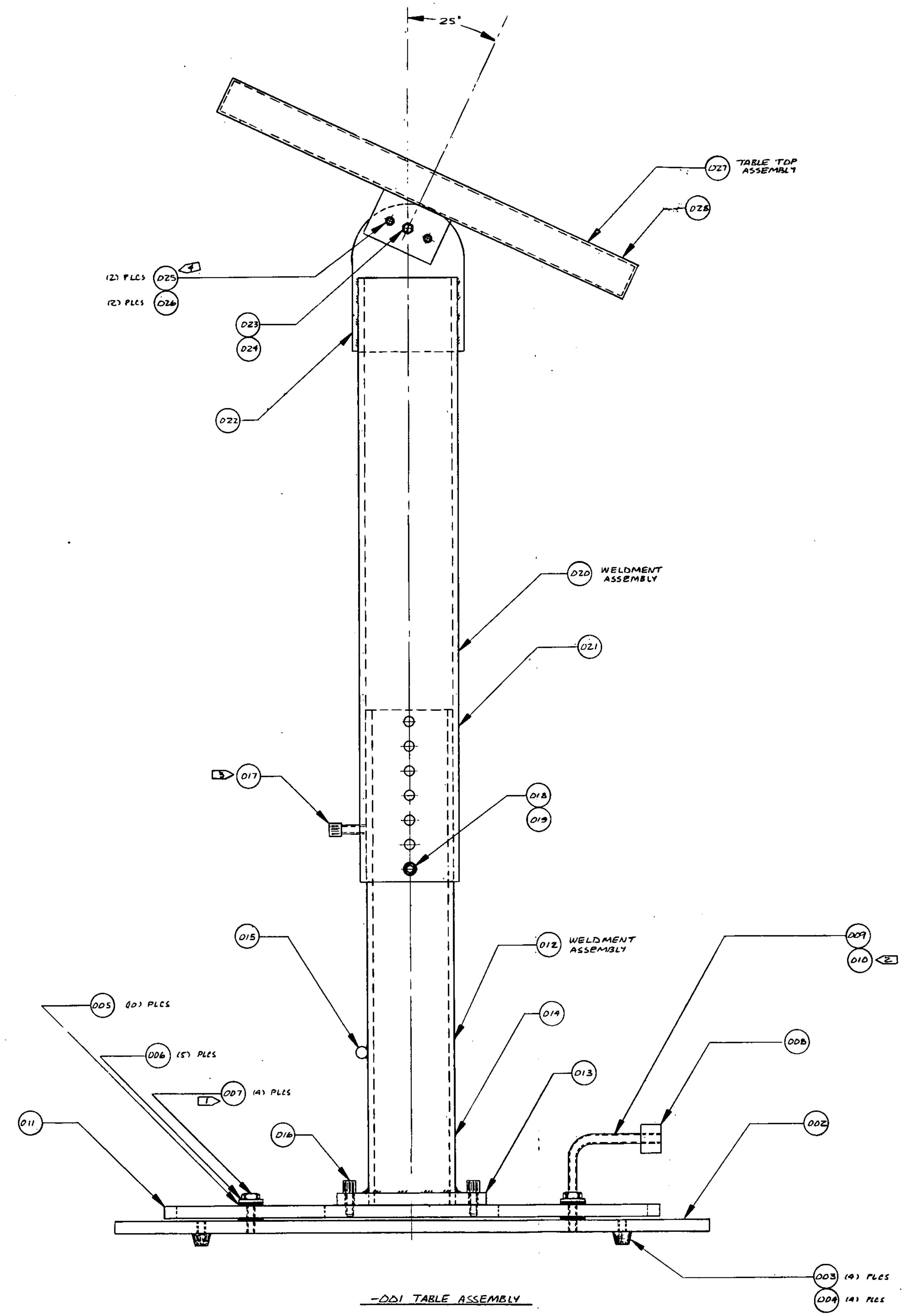
SIZE F CODE IDENT. NO. 04236 NAS911947-000

SCALE 1/4

Figure III-3 Chair and Table Design Layout (Sheet 1)

FOLDOUT FRAME 1

FOLDOUT FRAME 2



REVISIONS

FLAGNOTES

1. BOLTS TO BE LOOSE TO ALLOW TRANSVERSE MOVEMENT OF -011 PLATE, BUT TIGHT ENOUGH TO ELIMINATE EXCESS VERTICAL MOVEMENT
2. ADJUST DURING ASSEMBLY FOR BEST OPERATION
3. TIGHTEN AFTER HEIGHT IS DETERMINED
4. INSTALL DURING ASSEMBLY TO HOLD ANGLE CALLOUT

GENERAL NOTES

ROUND OFF ALL SHARP CORNERS

PAINT ALL SURFACES MEDIUM BLUE, PRIME WITH ZINC CHROMATE

NEXT ASSY	DET NO.	DESCRIPTION	QTY	MATERIAL
027	033	POP RIVET	8	1/8" DIA x 1/4" GRIP LENGTH
027	032	SELF TAPPING SCREW	8	#10
027	031	ANGLE	1	OPPOSITE -030
027	030	ANGLE	1	AL6061-T4 1/8 x 6 x 18
027	029	CHANNEL	1	AL6061-T6 1 x 1 x 2 1/4 x 1/8 THK x 27
027	028	TABLE TOP	1	AL6061-T4 .125 THK x 24 x 33
001	027	TABLE TOP ASSEMBLY	1	—
001	026	NUT	2	STEEL 1/4-20 THD
001	025	SOCKET HEAD CAP SCREW	2	STEEL 1/4-20 THD x 1" LONG
001	024	NUT	1	STEEL 5/16-18 THD
001	023	HEX HEAD CAP SCREW	1	STEEL 5/16-18 x 1" LONG
020	022	PLATE	1	AL 6061-T6 1/2 x 4 1/2 x 6
020	021	TUBE	1	AL 6061-T6 4" O.D. x 25 1/2 LONG
001	020	WELDMENT ASSEMBLY	1	—
001	019	NUT	1	STEEL 3/8-16 THD
001	018	SOCKET HEAD CAP SCREW	1	3/8-16 THD x 4 1/2" LONG
001	017	SOCKET HEAD CAP SCREW	1	3/8-16 THD x 3/4" LONG
001	016	SOCKET HEAD CAP SCREW	4	3/8-16 THD x 1" LONG
012	015	ROD	1	AL6061-T6 1/2 DIA x 13 1/2" LONG
012	014	TUBE	1	AL 6061-T6 3 1/2" O.D x 20
012	013	PLATE	1	AL 6061-T6 1/2 x 6 x 6
001	012	WELDMENT ASSY	1	—
001	011	PLATE	1	AL 6061-T6 1/2 x 20 x 20
001	010	JAMB NUT	2	STEEL NUT 3/8-16 THD
001	009	THREADED ROD	1	STEEL ROD 3/8-16 THD x 8" LONG
001	008	KNOB	1	AL 6061-T6 1 1/4 DIA x 3/4 LONG
001	007	HEX HEAD CAP SCREW	4	3/8-16 THD x 1 1/4 LONG
001	006	WASHER	5	STEEL .062 x 3/8 I.D x 1" O.D.
001	005	TEFLON WASHER	10	TEFLON 1/8 THK x 3/8 I.D x 1" O.D.
001	004	SOCKET HEAD CAP SCREW	4	10-32 THD x 3/4" LONG
001	003	FOOT	4	RUBBER 1/2" HIGH
001	002	BASE PLATE	1	AL 6061-T6 1/2 x 24 x 24
—	001	TABLE ASSEMBLY	1	—

DIMENSIONING REF MIL-STD-8
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES AND ARE AFTER PLATING

DRAWN BY T. JONKONIEZ

MARTIN MARIETTA CORPORATION
POST OFFICE BOX 179, DENVER, COLORADO

TABLE — NEUTRAL BUOYANCY TEST

SIZE F | CODE IDENT. NO. 04236 | NAS911947-100

SCALE 1/2 | SHEET 1 OF 3

Figure III-3 Chair and Table Design Layout (Sheet 1)

a. Height - The seat height is derived from the anthropometric dimensions and a combination of seat slope and position of the foot restraint. Tests of GFP restraints indicated the height could vary from 20-1/2 inches to 23 inches depending on the foot restraint and the slope of the seat. As the slope angle of the seat is increased, the feet restraints will move closer to the restraint support and raise the seat height. Therefore, the seat height selected, variable 20" to 24", meets the anthropometric dimensions for man, utilizing a graduated slope of 8^{o} to 20^{o}, and a foot restraint incorporated into the device. Since the height is adjustable, the adjustment can be made with the man seated in the chair. The operating lever is accessible for two-finger operation with the right hand resting on the chair seat lip. The force to actuate the spring loaded pin is an initial one pound force graduated to 8 pounds at final release. The device is spring loaded to move down unless the user exerts an upward force with his legs.

b. Seat Design - The primary function of the seat is to provide the interface with the user and conform to the shape of buttocks with man in a sitting position. In addition the seat must serve as a restraint and mobility aid, body positioning device for performing tasks that require 30 minutes or more, and provide a stable platform for mounting the lap belt. The seat contour was determined by the requirement for a four-inch surface for mounting to the support in the center and a vertical position on the back three inches above the seat for the back bottom curve. From the back a gentle slope, approximately eight degress, to four inches from the gront and then 20 degrees to the front edge was used. The ten-inch seat depth provides adequate support yet allows freedom for the thighs as well as providing access from the front. The 1-1/2 inch rolled lip on the seat provides a continuous hand restraint from front edge to front edge and serves as a mobility aid for pushing off with hand or foot. The retractable lap belt is mounted at 45 degress with respect to the horizontal and vertical portions of the seat. This mounting provides the maximum force available in restraining the body in the seat with the upper torso and arms completely free.

c. Swivel Capability - The swivel capability provides for better volume utilization of the area around the chair and makes for easier access to the chair. A swivel chair also allows the user some freedom in the position he must take and remain restrained to a fixed point.

d. D-Ring - A D-ring restraint was selected for testing to give a restraint device for the feet in any position of the seat with the straight section positioned parallel to the task station. The straight section provides better control than the curved sections. Four spokes, one each side, fore, and aft, are used to support the D-ring at a ten-inch radius from either side and the rear with the front section eight inches from the center of the seat support. This design also provides a mobility aid as a push-off point with the feet when leaving the area.

In the deliverable item, the D-ring was replaced with a rectangular shaped restraint attached to the seat support tube and will swivel in conjunction with the seat. The size was reduced to 8 inches by 18 inches which saves volume and weight and still provides the optimum restraint and mobility capabilities for the chair restraint.

B. COMMANDER'S STATEROOM COMPLEX DESIGN

1. Introduction

The volumetric criteria defined for each of the rooms in the stateroom complex and for the wardroom/galley can be more adequately understood if the following definitions are kept in mind. Gross Volume is that volume which would be available if all furniture items, storage modules, controls and control panels, etc. were removed from the room leaving the room frame only. Net Volume is the usable room volume that remains when all furniture items are deployed as they are to be used and when all storage modules, etc. are in place. Visual Volume is the amount of space which is visually perceived as usable from a specified position within a room. This value is related to the physical objects in a room and the placement of these objects relative to the observer's eye level.

2. Stateroom Design Concept

The stateroom which has been conceived and developed for this study is considerably smaller than the one-gravity stateroom defined in existing guidelines: 122 vs 343 cubic feet gross volume. The net volume with the desk, chair and sleep restraint in position is approximately 80 cu. ft. The visual volume for a man seated in the chair and all hatches closed is approximately 68 cu. ft. With both hatches open, the visual volume increases to 182 cu. ft. for the individual seated at the desk. For a man in the sleep restraint with hatchways closed and chair and table stowed, the visual volume is approximately 76 cu. ft. With the office hatchway fully open, the visual volume for a man in the sleep restraint totals 163 cu. ft., of which 87 cu. ft. is in the office and the remaining 76 cu. ft. is in the stateroom. The methods of achieving these economies are explained in following paragraphs; however, it should be understood that hypothetically, the room concept which was selected for testing was to be used as one room in a complex of three rooms (stateroom, office and head) for a station commander, and would not therefore be used for entertaining or socializing of any sort. It is strictly a one-man room, sized for functional not social or cultural acceptability. It is felt that neutral buoyancy testing will not provide much meaningful data regarding the latter two items.

The staterooms conceived and selected for neutral buoyancy testing were designed to support all but one of the six basic activities (social) outlined in the Habitability Data Handbook. These are: sleeping and relaxing in bed, private recreation, personal work, limited grooming and dressing. To support these activities, various pieces of equipment and storage areas were provided. The design process and related rationale used to assemble these items into an efficient, effective stateroom are represented by the following list of considerations.

3. Stateroom Design Considerations

a. Spacial Economy - Taking advantage of the increased freedom of movement resulting from the absence of the effects of gravity, more wall surface was utilized for storage and equipment placement than would have been practical in a gravity environment. This was done by creating two different "heads-up" orientations within the room. Activities (and related equipment) to be performed in each orientation were selected on the basis that no activity interrelationships existed which would result in excessive personal reorienting. Specifically, all clothing storage and provisions for limited grooming were located in the "lower" half of the stateroom, while provisions for study, entertainment, sleeping and relaxation were located in the "upper" half.

In addition to the wall space being fully utilized, the placement of items in the up or down half of the room does away with the need for bending over to reach something since all items are at waist level or above. This also makes maximum utilization of volume required for access envelopes for storage and the interface with restraint devices.

Another area in which considerable spacial economy was realized was in the sizing and placement of hatches. Neutral buoyancy testing substantiated the adequacy of a 30" x 30" hatch and by locating one of the two required hatches in the "ceiling", only one hatch had to be placed in what could be considered prime usable wall space. However, the hatch placed in the wall provided a considerable amount of visual volume in addition to providing a direct access to a passageway.

b. Activity/Equipment Relationship - Prior to commencing layout studies, a chart was prepared illustrating the relationship of activities to equipment in the stateroom. Using this chart as a guide, equipment and storage area groupings and locations were established which would allow easy access to these items from related activity positions of restraint. For example, based on the activity/equipment relationship, the bed was positioned so that a person restrained therein would have access to his personal effects, waste storage, general and directional lighting controls, CRT (entertainment) controls, the intercom, alarm clock controls, and the emergency oxygen unit. Those items to which access was required from both a "heads-up" and a "heads-down" orientation (light controls, oxygen, etc.) were located in the center of the room.

c. Anthropometric Considerations (Point Movement) - Once the activity grouping and rough locations were established, the final locations were determined based on the reach characteristics of man from the activity related restraint positions. In the case of the stateroom, two prime positions of restraint were considered essential, 1) the chair (personal work and relaxation) and 2) the bed (sleep and relaxation).

d. Spacial Requirements for Transfer Movement - The only major transfer movement required within the stateroom is that movement required in reorientation from the "heads-up" to the "heads-down" position. As determined in neutral buoyancy test, a minimum clearance of 48" between partitions is required for comfort when tumbling. Based on this minimum, the room length was set at 60" to ensure ease of reorientation. This reorientation can be accomplished with the desk and chair deployed, however, there could be some interference with some storage compartments.

e. Equipment Spacial Requirements - The only three pieces of equipment for which definite size guidelines were available were hatches: 30" x 30", a folding desk: 18" x 30", and a bed: 33" x 78". The bed being the largest element in the room was the major determinant in establishing both the width (36") and height (78") of the room. The desk and chair access envelopes plus the volume required to maneuver to the different orientations helped dictate the length (60") of the room.

f. Level of Accommodations - As discussed in the first paragraph, the stateroom was designed to accommodate only its inhabitant. Any socializing or conferring would be accomplished in the adjacent office.

g. Safety - With the exception of mobility aid devices, the majority of elements within the area were represented as flush (wall) mounted. Edges of items which did protrude into the space were illustrated as rounded and emergency oxygen was located centrally in the space accessible from both major restraint positions.

h. Visual Space - To relieve the possible claustrophobic effects of working or relaxing for extended periods in the stateroom, the main entrance into the room was placed in the side wall at the study/sleeping end of the room. From either major position of restraint, the inhabitant could expand his visual space appreciably by opening the main hatch. This door was made as large as possible (44" x 42") to take full advantage of the outside space. The other hatch (30" x 42") also added to the visual volume even though it was directly overhead when sitting in the chair restraint.

i. Space-to-Space Orientation - Based on reported neutral buoyancy experience, it has been observed that the people when transferring from one space to another tend to reorient themselves prior to entering the space when transferring from a large to a small space. The opposite seems to be true when transferring from a small to a large space. Based on this assumption, it was decided that the vertical axis of the hatch to the bathroom and the stateroom (the smallest rooms studied) should be oriented parallel to the major vertical axis of the room so as to indicate to a person entering these spaces how he should orient himself. It was further determined that the hatch or hatch handles could be marked or color coded to reflect the orientation of the room within. Another noticable factor was that the natural tendency for the test subjects was to orient themselves to operate the doors by pushing them to the sides rather than from top to bottom.

j. Appearance - The interior of the stateroom was kept as simple and visually clean as possible by consolidating related articles into major storage compartments, i.e., all articles relating to study were stored behind the fold desk. Simplicity of design is especially important in small spaces such as a stateroom which very easily becomes cluttered in appearance with the introduction of too many items. Figure III-4 depicts the selected concept and the design layout is included as Figure III-5.

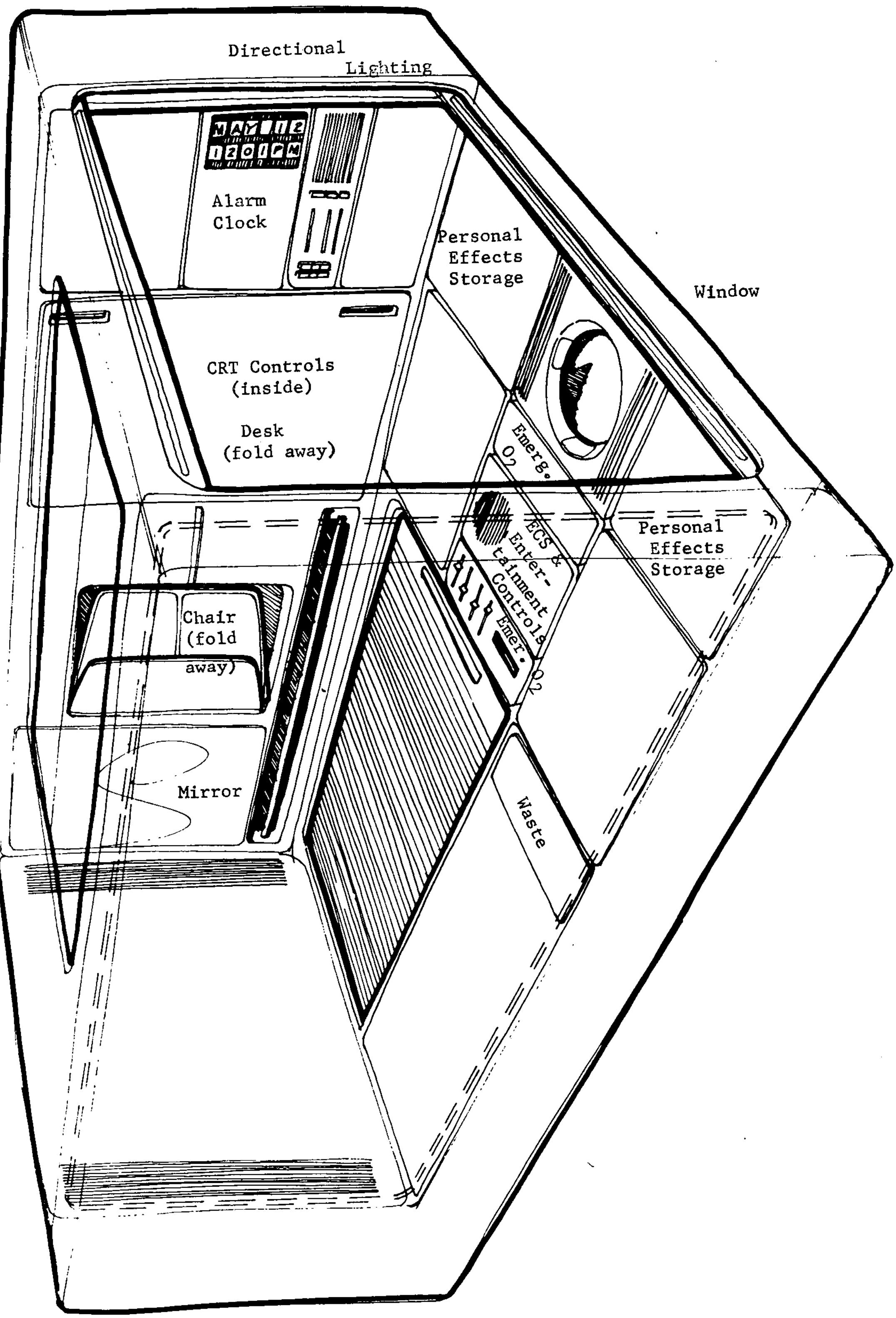


Figure III-4 Commander's Stateroom

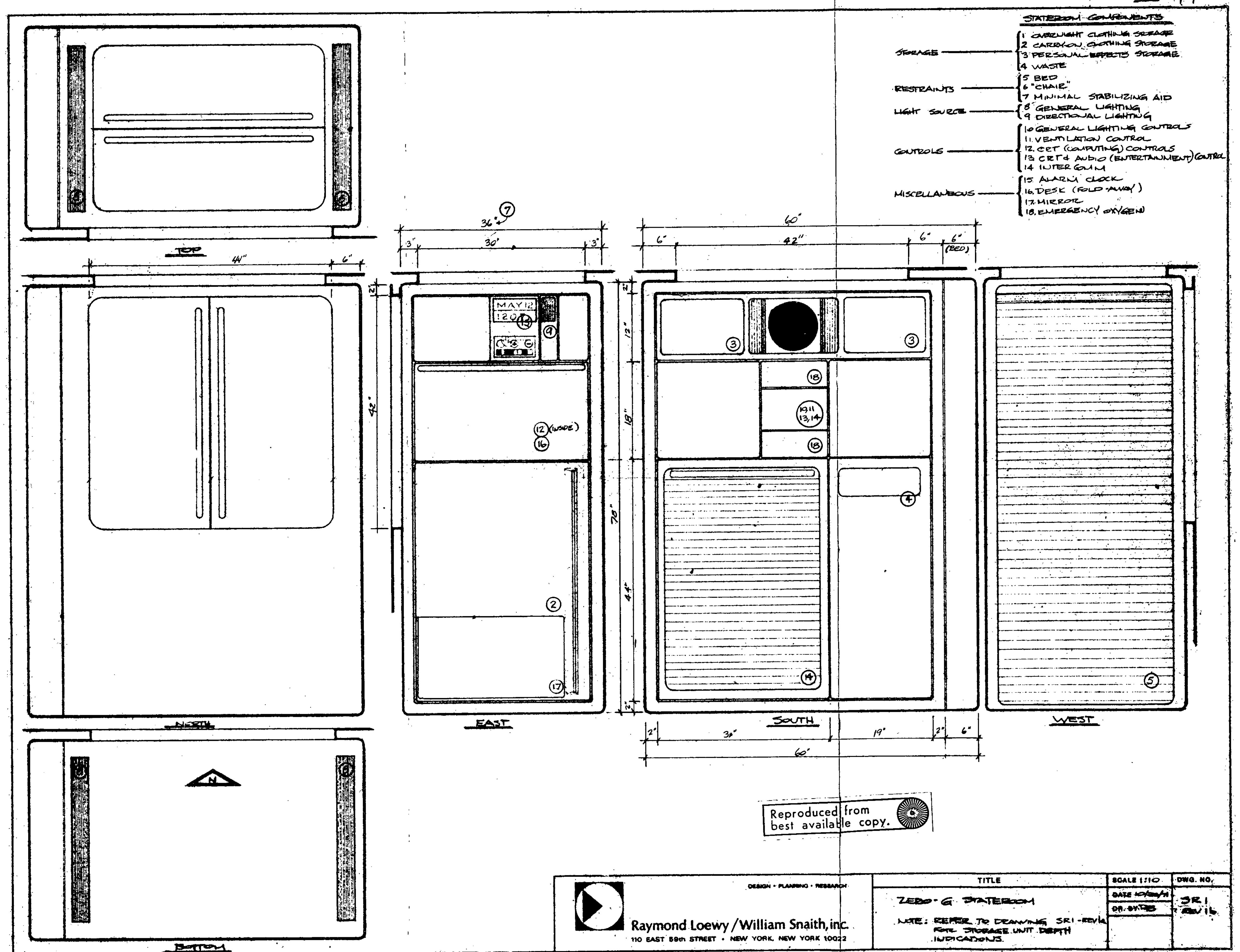


Figure III-5 Stateroom Design Layout

4. Bathroom Design Concept

The bathroom concept selected for testing was developed utilizing dimensional figures of existing prototype hardware. Although it was to serve primarily as a private bathroom for the commander, it might be required to support two people in an emergency and therefore adequate space was provided for one person to use the fecal collector or handwash unit while another person was showering. A number of one-man concepts developed made dual use of the shower volume for partial body wash, urination and defecation. The room was designed to accommodate eight activities: 1) urination, 2) defecation, 3) regurgitation, 4) partial body wash, 5) whole body wash, 6) drying, 7) donning/doffing clothes, and 8) housekeeping. The gross volume of the bathroom tested was 114 cu. ft., of which 36 cu. ft. is required by the shower. Approximately 23 cu. ft. is taken up by equipment and equipment storage, leaving a net volume of 91 cu. ft., or 55 cu. ft. not including the shower. The visual volume from various positions in the bathroom is essentially the same as the net volume since the hatches would remain closed when the bathroom is occupied. The design process and accompanying rationale is presented in the following discussion of design considerations.

5. Bathroom Design Considerations

a. Spacial Economy - With the exception of the placement of the fecal collector at a 60° angle relative to the floor of the compartment, the design of the bathroom has essentially a one-g orientation. The reasoning behind this is spacial efficiency. By designing the compartment as a single orientation unit, it was not necessary to provide 48" clear "horizontal" space for tumbling. The maximum clear "horizontal" dimension in the bathroom is 41 inches which is above the handwash unit and the fecal collector.

b. Activity/Equipment Relationship - Prior to commencing layout studies, a table was prepared illustrating the relationship of activities to equipment in the bathroom. Using this chart as a guide, equipment and storage area groupings and locations were established which would allow easy access to these items from related activity positions of restraint. The three main points of restraint from which the majority of support equipment has to be accessible are urination, defecation and partial body wash.

c. Anthropometric Considerations (Point Movement) - Once the activity grouping and rough locations were established, the final locations were determined based on the reach characteristics of man from the activity related restraint positions.

d. Spacial Requirements for Transfer Movement - Due to its small size and one-g orientation, all intercompartment movement would probably be slight and simple in nature, accomplished while in contact with some type of mobility aid (handles, etc.).

Hand rails provided on the fecal/urine collector, the hatch and the handwash unit should provide sufficient mobility and support. A lap belt on the fecal collector would be a desirable addition to provide complete restraint with both hands free.

e. Equipment Spacial Requirement - All equipment sizes used in the development of concepts were taken from NASA documents.

f. Level of Accommodations - The bathroom was designed as a one-man unit with limited capability to support two people in an emergency with one person using the shower while another used the fecal/urine collector or handwash unit.

g. Safety - With the exception of mobility aid devices, the majority of elements within the area were represented as flush (wall) mounted. Edges of items which did protrude into the space were illustrated as rounded and emergency oxygen was located centrally in the space accessible from all major restraint positions.

h. Visual Space - Because the amount of time spent in the bathroom is so limited, maximum visual space was not considered of prime importance. The space provided should prove adequate based on experience with minimum sized bathroom facilities in such commercial carriers as aircraft and railroad cars.

i. Space-to-Space Orientation - Due to the fact that no head-to-foot reorientation was possible once inside the bathroom, the entry hatch opening was oriented parallel to the vertical axis of the bathroom so that only a pivoting, rather than a tumbling motion would be required of an individual to close the hatch once inside the room.

j. Appearance - The bathroom interior was kept as simple and visually clean as possible.

k. Design Concepts - The bathroom concept selected to test is depicted in Figure III-6 and by the detailed design layout identified as Figure III-7.

6. Office Design Concept

The office layout selected for neutral buoyancy testing was designed to accommodate the commander and two guests in a formal, businesslike orientation. The only equipment provided in the space was a work surface, some storage compartments, a console unit of undefined nature and three restraints. This concept is depicted by Figure III-8. The office gross volume is 214 cu. ft. versus 250 cu. ft. recommended for a one-gravity office for a six-man crew, seating only two men. A three-man one-g office has a recommended gross volume of 299 cu. ft. The office net volume is approximately 160 cu. ft. The visual volume for a man seated in the commander's chair with hatches closed is approximately 110 cu. ft.; for a man seated in one of the visitor's chairs with hatches closed, the visual volume is approximately 85 cu. ft. When the office/stateroom hatch is fully open, a man seated in the commander's chair (in the recommended furniture configuration) has a visual volume total of approximately 170 cu. ft., of which 100 cu. ft. is within the office (observer turned, looking toward hatch); 70 cu. ft. of the stateroom is visible from such a position.

Used in conjunction with the stateroom and bathroom concepts previously discussed, the office became a focal point of traffic. With three hatches in a relatively small, multiple-occupancy space, some rather difficult traffic problems occur. This is compounded by the fact that people entering this space are coming from even smaller spaces (passage, bathroom and stateroom), and will most likely be reorienting themselves after entering the room, which could be a rather space consuming activity. Due to the potential problems of traffic/restrained personnel interference, the office was designed for maximum flexibility within a fixed size space.

The design consisted of a rectilinear volume 5'-6" x 6'-0" x 6'-6" with hatches located in three bulkheads. The means were provided to reorient the hatch axis 90° depending on the test result input. Similarly, the desk/console unit was designed (maximum dimensions 5'-5") so that it could be placed in any orientation within the office space reflecting the need for change as determined by neutral buoyancy test.

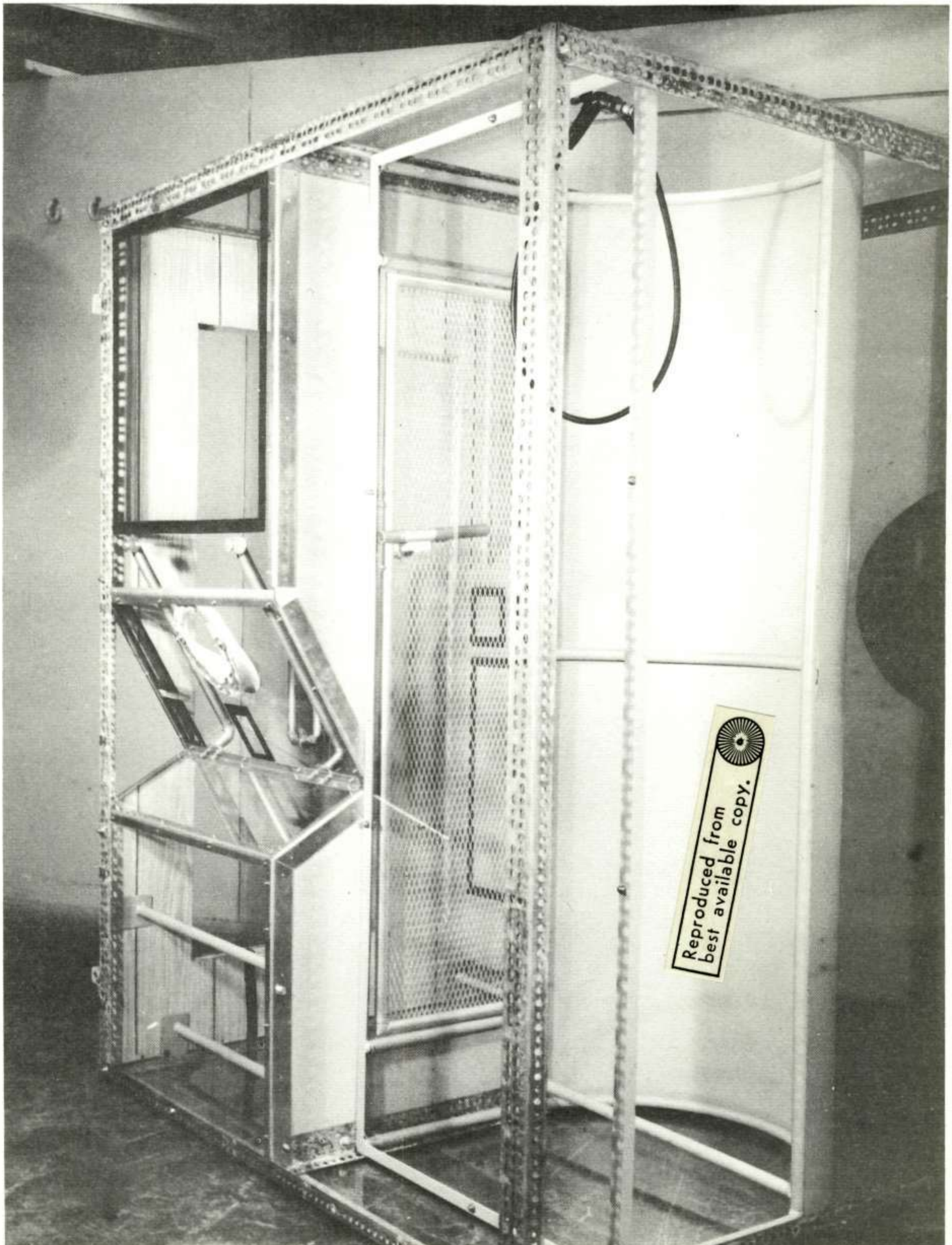
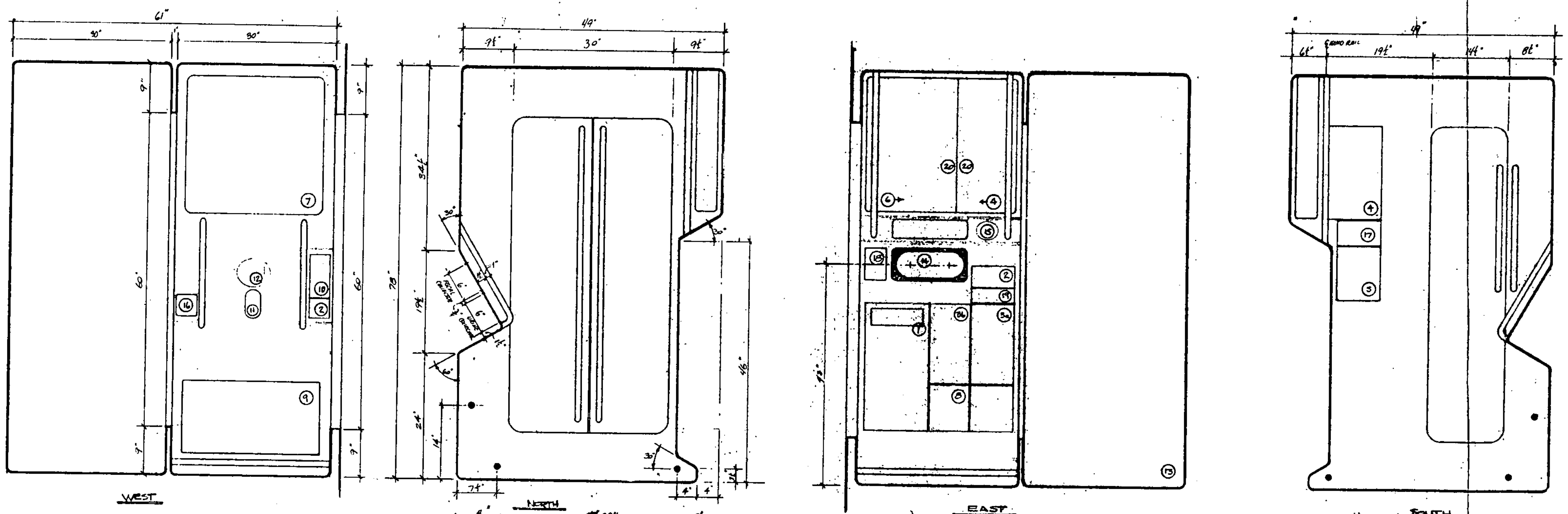
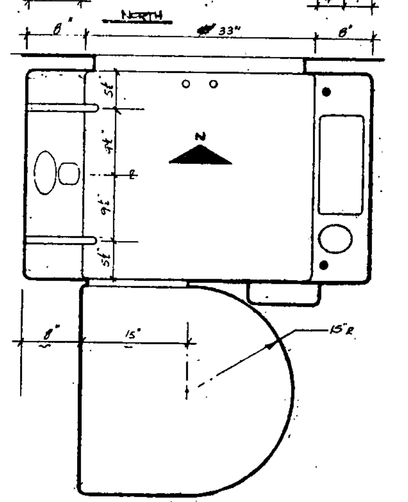


Figure III-6 Bathroom Concept

FOLDOUT FRAME 1

FOLDOUT FRAME 2





STORAGE
1 WASTE CONTAINER
2 WIPES DISPENSER
3 TOWEL (A) / WASH CLOTH (B) DISPENSER
4 TOWEL STORAGE (TEMPORARY)
5 WASH CLOTH STORAGE (TEMPORARY)
6 PERSONAL HYGIENE EQUIPMENT (SHAVER, TOOTHBRUSH, ETC.)
7 TEMPORARY CLOTHING STORAGE
8 CLEANING AGENT
9 HOUSEKEEPING EQUIPMENT (VACUUM CLEANER, BAGS)
10 VOMIT BAG DISPENSER

OPERATIONAL UNITS
11 URINE COLLECTOR
12 FECAL COLLECTOR
13 SHOWER
14 HANDWASHER UNIT
15 ORAL HYGIENE UNIT

CONTROLS
16 URINE / FECAL COLLECTOR CONTROLS
17 INTERCOMM CONTROLS
18 ENVIRONMENTAL CONTROLS

MISCELLANEOUS
19 EMERGENCY OXYGEN
20 MIRROR
21 RESTRAINTS

DESIGN · PLANNING · RESEARCH

Raymond Loewy / William Snaith, inc.
110 EAST 59th STREET · NEW YORK, NEW YORK 10022

TITLE: ZERO-G HEAD

Figure III-7 Bathroom Design Layout

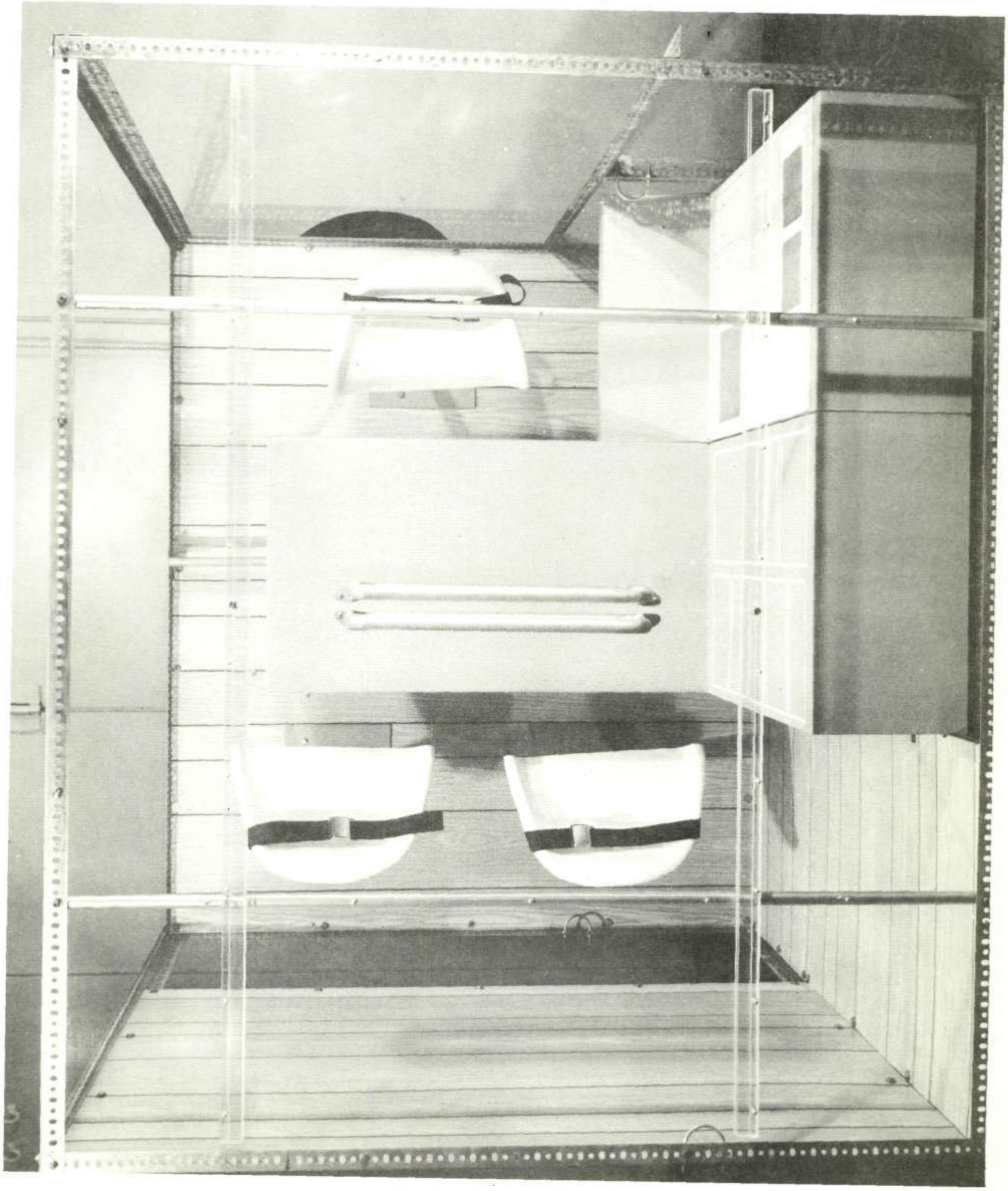


Figure III-8 Office Concept

The three rooms, Commander's Stateroom Complex, were assembled as illustrated by Figure III-9 for the majority of the test. A configuration with the bathroom over the stateroom was also tested to determine additional traffic patterns and acceptability of this concept.

C. WARDROOM/GALLEY DESIGN CONCEPT

1. Wardroom Design

The wardroom design concept selected for neutral buoyancy testing has been designed to serve as a dining room, lounge, recreation room, library, study and chapel.

The concept reflects the belief that the design character of the area should reflect the needs of the primary use. Specifically, the attempt has been to create a simple, uncluttered environment for dining and lounging by visually separating the galley from dining/lounge area and keeping storage units and environmental and audio visual control units to a minimum.

To avoid an erector set appearance, the directions and distances required to move such items as tables and "chairs" during area reconfiguration have been minimized. This also serves to reduce time and effort involved in reconfiguring the area, thus reducing the nuisance factor and simplifying implementation of automation if desired.

The concept that was selected to be tested is depicted by Figure III-10. This concept provides for a one-man galley attendant, easy access including visibility, to all seats without moving over the other diners, access to the tray pick-up point from several directions, staging area for personnel prior to food tray pick-up, dual purpose table-flat for conferences and beveled edges to accept food trays, table can be stowed in ceiling divider to provide multiple usage of the room, lounge area for 2 to 4 men, and swivel and adjustable seat restraint devices. The detailed design layout is included in addition to the perspective view and is identified as Figure III-11. The wardroom as tested has a gross volume of 444 cu. ft. The net volume, excluding eight chairs, a dining/conference table, and a recreation table and storage modules, is approximately 312 cu. ft.

2. Wardroom Design Considerations

a. Spacial Economy - To realize maximum spacial economy in the dining/lounge area, advantageous use has been made of the

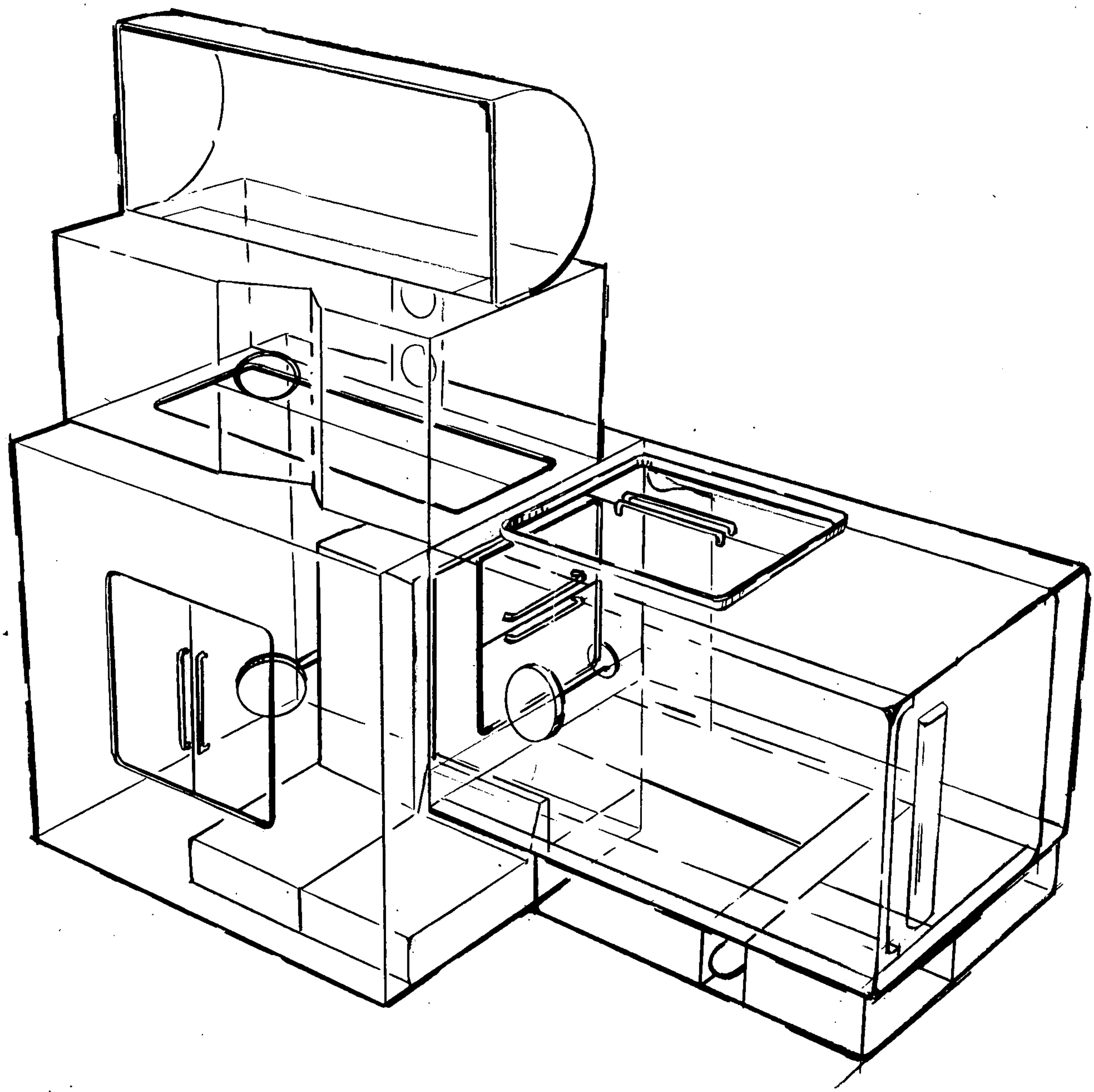


Figure III-9 Commander's Stateroom Complex

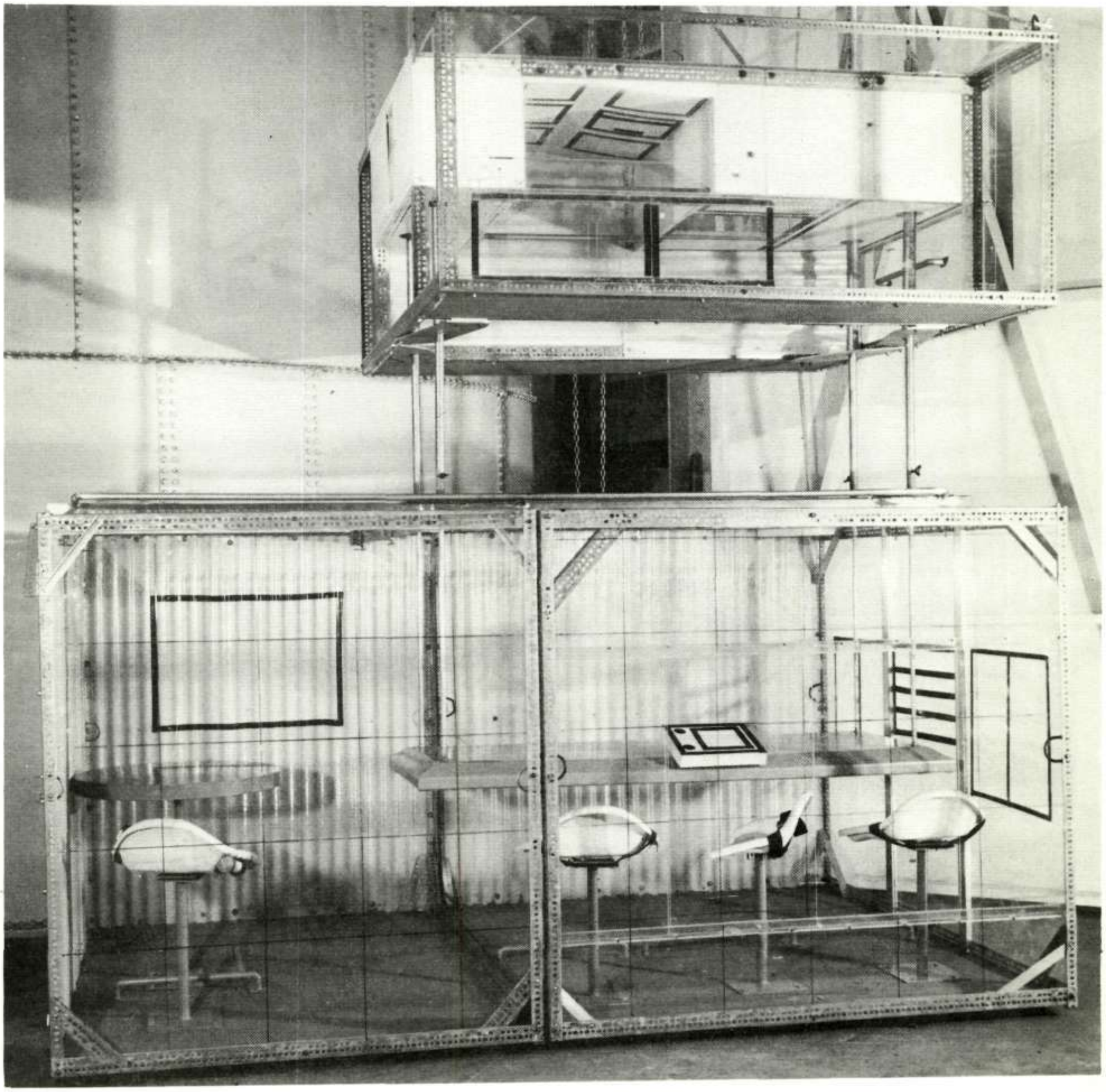
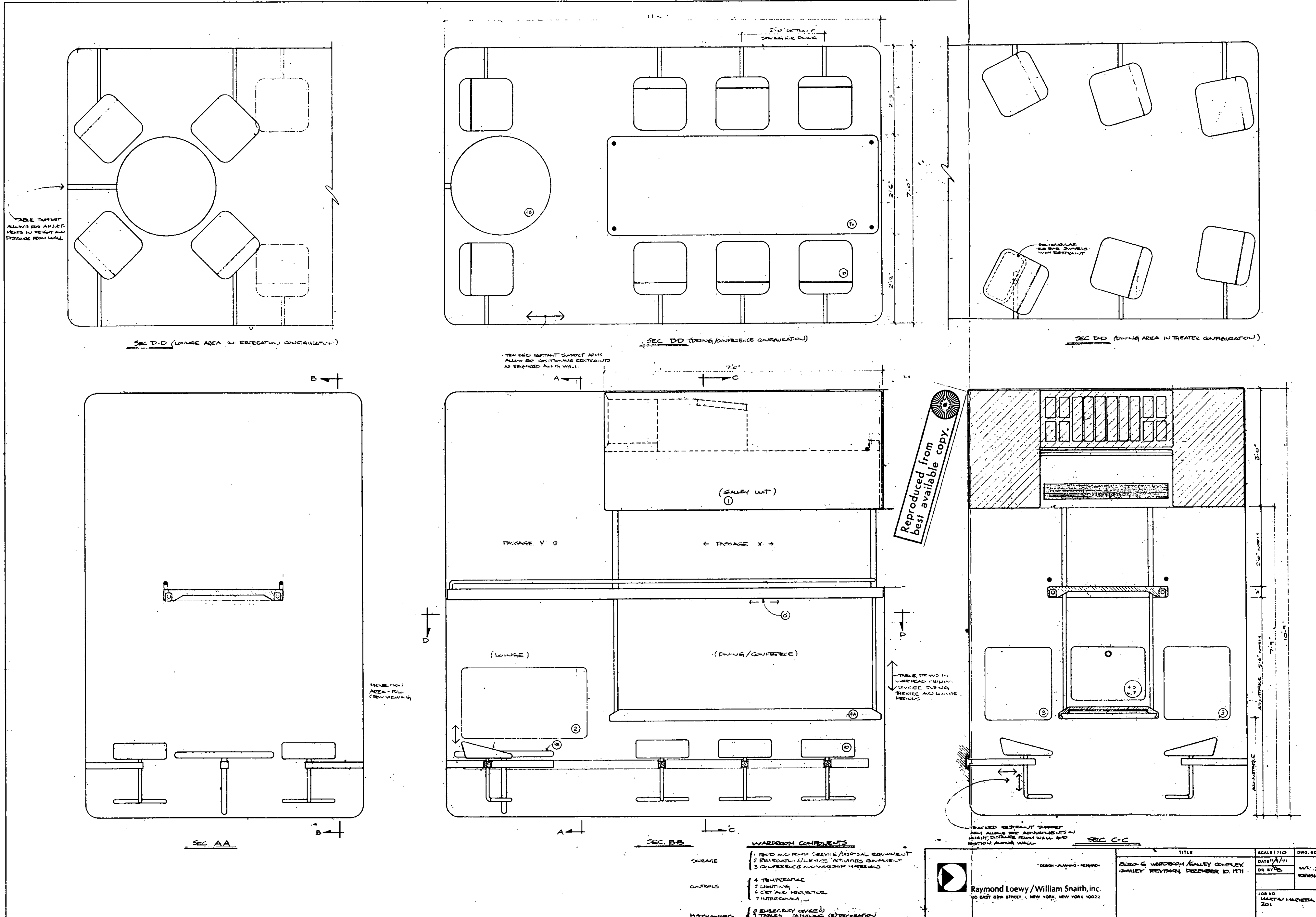


Figure III-10 Galley/Wardroom Concept



TITLE	SCALE 1/10	DWG. NO.
ZERO-G WARDROOM/GALLEY COMPLEX GALLEY REVISION, DECEMBER 10, 1971	DATE 11/4/71	WR-2R REVISION
	DR. BY	
	JOB NO. MARTIN MARIETTA 201	

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DESIGN · PLANNING · RESEARCH
10 EAST 38th STREET · NEW YORK, NEW YORK 10022

Figure III-11 Galley/Wardroom Design Layout zero-gravity environment by directing traffic to the dining area from above, thus eliminating the need for "horizontal" aisles.

This has been accomplished in such a manner that the premise of "no flying over a table" is not violated, and so that a person descending into a restraint position may maintain contact with a mobility aid at all times for precise movement control.

The "floor area" of the dining and lounge areas combined is 77 square feet or 13 square feet per man. A one-g design based on the same seating arrangement would have required a minimum of 32 square feet more space to accommodate minimum sized aisles on both sides of the dining table.

Since no "standing" activities are planned for the area, the ceiling height has been set at 5'-6", or about one foot above eye level for the average seated male. This height is 12"-18" lower than existing guidelines, however, this should be acceptable since the ceiling panel appears to float 2 feet away from both side walls and should therefore allow for considerable spacial bleed-up and around the ceiling panel.

b. Activity/Equipment Relationship - Prior to commencing layout studies, a table was prepared to illustrate the relationship of activities to equipment in the wardroom galley area. Using this chart as a guide, equipment and storage area groupings and locations were established which would allow easy access to these items from related activity positions of restraint. Based on this analysis, the following three basic equipment/storage locations have been created: 1) food preparation, 2) audio/video control and conference/religious storage, and 3) recreational/lounging storage. All units in each area are accessible from a single point of restraint.

c. Anthropometric Considerations (Point Movement) - Once the activity grouping and rough locations were established, the final locations were determined based on the reach characteristics of man from the activity related restraint positions.

d. Spacial Requirements for Transfer Movement - The three major types of transfer movement relating to the wardroom galley complex are: 1) ingress to wardroom area (with or without tray), 2) transfer from dining to lounge area within the wardroom, and 3) egress from wardroom (with or without tray). As shown in the illustration of the complex in the dining mode, a person descending into or ascending out of the area would control his movements by means of a hand rail located above the sides of the ceiling partition and running the entire length of the wardroom.

The height of the hand rail is such that a woman of average height would have no trouble reaching it from a restrained position prior to ascending out of the area.

Transfer movement from the dining area to the lounge area would normally be made only during non-meal hours in which case the dining/conference table would be stowed in the recessed area in the ceiling panel, creating a completely open room. Transfer movement would then simply be a matter of push off (from seat or foot restraint) and point-to-point transfer. As in the ingress/egress transfer, finite movement control could be accomplished by utilizing the overhead hand rail.

e. Equipment Spacial Requirements - The two pieces of equipment which had a major impact on the size of the wardroom were the tables. The dining table and recreation table sizes were based on existing guidelines, that is 30" x 84" for the six-man table (28" width per man) and a 30" diameter four-man table for recreation.

f. Level of Accommodations - The wardroom was designed to accommodate six people involved in one or more activities at one time. To allow for and to facilitate ease of area modifications required to accommodate the various activities, all restraints are mounted to horizontal tracks running the entire length of the room. The mounting bracket arm, running from the track to the centered restraint vertical support, would allow the user to swivel, adjust the restraint height and adjust the distance from the wall. All of these adjustments would be accomplished by an individual in a restrained position who, after releasing the locking mechanism, would essentially "walk" to the position desired. It is important to note that all area modifications can be accomplished from restrained positions.

A description of the various wardroom activities considered in the concept development effort follows:

Dining/Conference - To support this activity, the dining table would be lowered to the desired height (30"-35"). In this mode movies could be shown (i.e., during conference), however, the support posts would cause some visual interference.

Two-Table Recreation - Both tables may be used simultaneously with two people at the recreation table and four at the dining/conference table.

Film/TV Projection (Entire Crew) - For unobstructed viewing of projected films or TV, the dining conference table would be raised into the ceiling panel creating a completely open room. Next, the six dining restraints would be repositioned with the distance between restraints being increased from 24" to 32" or more, the rear most restraints (relative to projection screen) moved toward the center of the room and the forward most restraints moved as close to the side walls as comfortable.

Film/TV Projection and Recreation - For this mixed mode, the four rear restraints (relative to projection screen) would be positioned similarly to those described in the paragraph above, while the forward two dining restraints would be moved forward to the recreation table. Finally, a midroom projection screen/space divider would be unfolded from the underside of the dining table. In this mode, 2 or 4 people could relax playing cards while the other two crew members watched a movie or vice versa. In this mode the people viewing the movie would most likely use headsets for audio pick-up to reduce interactivity friction.

g. Safety - One of the major concerns reparding safety in a public area is the ability of people therein to exit quickly in the event of an emergency. This ability is maximized in this concept by the fact that all individuals can exit immediately from the area simultaneously by simply ascending over the ceiling panel.

Ten emergency oxygen units (4 over the recreation table and six over the dining/conference table) are located in the periphery of the ceiling panel.

With the exception of mobility aid devices, the majority of elements within the area are represented as flush (wall) mounted and edges of items which protrude into the space are illustrated as rounded.

h. Visual Space - Although the ceiling panel is quite low relative to existing guidelines (5'-6" versus 6'-6" to 7'-0"), the space bleed around both sides of the panel should prevent any feeling of claustrophobia. The low position of the ceiling panel is intended as a means of inhibiting inhabitants from looking up into the passage and galley areas.

i. Space-to-Space Orientation - The wardroom is designed so as to allow an individual to select his restraint and orient himself accordingly prior to entering the area. This is accomplished through the use of a ceiling system which would allow the individual entering the area to view the entire room prior to entering to enable him to make a decision as to where to sit or who to sit next to, etc. This could be accomplished in various ways, such as a one-way mirror or egg crate system of louvers. Entering the wardroom from the galley restraint position would simply entail executing a 180° longitudinal roll, looking into the area to select a restraint and orienting oneself for entry into that restraint position. Upon leaving the wardroom area, an individual would be able to assume any orientation aided by the hand rail running the entire length of the ceiling panel.

j. Appearance - The appearance of the wardroom has been kept as simple and visually clean as possible by consolidating related articles and equipment into common storage or console units. For example, all audio visual, special effects lighting, etc., have been located together and hidden from view by a cover panel. Details of the use of color, texture, trim, etc., are beyond the scope of this contract; however, let it suffice to say that this area should be detailed to provide visual relief from what may be a rather mechanical interior throughout the working areas of the station.

3. Galley Design Concept

The galley design is based on the premise that all food preparation and cleanup activities are performed by one man. The galley contains storage space for food, trays, utensils and housekeeping equipment; in addition, refrigerator and oven space, a work counter, and a complete water storage system is provided. Because of these hardware requirements and the need to store 84 man-days of food and water in the galley, the area is devoted largely to storage space. The galley gross volume is approximately 120 cu. ft. and the net volume is approximately 35 cu. ft., meaning that 85 cu. ft. are occupied by storage space, hardware, etc. The volume available for the galley attendant to perform his duties is entirely adequate and all storage and work areas are readily accessible.

a. Spacial Economy - Because of the relatively large volumes required for food and equipment storage, spacial economy is realized principally by making the galley a one-man area. At no time is more than one man in the galley area; prepared food trays are placed at a retrieval point accessible from the outside of the galley where crewmen pick up their individual meals. The galley attendant has all the necessary equipment and material within his reach.

b. Anthropometric Considerations - The net volume of the galley (35 cu. ft.) and the individual dimensions are sufficient for the attendant to perform all functions, movements, ingress and egress from the galley. Using the toe bar restraint and handholds provided, all storage spaces and equipment can be reached from the normal position.

c. Spacial Requirements for Transfer Movements - Ingress into and egress from the galley area are the only major transfer movements relating to the galley. All functions in the galley can be performed from one position. Movement to and from the galley can be accomplished from a number of different positions; hand rails located on each side of the galley along the entire length of the wardroom/galley partition can be utilized as mobility aids.

d. Equipment Spacial Requirements - The requirement that a 84 man-day supply of food and water plus related equipment be stored in the galley is the major factor in determining gross galley volume. A total of 85 cu. ft. is required for food storage, refrigerator, freezer, oven, tray and utensil storage, housekeeping equipment, and water system.

e. Level of Accommodations - The galley was designed to accommodate only one person who performs all the food preparation and cleanup functions from one position. Since the tasks to be performed are very specific and limited, the galley design, including restraint requirements and equipment placement, is vastly simplified. Food items can be taken from the oven, refrigerator or storage lockers as required and placed in the tray restrained on the work counter. Water and other beverages can be added as required and, as each meal is completed, the filled tray is placed in the retrieval area above the attendant's head where it is picked up by the individual crewman. The attendant can prepare his own tray, move to the wardroom dining area and return to the galley when he completes his meal. When each crewman completes his meal, he places the tray back in the appropriate slot in the tray pickup area. The galley attendant takes each tray, discards empty food containers, food waste, etc. and uses the housekeeping equipment to clean the tray, work counter and other items as necessary. All trays and equipment are then placed in their storage locations and the galley is configured for the next meal period.

f. Safety - In the event of an emergency, the galley attendant can safely and quickly exit the area in any of three different directions. The attendant can easily see any people exiting from the wardroom and plan his own exit accordingly.

The attendant can quickly reach one of the six emergency oxygen units located in the wardroom ceiling panel if the emergency occurs while he is in the galley.

With the exception of mobility aid devices, the majority of the elements within the area are flush mounted and all edges are rounded.

g. Visual Space - The spacial economy built into the galley and its limited level of accommodations greatly reduces the visual space but the requirements in such a case are also very limited.

h. Space-to-Space Orientation - No changes in orientation occur within the galley area. All turning, bending and reaching functions are performed from one position. The most complex movement required is entering the wardroom from the galley restraint position, which requires only a 180° longitudinal roll and orienting for entry into the desired wardroom restraint position.

i. Appearance - The galley is designed strictly as a work area, with functional and cleanliness requirements paramount. The unit should be arranged to provide a pleasant environment in which to prepare food.

C.2

IV. NEUTRAL BUOYANCY TESTING AND EVALUATION

A. GFP CHAIRS/RESTRAINTS

During this phase of the program, the two GFP chairs were tested in the neutral buoyancy facility to determine their merits and deficiencies. For identification purposes, the GFP supports were designated Chair A for the support defined by NASA drawing SAY 44100043 and Chair B for NASA drawing SEC 39-103430. A test plan was prepared to determine the form, fit, and functional capabilities of the chairs for a zero-g environment. This included determining the optimum height, seat-to-back support relationship, optimum chair position for relaxation, optimum distance from and orientation to a writing surface, optimum distance and orientation to a control panel, restraint devices assessment, and mobility aids incorporated in the design. Two test subjects of different size were used for each sequence or task to obtain more factual data. One test subject was 6 feet 2-1/2 inches tall and weighed 194 pounds, the other test subject was 5 feet 6 inches tall and weighed 155 pounds. Other dimensions recorded for the test subjects in a normal seated position were: lower back to the inside (calf) of leg and to the outside (front of knee), floor to underside of upper leg (thigh) and to top of upper leg (thigh), seat width, and reach.

One factor which adversely affected the capabilities of Chair A was the looseness of the support shaft. This is borne out in the movie film and the test subject's comments relating to the instability of the chair. It was clearly evident that the chair must serve as a mobility aid and/or restraint for entering or exiting the chair and on the approach or leaving the chair area.

In evaluating the two items, Chair B satisfied more requirements than Chair A for form, fit, and function. However, it was determined that foot restraints will determine chair height depending on where they are located. The use of the chair for a mobility aid is essential, but other aids must be provided to give the astronauts the control needed to maneuver to the chair with accuracy and safety. Also to accommodate various size astronauts, very little if any adjustments are needed for performance of tasks.

B. PRELIMINARY NEUTRAL BUOYANCY TESTING

The preliminary neutral buoyancy tests were performed to obtain data that could be applied directly to the design of architectural concepts and furniture items. The dimensions, volumes, and shapes obtained during these tests provided a base for the design of the stateroom and galley/wardroom to accommodate the functions and requirements for an extended zero-g shirtsleeve environment. The tests consisted of testing restraint devices, mobility aids, volume vs tasks, traffic/locomotion patterns, zero-g man model definition, efficiency of volume, and explore orientation. Table IV-1 is a summary of the preliminary neutral buoyancy testing evaluation. The data has been further analyzed and minimum standard dimensions presented in the A/E Handbook supplement to aid designers for spacecraft habitability. Figures IV-1 through IV-19 depict various task elements tested during this phase.

C. PROTOTYPE CHAIR/TABLE TEST AND EVALUATION

The prototype chair and table developed during this contract was tested per the test plan prepared by MMC and approved by NASA-MSC. These tests were to verify the design of the chair and table for use in an extended zero-gravity shirtsleeve environment. The specific items determined were: 1) optimum chair and table height/angle; 2) optimum distance from and orientation to a writing surface; 3) lap belt restraint assessment; 4) relative ease of operation; and 5) mobility aids incorporated into the furniture design.

The results from the neutral buoyancy testing of the chair/table indicated that the general design met all the requirements for a restraint and a writing surface for a zero-g environment. The basic evaluation is presented in Table IV-2 with a more detailed evaluation presented in the sequence of Figures IV-20 through IV-27. In Figures IV-20 through IV-22, the lip of the chair is being used as a restraint device (handhold) to maneuver the body to a sitting position. Figure IV-23 shows the chair seat being used as a mobility aid to direct his translation with the hand and as a push-off point with the feet. Figure IV-24 illustrates the use of the foot restraint D-ring as a mobility aid to push off in a different attitude. Figure IV-25 depicts the subject using the height adjustment mechanism to obtain a comfortable position. The height adjustment is necessary to accommodate the various sized individuals with the least amount of stress. Figure IV-26 illustrates the subject using his foot

Table IV-1 Preliminary Neutral Buoyancy Test Evaluation

Test I Restraint Devices

Task Element		Description	Comments
I-1	Sitting	With lap belt restraint, assumes a relaxed position, then simulates work tasks.	Very good for work tasks & relaxing, however feet would float up if allowed to do so. As a waist restraint it restricted movement a considerable amount. (see Figure IV-1)
I-2	Sitting	With toe restraint, assumes a relaxed position, then simulates work tasks.	Was satisfactory for work tasks of short duration only. (see Figure IV-2)
I-3	Sitting	With foot restraints, assumes a relaxed position, then simulates	Was satisfactory for work tasks of short duration only. (see Figure IV-3)
I-4	Sitting	With thigh restraints, assumes a relaxed position, then simulates work tasks.	Very good for work tasks and relaxing, however like the belt, the lower legs would tend to float up. Adjustment is definitely required. (see Figure IV-4)
I-5	Sitting	With shoulder restraints, assumes a relaxed position, then simulates work tasks.	Restrained the upper torso very well but prevented movement outside the arm reach. (see Figure IV-5)
I-6	Sitting	With best combinations of restraints, assumes a relaxed position, then simulates work tasks.	Either lap belt or thigh and a toe or foot restraint was satisfactory. Therefore the lap belt and toe bar is recommended. (see Figure IV-6)
II-1	Standing	With foot restraints, reaches in all directions.	Satisfactory for most tasks, very flexible. (see Figure IV-7)
II-2	Standing	With foot restraints, removes and replaces objects from drawers or cabinets using both hands	Satisfactory for long-duration tasks that do not require large torque values. (see Figure IV-7)
II-3	Standing	With waist restraint, reaches in all directions.	Not satisfactory as a one point attachment. (see Figure IV-8)
II-4	Standing	With waist restraint, removes and replaces objects from cabinets and drawers using both hands.	Satisfactory only if a downward force is applied at two points, one each side. (see Figure IV-8)

Table IV-1 Preliminary Neutral Buoyancy Test Evaluation (continued)

Test I Restraint Devices (continued)

Task Element	Description	Comments
II-5 Standing	Using handhold or rail, reaches in all directions with free hand.	Very satisfactory within limits of the hand hold, approximately 5 foot radius from the hand hold. (see Figure IV-9)
II-6 Standing	Using handhold or rail, removes and replaces objects from drawers or cabinets with free hand.	Very good for one handed operations, some energy needed to stabilize body position. (see Figure IV-9)
II-7 Standing	With toe rail restraint, reaches in all directions.	Very satisfactory, gave good control in reaching even directly behind the test subject. Dimensions: 1" Dia. with 2" clearance between floor and rail. (see Figure IV-10)
II-8 Standing	With toe rail restraint, removes and replaces objects from drawers and cabinets.	Very good for many positions and doing tasks that require little torque. Toe rail should be designed for the area as part of consoles, cabinets, etc. (see Figure IV-10)
II-9 Standing	Using a combination of restraints, reaches in all directions.	Toe or foot restraint with occasional need for hand holds performed best.
II-10 Standing	Using a combination of restraints, removes and replaces objects from drawers or cabinets.	Toe or foot restraint with two point waist restraint provided maximum stability but limited movement. Toe or foot with hand holds provided good stability and maximum movement.
III-1 Sleeping	Enters sleep restraint and assumes sleeping positions.	Sleep restraint provided complete restraint of the entire body. (see Figure IV-11)
III-2 Sleeping	With sleep restraint unzipped, restrains himself with belts at waist, thighs, and chest and assumes sleep positions.	In the unzipped position the feet were still restrained and the belts would restrain the rest of the body as long as they were at the waist or chest. (see Figure IV-12)
IV-1 Stowage	Using various restraint aids, stows various objects.	Velcro strips, bungee cards, snaps in this order are recommended for stowing small objects.

Table IV-1 Preliminary Neutral Buoyancy Test Evaluation (continued)

Test II Volume vs Tasks

Task Element		Description	Comments
I-1	Clothing	Don-Doft clothing in various size rooms. Obtain optimum room size.	A small room provides restraint enough by wedging. No restraints needed for dofting and needed only occasionally for donning.
I-2	Clothing	Repeat of step 1 using restraint devices as required.	
I-3	Hygiene Tasks	Use the hygiene facilities by donning-dofting clothes, using waste management device, and personal grooming. Obtain optimum room size.	Hygiene facilities needed only enough room for clearance. Additional restraint hand holds required along side of seat and more positive restraint in defecation position. (see Figure IV-13)
I-4	Sleeping	Enter sleep area, undress, enter and exit sleep restraint. Obtain optimum room size.	Sleep area only requires enough volume to don-doft clothes and provide storage for clothes and other personal equipment.
I-5	Food	Prepare food trays and place at central pickup point. Obtain optimum free volume.	Space to store food and equipment such as trays and preparation equipment are the determining factors for the galley. Free volume is very minimal. (see Figure IV-14)
I-6	Exercise	Enter exercise area, prepare equipment, and perform exercises. Obtain required volume.	A small room, 120 ft^3, is sufficient for stretch and other similar exercising. Large free area, 325 ft^3, needed for soaring and bouncing exercise. (see Figure IV-15)
I-7	Maneuverability	Enter room in a soaring attitude then tumble 360 degrees forward.	Free area must be 4 feet by 4 feet and at least shoulder width wide.

Table IV-1 Preliminary Neutral Buoyancy Test Evaluation (continued)

Test III Traffic Locomotion Patterns

Task Element		Description	Comments
I-1	Single Passage	One test subject translating through passageways.	Passage size is dependent upon size of personnel, cross section of 24" x 30" is more than adequate. (see Figure IV-16)
I-1	Double Passage	Two test subjects translate through passageways at same time.	The 30" diameter was close but could be negotiated, 48" width was much better. (see Figure IV-17)
I-3	Hatch, Open	Test subject passes through open hatches, round and rectangular.	The 30" diameter hatch was adequate for all single passages, although a rectangle or square hatch would satisfy the requirement.
I-4	Hatch, Closed	Test subject simulates opening hatch, passes through, close hatch, and move away.	Hand holds required in vicinity of hatch for loads and maneuverability. (see Figure IV-18)
I-5	Stateroom	Test subject translates to various areas in the stateroom.	Since walls were always in reach with hand or foot no problems anticipated.
I-6	Wardroom	Test subject translates to various areas in the wardroom.	With all furnishings installed, no trouble should be encountered in moving about a large area.

Test IV Zero-G Man Model Definition

I-1	Activity Evaluation	Compare the task performed in one-g and the neutral buoyancy facility.	Major difference is in moving from one place to another and controlling that movement in zero-g. Hands are used extensively for positioning the body.

Test V Efficiency of Volume

I-1	Efficiency	From the test performed, determine the efficiency of the various devices and where equipment (chairs, cabinets, etc.) should be located.	In the restraint category, hand holds, toe or foot, and lap belt are essential. Room furnishings must be placed, within the volume available, to allow astronauts to use the equipment and maneuver as required.

Table IV-1 Preliminary Neutral Buoyancy Test Evaluation (concluded)

Test VI Explore Orientation

Task Element	Description	Comments
I-1 Orientation	Test subject enters a room facing a minimum of four different ways and then orients himself to the room configuration.	Test subject had no trouble in orienting himself with respect to the room. Either a roll or pitch maneuver was required to position himself in relation to the room.

Figure IV-1
Task Element I-1 Test I

Figure IV-2
Task Element I-2 Test I

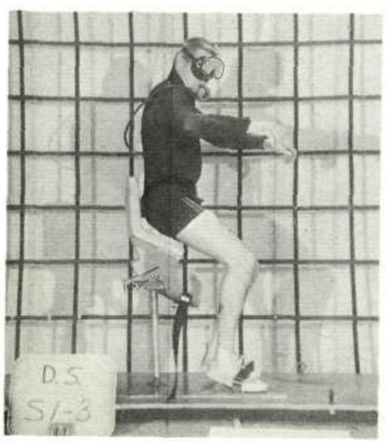


Figure IV-3
Task Element I-3 Test I

Figure IV-4
Task Element I-4 Test I

Figure IV-5
Task Element I-5 Test I

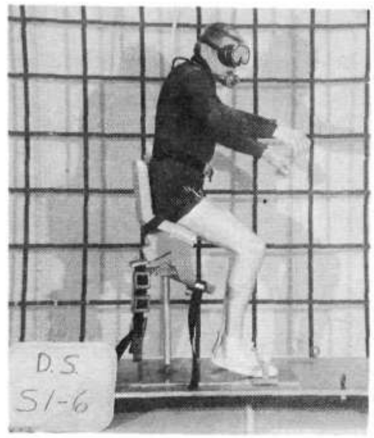


Figure IV-6
Task Element I-6 Test I

Figure IV-7
Task Elements II-1&2 Test I

Figure IV-8
Task Elements II-3&4 Test I

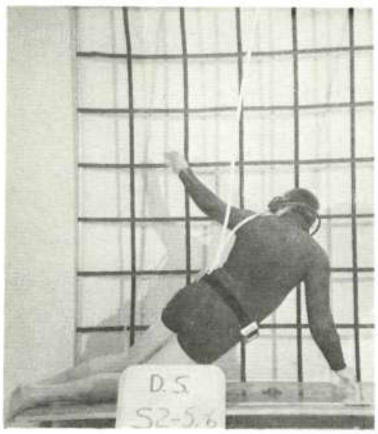


Figure IV-9
Task Elements II-5&6 Test I

Figure IV-10
Task Elements II-7&8 Test I

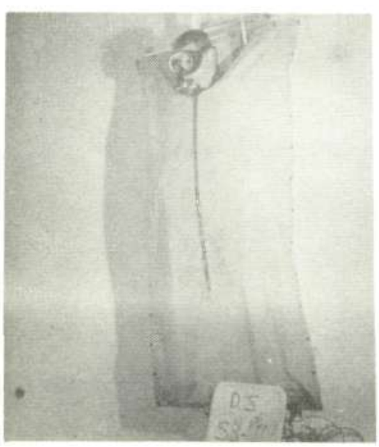


Figure IV-11
Task Element III-1 Test I

Figure IV-12
Task Element III-2 Test I

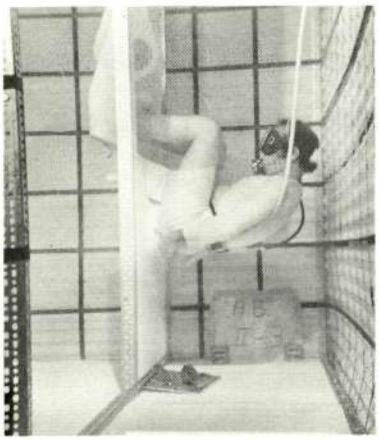


Figure IV-13
Task Element I-3 Test II

Figure IV-14
Task Element I-5 Test II

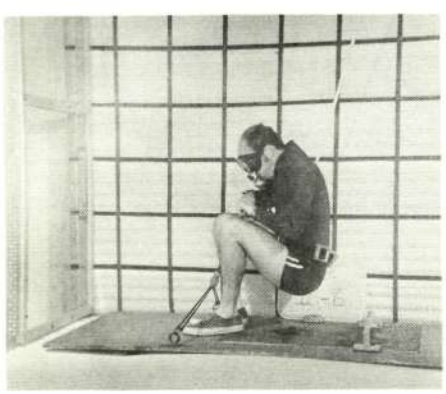


Figure IV-15
Task Element I-6 Test II

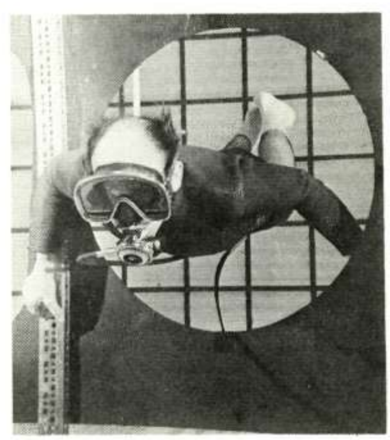


Figure IV-16
Task Element I-1 Test III
(single passage)

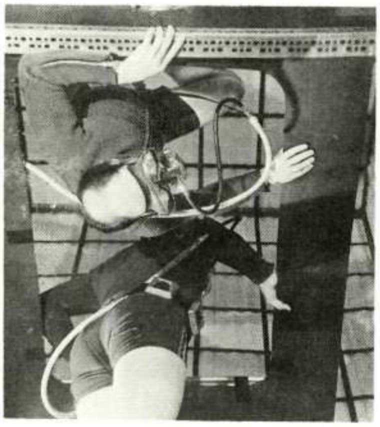


Figure IV-17
Task Element I-1 Test III
(double passage)

Figure IV-18
Task Element I-4 Test III

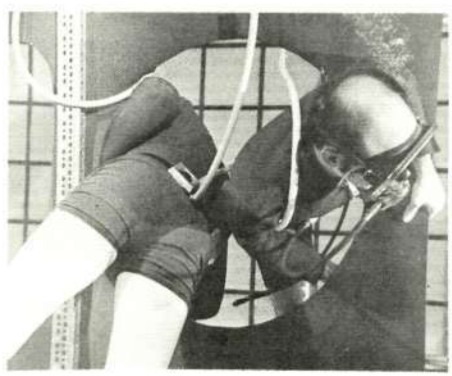


Figure IV-19
Task Element I-1 Test III
(double passage)

Table IV-2 Chair/Table Evaluation

Parameters	Requirements for Test Subjects: 5th Percentile R. Boyd, Test Subject	Requirements for Test Subjects: 95th Percentile J. Shea, Test Subject	Remarks
Accessibility	N/A	Minimum of 12 inches of clearance on 3 sides; side facing work area is always included.	Chair tested provided excellent accessibility from either side or rear.
Chair Height	21 inches	23 inches	Chair height is dependent on position of foot restraint & work surface height. Chair tested satisfied requirement.
Table Interface	20 inches	17.8 inches	Test indicated personnel preference. Not a critical dimension as long as accessible.
Restraints			
Torso	Retractable Lap Belt	Retractable Lap Belt	Provided excellent restraint and easy to operate.
Feet - D-Ring on Chair - Bar under Table	Required Desirable	Required Desirable	Both provided adequate foot restraint. D-ring could be lowered to 4" from floor.
Mobility Aids			
Chair	Seat Lip	Seat Lip	Provided a good hand hold for positioning body.
	D-Ring on Chair	D-Ring on Chair	Provided a good push-off point when leaving area.
Table	1" Lip on Table Top	1" Lip on Table Top	Provided a good hand hold to assist entering chair and good push-off point.

Table IV-2 Chair/Table Evaluation (continued)

Parameters	Requirements for Test Subjects		Remarks
	5th Percentile R. Boyd, Test Subject	95th Percentile J. Shea, Test Subject	
Chair Operation			
Vertical Adjustment	Required	Required	Adjustment lever needs redesign to place lever closer to chair lip.
Swivel Adjustment	Required Not definite enough, too easy to turn.	Required Need more indication of locked position.	Spring loaded ball worked well but needs smaller holes and stronger spring.
Table Height	41 inches to center of table	43 inches to center of table	Table height could vary 1 or 2 inches without any noticeable difference.
Table Top Angle	24° Did not feel angle was important, but accustomed to a writing surface perpendicular to body.	26° Could have varied $\pm 10^{\circ}$ with same result.	Table top could be from horizontal to vertical, however space utilization will dictate space be allowed for the lower torso and legs which will determine table position.
Table Lateral Adjustment	Desirable	Desirable	Provided the capability to change positions and accommodate different personnel. Mechanism was easy to operate and good visibility even with mask on.

Figure IV-20
Subject Entering Chair Restraint

Figure IV-21
Subject Utilizing Chair/Table Hand Restraints

Figure IV-22
Subject Utilizing "D" Ring Foot Restraint for Entering

Figure IV-23
Subject Utilizing Chair Lip for a Mobility Aid in Soaring

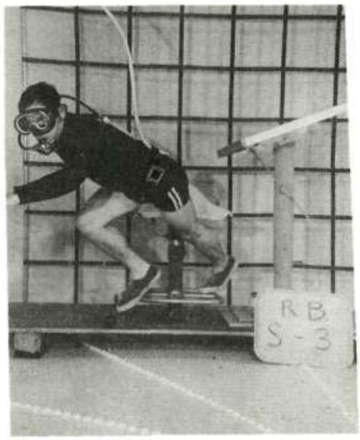


Figure IV-24
Subject Utilizing "D" Ring
for Mobility Aid in Soaring

Figure IV-25
Subject Adjusting Chair Upward

Figure IV-26
Subject Adjusting Horizontal
Sliding Mechanism on Table

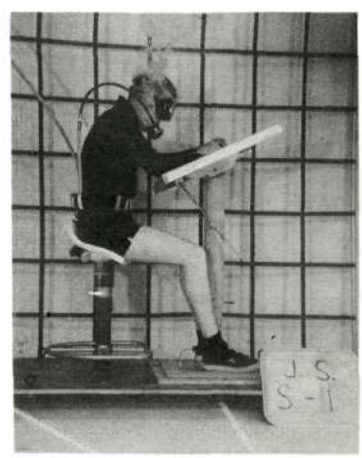


Figure IV-27
Subject Sitting at Table
Utilizing Table Foot Restraint

to release the lock on the lateral adjustment of the table. As indicated by the neutral buoyancy test, this feature is desirable and either the chair restraint or the table should have lateral adjustment to provide flexibility and as a change for personal preference. Figure IV-27 depicts a 95 percentile subject using the equipment and using the bar on the table support as a foot restraint. The deliverable item will be streamlined with some redesign of the support, belt restraint, swivel mechanism, and D-ring foot restraint.

D. STATEROOM COMPLEX TESTING AND EVALUATION

The neutral buoyancy testing of the Commander's Stateroom Complex as depicted by Figure IV-28, consists of a stateroom, bathroom, and office, was performed per the test plan prepared by MMC and approved by NASA-MSC. The dimensions, volumes, and shapes tested verified the design of a stateroom complex to accommodate the functions and task requirements for an extended mission of zero gravity in a shirtsleeve environment.

The test subjects' comments verified the design, in that, they felt there was adequate room to perform the normal habitability tasks and yet not feel restricted. Some design features that were particularly appealing were the size and operation of the hatches, hand holds to operate the hatch doors, restraint devices consisting of handholds and foot bars in the bathroom, restraint provided by the table and chairs in the office and stateroom, and the mobility aids incorporated into the table, chairs, desk, and door handles in addition to all other surfaces in the rooms. A more detailed evaluation of the stateroom complex is provided in Table IV-3 through IV-5.

E. GALLEY/WARDROOM TEST AND EVALUATION

The neutral buoyancy testing of the Galley/Wardroom was performed per the test plan prepared by MMC and approved by NASA-MSC. The dimensions and volumes verified a galley/wardroom complex which would accommodate the functions and task requirements of a zero-gravity shirtsleeve environment. The tested configuration is shown in Figure IV-49.

The test results indicated the overall design was adequate to perform the tasks outlined in the test plan. However, there were two areas that proved to be more of a nuisance factor and others were deficiencies in the design of the mock-up and the associated equipment. In the niusance factor category, the

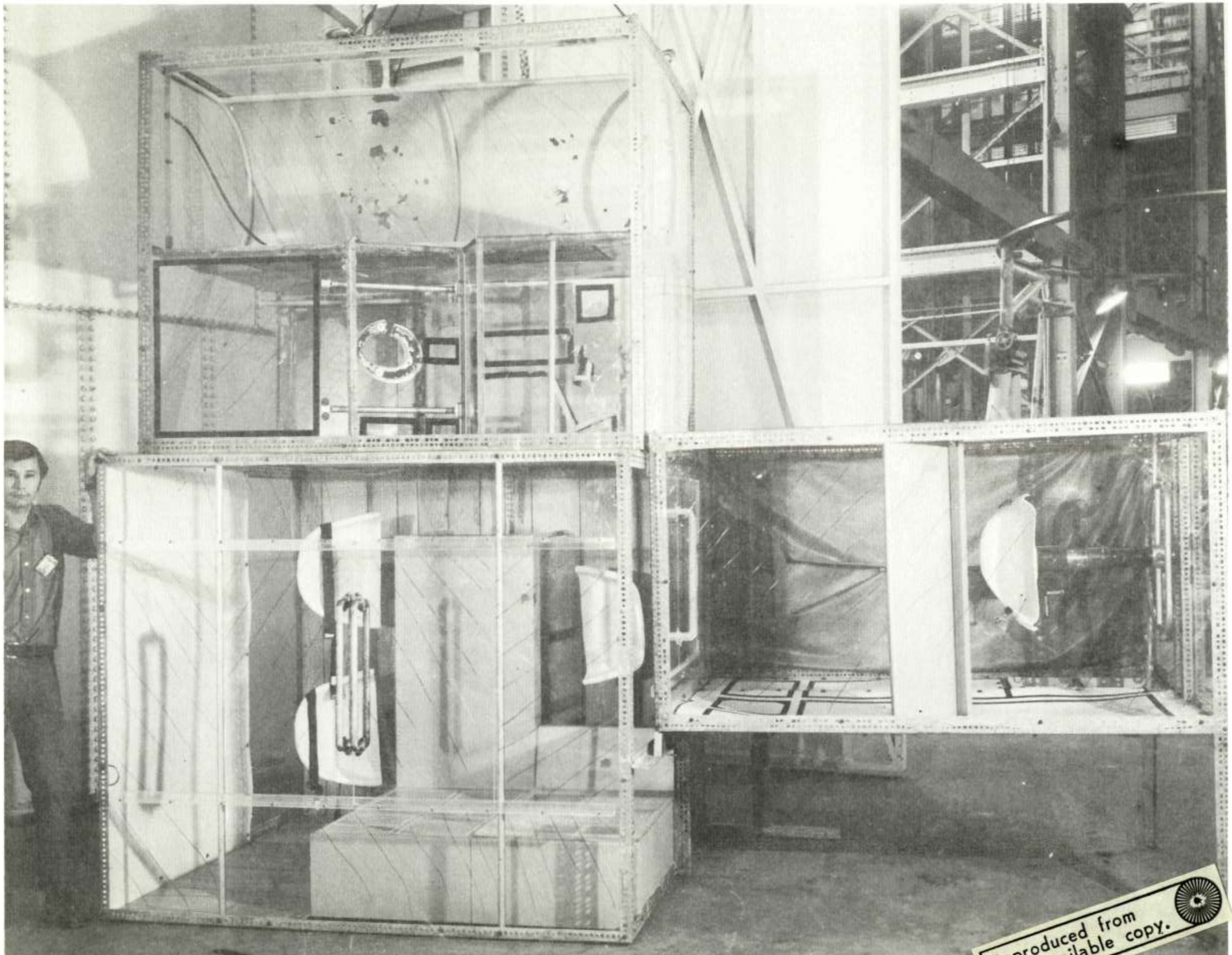


Figure IV-28 Commander's Stateroom Complex

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-3 Evaluation of the Stateroom Components

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Access Doors	• The 30"x32" sliding doors from the Stateroom to the Office provided ample room to enter either head first or feet first. It also provides additional visual space. See Figures IV-29 and IV-30. • These dimensions will also accommodate a 95 percentile suited man 29.4 in x 17.4 in. • The 42"x44" sliding doors from the stateroom to the passageway provided ample room to enter either head first or feet first. See Figure IV-31. • Provides additional visual space.		• There should be no more than two doors to any particular room and they should be located in conjunction with an adjoining room or a passageway. • The open and closed position are achieved by friction forces.	Sliding or tambour doors use a minimum envelope size. They open flush with the wall and do not swing out into the room volume.	• Long handles 18 inches in length and 2 inches from the door surface provided the required mobility/restraint aids for the room and ease of operation of the doors. • Sliding or tambour doors are best in space utilization and operational room required. • These doors also provide additional visual volume when the occupant is seated or in the sleep restraint.
Sleep Restraint	• The 3"x36"x78" sleep restraint provided an adequate volume for the crewman to rest and relax. • The crewman was free to assume any desired sleeping position. See Figure IV-32.	• An optional chest restraint is recommended to give a greater temperature range of comfort and flexibility to the restraint. • A pillow and materials conducive to sleeping, soft, smooth, etc., are also recommended.	• The means of converting the sleep restraint from the stowed position to the actual fastening of the restraint to the wall is done with simple zipper or snaps. • The zipper which was used to contain the sleeping crewman must have the capability to be employed from both the inside and the outside.	Sleep restraint should accommodate all men from 5 to 95 percentile man. These heights are 63.75 in. and 72.5 in. respectively.	• An adequate access envelope was provided for ease of entry by the crewman. The envelope was 24"x36"x78" in front of the sleep restraint.
Room Volume	• Designed to accommodate only its inhabitant. • A 36"x60"x78", 98 ft^3 volume is recommended to facilitate changing clothes and all other tasks associated with the room. See Figure IV-33. • There is ample room for maneuvering to any part of the room. A volume of 24"x48"x 48" is required to execute a roll-type maneuver.	• Socializing or conferring could not be held in this room. • A volume of 42"x60"x78", 114 ft^3 was tested and found to be larger than necessary for one man. • Two hatches utilize prime usable wall space.		• One room complex to serve multi functions: 1. Sleep 2. Personal Entertainment 3. Administration & Study 4. Limited Grooming & Dressing This room would not therefore be used for entertaining or socializing of any sort but for functional acceptability.	• Absence of gravity allows more utilization of wall surface for storage & equipment placement. Creation of two different "heads-up" orientations within the room. • Activity/Equipment relationship were considered and the equipment was positioned within access to the associated activity, i.e., items to which access was required from both "heads-up" and "heads-down" orientation were located in the center of the room. • Majority of elements within the stateroom volume were represented flush. This allowed no sharp edges to protrude. • Emergency Oxygen was located in a place from both major restraint positions, sitting and sleeping. • The main entrance to the room was placed in the side wall at the study/sleeping end of the room to relieve the possible claustrophobic effects of working or relaxing for extended periods. Door made as wide as possible, 44"x42" • The interior of the stateroom was kept as simple and visually clean as possible by consolidating related articles into major storage compartments.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-3 Evaluation of the Stateroom Components (continued)

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Chair	• Provided a restraint which allowed free movement of hands and eyes on horizontal or vertical surface; unrestricted head and upper torso movement. See Figure IV-34. • The actual seat allowed chair seat swivel, vertical height adjustment while seated, movable foot restraint ring and mobility/restraint aids. See Figure IV-35. • No undue stress was placed on any muscle of the body due to lap restraint. See Figure IV-36. • Maximum usage of the available volume. • Straight section of D-ring foot restraint provided a foot restraint parallel to the task station.	• Fixed chair restricts the room volume utilization and access area. • Swivel capability required too small a force (12 lb) to activate. A 30-pound force is adequate.	The main support of the chair seat was located 12 inches from the table edge and the height was adjusted to the crewman's desire.	• Provide stability of controlling the body and maintaining body position while performing tasks in a specific space. • Provide stability without undue stress on any muscle of the body. • Maximum usage of the available volume.	• The combination of the seat slope, the position of the feet restraint, and the anthropometric dimensions determine the seat height. • Previous tests indicate that the seat height could vary from 20.5 inches to 23 inches. • Operating lever for seat adjustment is accessible for two finger operation with the right hand resting on the chair seat lip. • Swivel capability provided far better volume utilization. • Recommend swing away from wall for better volume utilization. • D-ring restraint provided an adequate restraint parallel to the task station. It also provided a push-off point with the feet when leaving the area. • For maximum comfort, the seat dimensions are 18" wide x 10" deep, and a graduated slope starting at 8° at the back and going to 20° slope 4" from the front of the seat, with a back height of 5 inches.
Desk	• Angle of desk provided by foldaway capabilities. • The recommended desk size is 18"x32" with an angle of $25^\circ \pm 5^\circ$ from the horizontal.	The fixed desk that was tested was 18"x42" and therefore did not provide access to storage areas on the sides and behind the desk in the stowed configuration.	The desk edge was located 12 inches from the main support of the chair seat.	Provide a fixed yet adjustable surface to perform writing tasks.	• The table had a 1" lip around the edge to be used as a hand mobility/restraint aid. • A 3/4" bar, 18" long and 8" off the floor provided a foot mobility/restraint aid. • The tests proved that for proper volume utilization, the desk should swivel up to make lower storage areas accessible. • To provide a comfortable working area, the tests suggested that the vertical height should be 42" with a horizontal movement of $\pm$ 3" sliding base with adjustments operated by a foot locking lever.

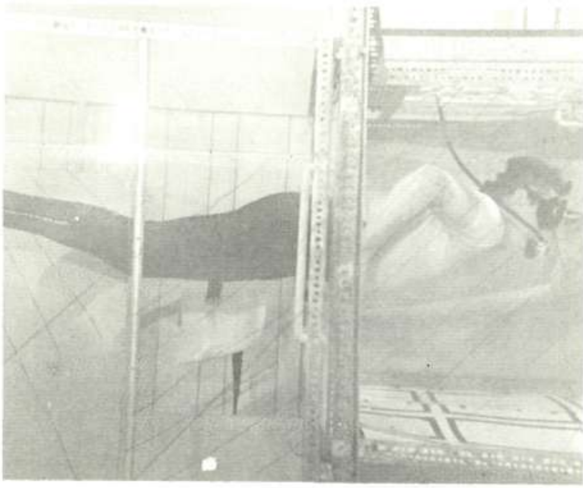


Figure IV-29 Entering Head First

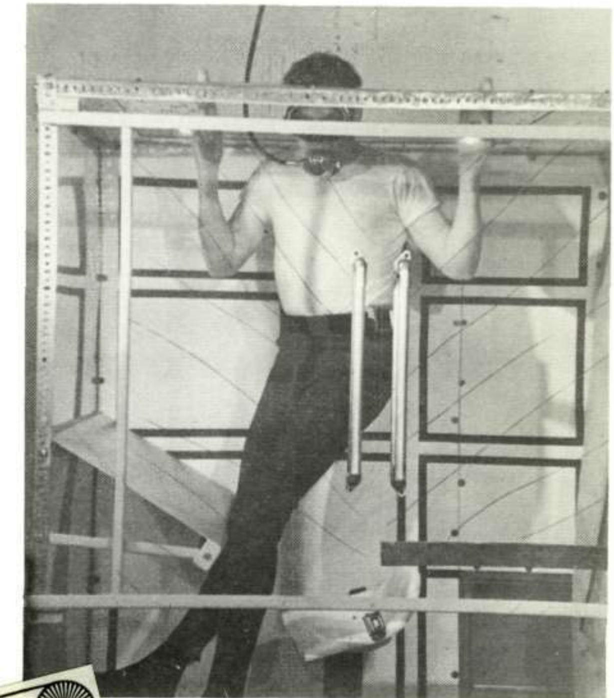


Figure IV-30 Entering Feet First

Figure IV-31 Entering Passageway

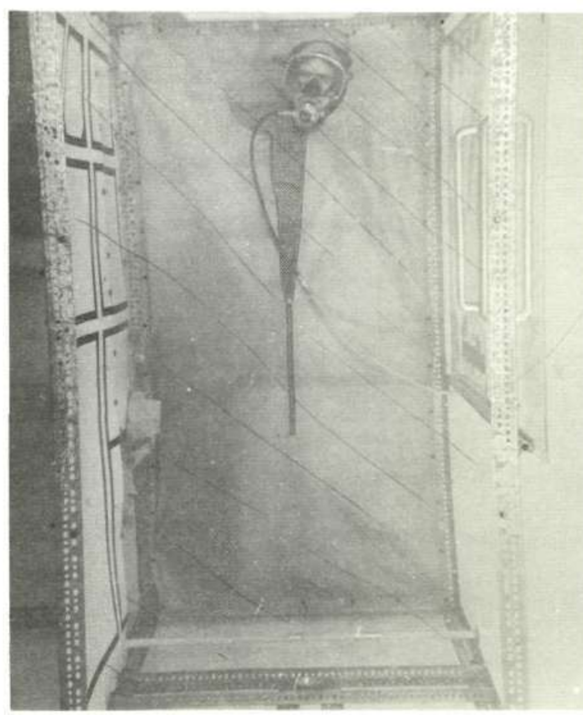


Figure IV-32 Sleep Restraint

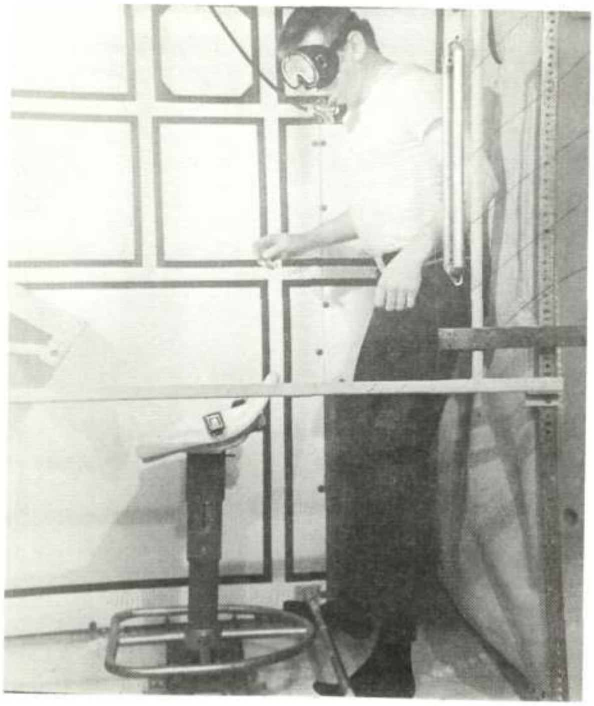


Figure IV-33 Clothes Changing Area

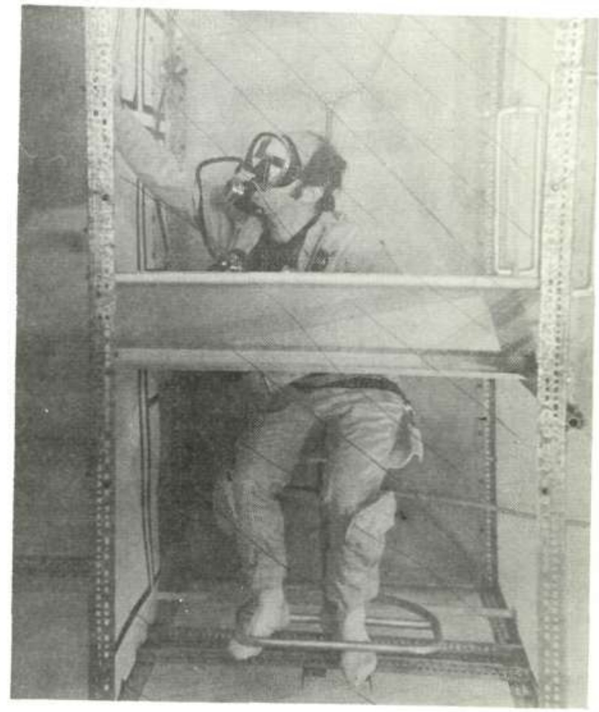


Figure IV-34 Working at Desk

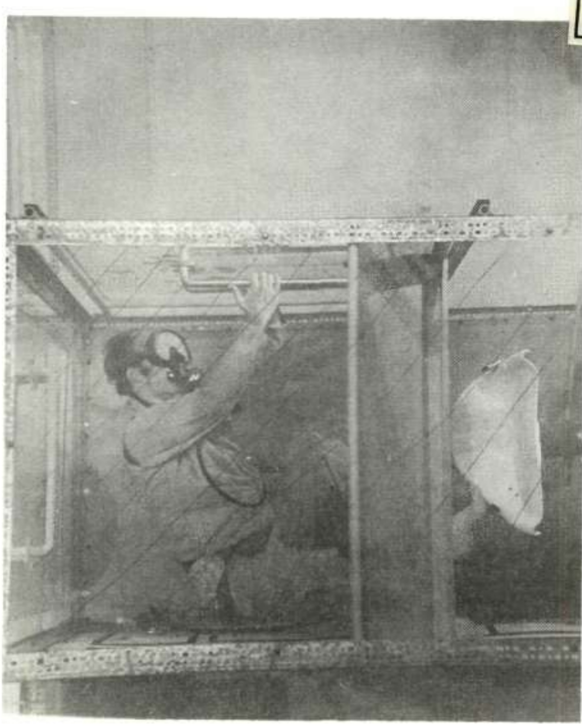


Figure IV-35 Chair as Mobility Aid

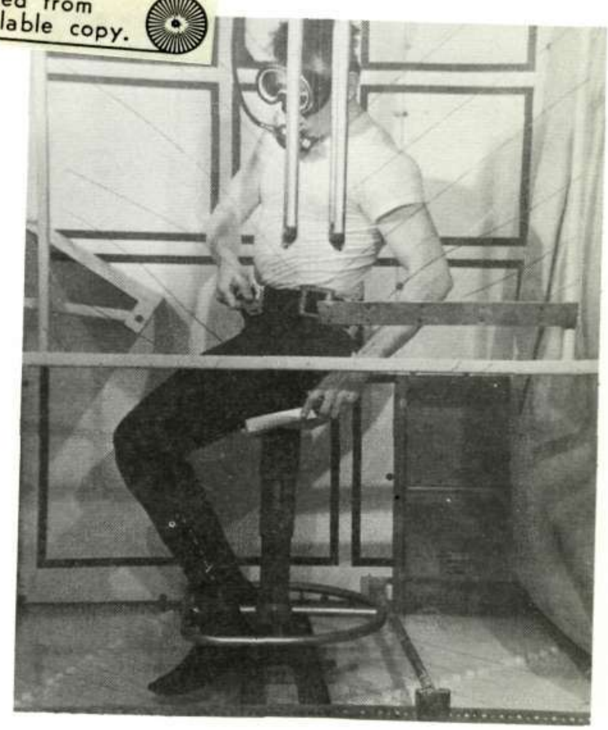


Figure IV-36 Sitting Chair Restraint

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-4 Evaluation of the Bathroom Components*

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Access Doors	The sliding door to the bathroom was 30"x60" as shown in Figure IV-37.			Sliding or tambour doors use a minimum envelope size. They open flush with the walls and do not swing out into the room volume.	Long handles 18 inches in length and 2 inches from the door surface provided an additional mobility and restraint aid as well as assisted the operation of the doors.
Entrance Door	• This provided ample room to enter either head first or feet first, or in a plane parallel to the door. • These dimensions will also accommodate a 95 percentile suited man 29.4 in x 17.9 in.		The open and closed positions are achieved by friction forces.		Sliding or tambour doors are best in space utilization and operation room required. The door shape provided an orientation aid but to correspond with the recommended rearrangement of the office, a smaller 30"x48" sliding door is recommended.
Shower Door	• A 15"x60" swinging door was tested as the entrance door to the shower stall. • This door size provided adequate accommodation for an undressed 95 percentile man. No provisions for a suited crewman seem necessary.		The swinging door provided access in both directions.	The swinging door was designed to open into the bathroom at 180° and also into the shower stall 90°.	• The door handle provided an additional mobility restraint aid both inside the shower stall and in the bathroom area. • Instead of the door being hinged in the central position of the bathroom allowing a 180° swing arc into the room volume, it is suggested that the door be hinged near the wall with a swing arc of 90° into the room to allow easier access into the shower stall.
Room Volume	• The volume of the bathroom 31"x49"x78" is presently designed for use by only one person at a time. • This volume provides sufficient room to perform the functions associated with the bathroom. • Even the 95 percentile man had adequate room to do a flip in the upper part of the room for housekeeping purposes. His required volume for this flip is 24"x48"x48". • The small volume and one-g orientation allowed only minimum intercompartment movement while in contact with some type of mobility/restraint aid as indicated by Figure IV-38.		• In the event that an emergency situation arises two crewmen can utilize the bathroom facility simultaneously. • One person would use the fecal/urine collector or handwash unit while the other person uses the shower.	• The concept selected for testing utilized dimensional figures of existing prototype hardware. • Designed to accommodate only one person, it might be required to support two people in an emergency.	• A sufficient amount of mobility/restraint aids have been provided to perform the required bathroom tasks within this room. The single occupancy room has been optimized to minimize intercompartment movement. • By designing the compartment as a single orientation unit, it was not necessary to provide 48" clear horizontal space for tumbling. For cleaning and housekeeping, the entry hatch opening was oriented parallel to the vertical axis of the bathroom so that only a pivoting rather than tumbling maneuver is required to reach the "lower" section of the bathroom. • Limited amount of time spent in bathroom eliminated the importance of maximum visual space. • The majority of elements within the bathroom were flush with the walls to avoid unnecessary protrusions. • The emergency oxygen was centrally located in a space accessible from all major restraint positions.

Table IV-4 Evaluation of the Bathroom Components*(continued)

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Shower Stall	• The dimensions of the shower that was tested were 15"Rx 30"x78". • The spray nozzle was used to direct water to all parts of the body. This decreased the mobility restraint to only one foot restraint. This is shown in Figures IV-39 & IV-40. • The hands were free to perform routine shower procedures.	Additional handhold restraints are recommended in the upper corners.	A whole body shower would be supplied in each bathroom facility.		The shower stall has restraint aids to stabilize the crewman while performing the routine shower procedures. These restraints include one for each hand 8" long x 4" from the surface, one foot restraint 30" long x 2" from the surface and the shower door handle.
Fecal Collector	• The location of the fecal collector provided a familiar type design that was easy to use and control. See Figure IV-41. • The 60° inclination provided the proper angle for utilization in zero gravity as shown in Figure IV-42.		A fecal collector would be supplied in each bathroom.	• The size of the fecal collector was dictated by anthropometric dimensions of the crewmen. • This unit was located within the room volume to allow a maximum access envelope to the unit.	Handholds were provided on the slanted section of the fecal collector. These 1" tubes 2 inches from the surface and 18" long provided adequate stabilization while defecating. It is recommended that these handholds be replaced with a simple 3/4" radius lip incorporated in the equipment design.
Urine Collector	The location of the urine collector is just beneath the fecal collector. This provides a centralized waste management system. See Figure IV-43.		A urine collector would be supplied beneath the fecal collector to centralize the waste management center.	The position of the urine collector was dictated by anthropometric dimensions with foot restraints and handholds for body control.	• Foot restraints were provided to stabilize the crewman while urinating. This 1 inch tube was 31" long, 8" from the wall and 2" from the floor and were adequate restraints for this collector. • The fecal collector restraints were also used to stabilize the upper portion of the body.
Handwash Personal Grooming	The location of the personal grooming area is located opposite the waste elimination units to provide a sanitary facility, as shown in Figure IV-44.		The personal grooming facility is located in a sanitary position opposite the fecal and urine collector.		• Foot restraints beneath the grooming area provide stabilization of the lower portion of the body. This restraint is a 1 inch tube, 31" long, 4" from the back wall, and 2" off the floor. • Handholds were positioned 6" from the back wall, 2" from side wall and extending from handwash to ceiling to provide additional upper torso stabilization. It is recommended that these handholds be replaced with a simple 3/4" radius lip incorporated in the equipment design. • This area is accessible by one man and is separated from the waste management collector.

*The physical dimensions of this facility were determined by anthropometric dimensions.

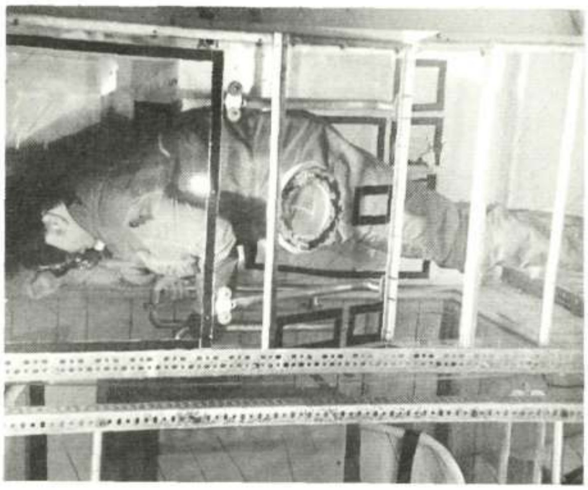


Figure IV-37 Entering Bathroom

Figure IV-38 Foot Restraint in Bathroom

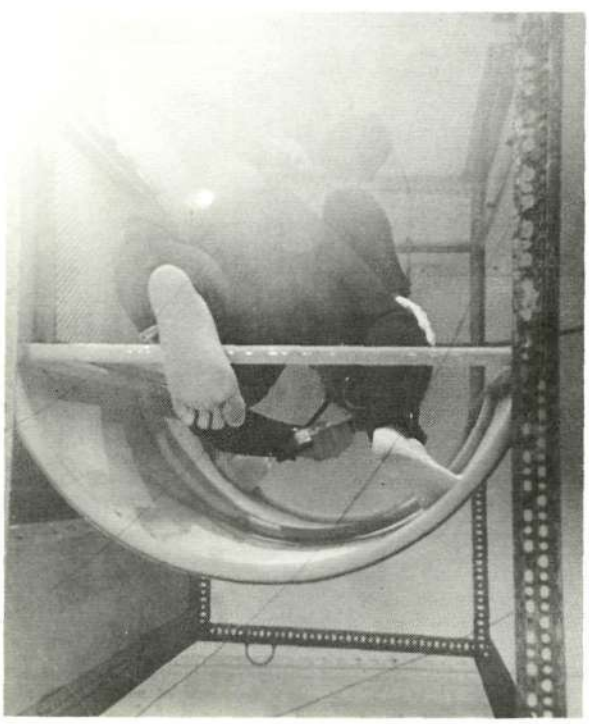


Figure IV-39 Shower Foot Restraint

Figure IV-40 Shower Volume

Figure IV-41 Fecal Collector - Man Interface

Figure IV-42 Bottom View on Fecal Collector

Figure IV-43 Urine Collector - Man Interface

Figure IV-44 Personal Grooming Area

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-5 Evaluation of the Office Components

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Access Door from Office to the Hall	• The sliding doors to the entrance of the office from the simulated hallway were tested with dimensions of 38 inches high by 42 inches wide. • This provided ample room to enter and exit either head first or feet first and good additional visual space with the doors open. See Fig IV-45. • These dimensions accommodated two crewmembers passing simultaneously through the passageway in the shirtsleeve environment. • One man can be accommodated through the hatch while wearing a pressurized suit.		• The open and closed positions are achieved by friction forces.	Sliding or tambour doors use a minimum envelope size. They open flush with the walls and do not swing out into the room volume.	• Hang handles 18 inches in length and 2 inches from the door surfaces provided an additional mobility & restraint aid as well as assisted the operation of the doors. • Sliding or tambour doors are considered best in space utilization and operation room required. • The long handles were an orientation aid for the door operation and provided a means of contact for the hands to control the body without actually looking at the doors.
Room Volume	• The tested volume was 66"x 72"x78" utilizing 215 cu. ft. • Office interior designed for maximum flexibility within a fixed size space.	• The furniture was not arranged efficiently. The rearrangement of the furniture allowed more volume utilization and the recommended room size is 66"x66"x72" utilizing 182 cu. ft. • Corners were not utilized to the fullest capacity.		The office was designed to accommodate the Commander and two guests in a formal businesslike orientation.	• Mobility and restraint aids have been provided in association with the individual furniture items inside the office. • Better volume utilization is recommended by a 66"x66"x72" configuration. This would allow 72" in the one-gravity configuration or for servicing on the pad which is adequate for these situations.
Table	• A 24"x44"x30" high table was tested with the Commander's office. • The table provided adequate space for conferences involving the commander and two guests. It also served as a rank divider, between the Commander and two guests, as indicated by Fig IV-46 & IV-47.		A table will be provided to assist in the orderly discussion of affairs.	• The table was designed to accommodate three men seated for a discussion. • The dimensions were determined from anthropometric data in conjunction with the seat restraint.	• The rolled edge of the table was used as a leg restraint while positioning into the seat restraint. • The table was used as a mobility aid to push off from.
Chair	The fixed chairs provided good restraint for the office functions.	• Housekeeping tasks would be difficult in the areas under the table and around the chair base. Specialized quick disconnects may be used. • The distance between the two fixed chairs were too close for "large" 95 percentile men to sit next to each other. This created an elbow nusiance factor. • The fixed chairs utilized an extensive free volume. It is recommended that these chairs have swing-away storage capabilities.	Chairs will be provided to be used as restraints near conference tables.	The chairs were designed as fixed restraints in the seated configuration. Chairs should be placed at 12" from each other to accommodate 95 percentile men.	• These chairs utilized a lap restraint which did not produce any undue stress on any muscles. This also allowed freedom of both hands and feet. • The chairs were also used as mobility aids to maneuver around the room. • The chairs should have a swing-away stored position to achieve better volume utilization. They might also be made removable for cleaning capabilities.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-5 Evaluation of the Office Components (continued)

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Console	• A 24"x36"x12" console with a 10"x24" fixed writing surface in front was tested. • The console controls are within reach of the commander and visible to all the personnel in the room.	The console location was in the main traffic pattern as tested. Controls could be inadvertently actuated in this condition. This is shown by Figure IV-48.	A console will be provided which will contain all communications, environment and instructional aid equipment.	Contain all communication environment, and instruction aid equipment.	• All controls will be recessed or covered to minimize obtrusions into the room volume. • All controls were made accessible by the commander and could be read by other members present in the room. • Relocate console out of main traffic pattern.
Storage	• A 24"x36"x12" volume was allowed for storage in the office. • The storage area at the end of the table was accessible by both the commander and the guest sitting next to the storage area. • The recommended storage area would be adjacent to the tested configuration.	A volume of 12"x24"x66" was not used and could be utilized in the total storage volume.	Storage area will be considered prime volume in any room of this design.	Storage volume should be optimized wherever possible.	The storage volume of 12"x24"x66" was overlooked and should be utilized in the total storage volume.

Figure IV-45 Exiting Office

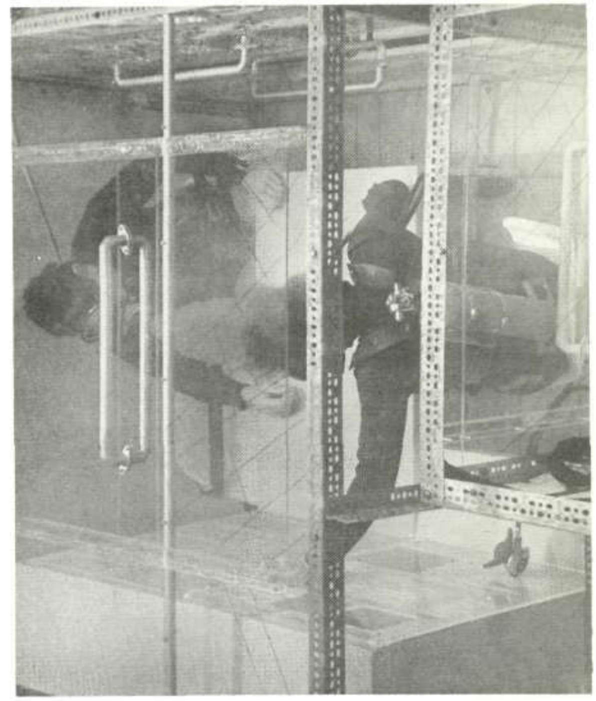


Figure IV-46 Commander and One Guest in Office

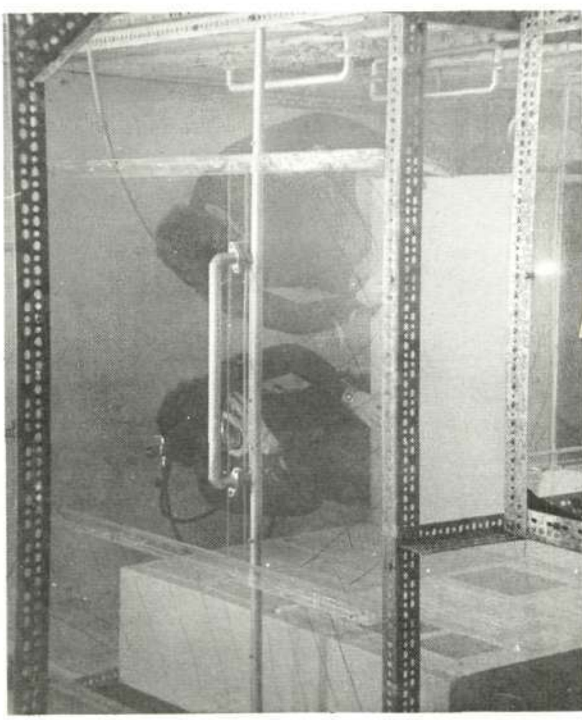


Figure IV-47 Two Guests in Office

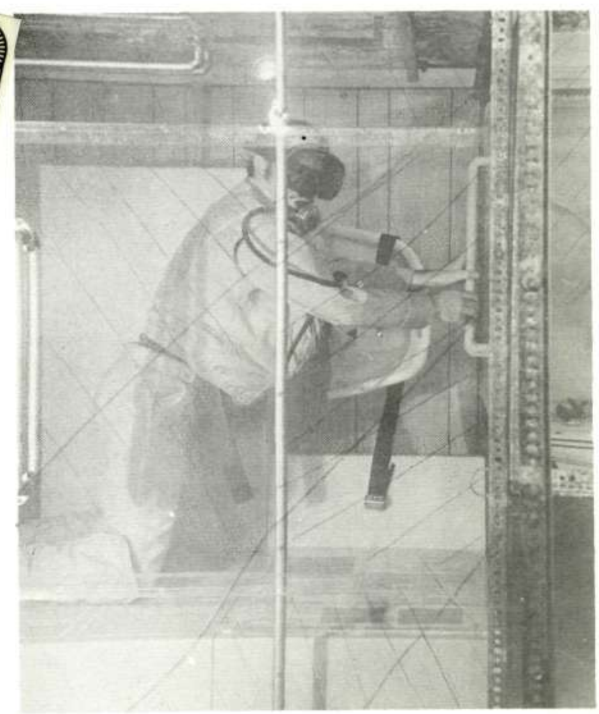


Figure IV-48 Interference with Console in Office

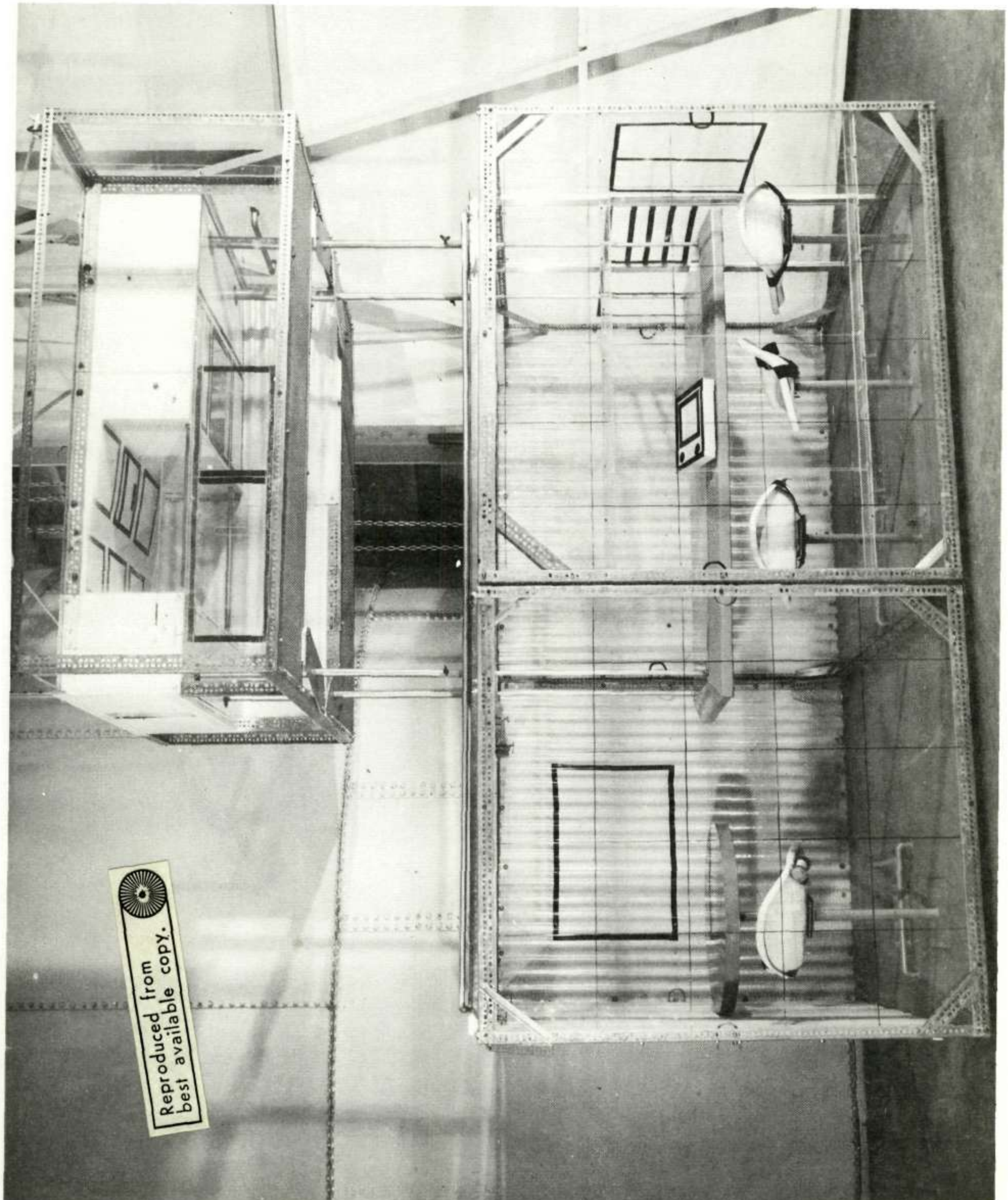


Figure IV-49 Galley/Wardroom Complex

placement of the food tray pick-up area was too low and forced the galley attendant into an awkward position when placing for pick-up or retrieving a food tray. The other nuisance factor was the lack of elbow room when seated at the dining table. Both of these factors can be alleviated by proper placement, such as, moving the tray pick-up point up and moving the chairs to maintain 12 inches between chair seats when in the dining position. The deficiencies consisted of the need for a hand hold in the tray pick-up area, moving the foot restraint to a distance of 24 inches from the chair support for the fixed chairs, and the tray design proved hard to hold and control.

Another design deficiency was the relationship of the tray pick-up point with entry hatches and the dining area. This caused many maneuvers of repositioning the body during locomotion to the tray pick-up point and then to the dining table. In a zero-gravity environment a direct point-to-point line of travel is desirable and will require fewer mobility aids.

A more detailed evaluation of the galley/wardroom complex is provided in Tables IV-6 and IV-7.

F. ORIENTATION AND TRAFFIC PATTERNS

The orientation and traffic patterns for all the rooms investigated were evaluated and the results shown in Table IV-8.

G. PARAMETRIC ANALYSIS

Table IV-9 presents the parametric analysis of the rooms tested with respect to the mission model as referenced in the contract statement of work. Since only one of each room was tested, the mission model parameters were evaluated as applicable to each room. Although other configurations for the rooms are not shown in the table, the mission parameters were considered and used in eliminating the other design concepts as well as in selection of the design tested.

FOLDOUT FRAME 1 FOLDOUT FRAME 2

Table IV-6 Evaluation of Galley Components

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Galley	• Separated from other components for aesthetic value. • Compact. • One man operation with wrap-around compartments. See Figure IV-50. • Food storage for 42-manday mission.		• Space Shuttle • SSP • Space Base	• Visually separated from dining & lounging area. • One man galley attendent.	• 7'0"x7'0"x3' nominal dimensions. • Gross volume is 120 ft^3. • Net volume is 35 ft^3. • Storage volume is 85 ft^3.
Access to Galley	• With galley 30" above lounge, access to galley was easy. • Easy to pass thru 30" high x 33" wide entry door (one man no suit). See Figure IV-51.	• Tray dispensing unit interferred with head (tray unit height 66" from floor - 95 percentile man height 73"). • Support structure created nusiance factor in lower and upper portions of the work area, as shown in Fig IV-52.		• Easy access including visibility to all seats from galley. • Access to tray pickup point from several directions.	• Necessary to flip 360° when entering from the tray dispensing end. 180° roll necessary on leaving area. • Maneuvering done easily when galley and lounge separated by 30" min. • Easy and quick exit in case of emergency.
Accessibility of Galley Components	• Tray storage in side compartment good. • Refrigerator (under prep area) easily accessible, as shown in Figure IV-53. Swinging refrig door (split door 18" to a side) would not block or interfere with a traffic land or an emergency exit (depth of galley is 18" at this point). • Oven (located on same level as preparation area) readily visible and easy to work at. • Water supply (located at side of preparation area) using a fixed spout or with a retractable hose is easily accessible & provides for easy food preparation. • Good access to food storage compartments. • Easy to reach back of food storage compartment (22") with 18"x18" door opening. • 40" wide galley preparation area provides room while all components are within easy reach.	• Must squat and lean back to see where tray dispensing slot is (lower edge 66" from floor). • Storage doors placed below knee difficult to reach (22" above floor or 18" below preparation surface for 95 percentile man).	• Water system demonstrated on Apollo and Skylab.	• Storage units kept to a minimum.	• All parts of galley above knee accessible. • All parts of galley visible. • Oven easily visible and accessible for safe operation.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-6 Evaluation of Galley Components (continued)

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Restraints & Mobility Aids	• Foot restraint on galley floor sufficient for performing all galley tasks. • Upper hand restraints necessary for entry and exit of galley. • Wall and door handles act as adequate mobility aids.			Although specific handholds were placed in the galley preparation area, they could be eliminated & replaced with a 3/4" radius lip on the front of the food preparation shelf. Built-in handholds are desirable over specific restraint devices being added.	• Recommend that tray dispensing unit be raised or moved to side. • Swing-out doors should not be placed below knee. • Optimum height of galley above wardroom was found to be 30". This provided easy access to wardroom or tray storage area with subject in galley area.

Figure IV-50 Galley Front View

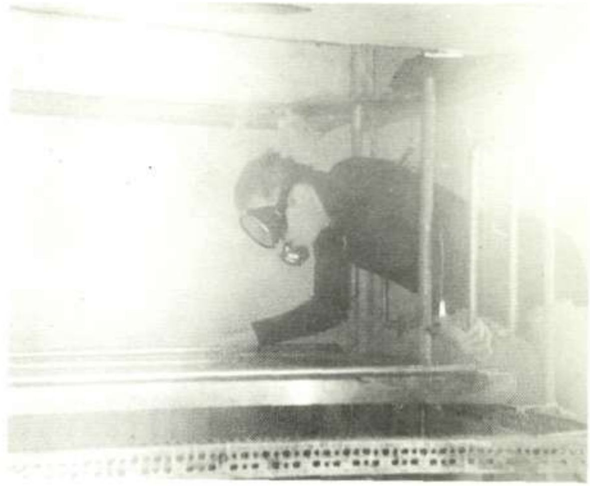


Figure IV-51 Entering Passageway for Galley/Wardroom

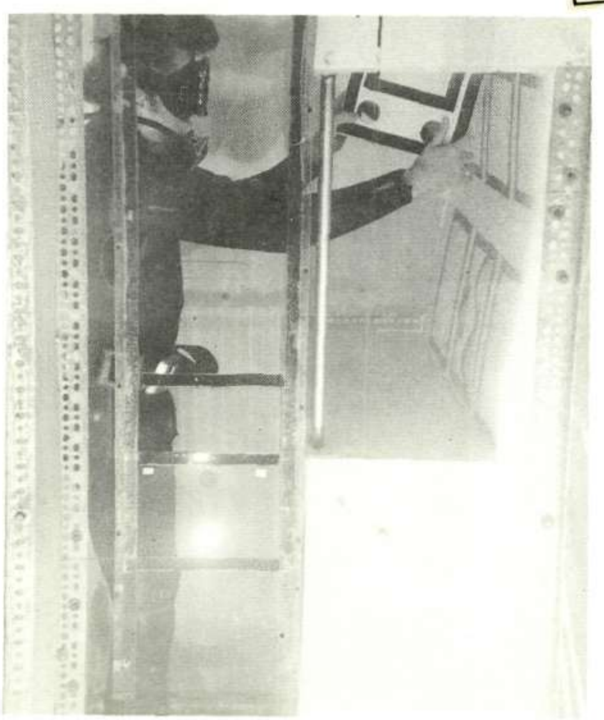


Figure IV-52 Placing Tray in Pickup Area

Figure IV-53 Getting Food from Refrigerator

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-7 Evaluation of Wardroom Components

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Wardroom	Volume provided ample room to perform all associated tasks without interference. The volume can easily be converted from a dining area to any one of the other configurations. In addition, a divider screen can separate the wardroom into two volumes to seat combinations of 3-6 or 4-4 people in each volume for two different activities as indicated in Figure IV-54.	Tested model had the chairs too close together and did not utilize available table area at the lounge end. See Fig IV-55. With divider screen deployed, screen cannot be utilized as a visual aid with six people due to the acute viewing angle of crewmen siting closest to screen.	Accommodates a maximum of eight crewmen at one time with a maximum of six crewmen for dining function. Applicable to a spacecraft of a habitable volume of 30,000 cu. ft. Maintainability aspects are simple.	• To serve as dining room, lounge, rec room, library, study & chapel. • Avoid erector set appearance by minimizing directions and distances. • Height of 5'6" since no standing activities are undertaken. • Simple, uncluttered environment for dining & lounging. • Keep environmental audio visual control units to a minimum.	• 11' x 7' x 5'6" nominal dimension. • Gross volume is 444 ft^3, includes recessed storage areas. • Net volume, excluding 8 chairs, dining & rec table and storage modules is 312 ft^3. • One way see-through ceiling required to determine availability of seating. • Handrails at 5'6" height provide ease of locomotion throughout wardroom area. • Ceiling provides a cove-type effect that provides a feeling of expansive volume. • Dropped screen provides a cove-type effect that provides a feeling of expansive volume to each divided volume.
Access	• Easy access to wardroom due to long opening around passageway floor sides (2'3" x 11'). • Access to wardroom chairs with seats occupied presented no problem with or without a tray. See Fig IV-56. • No problem with exiting with or without tray. Chair provides good push-off point and handrails are used to control direction. • No problems entering or exiting lounge either from wardroom or directly into the area. • Staging area for tray pickup 7' wide x 3'long x 5'6" high provides ample room for maneuvering.	• Trouble with moving about with the tray due to tray design shape and location of mobility aid handrail located on sides. A handrail located in the center of the passageway floor is desirable. • Egress/ingress to wardroom requires maneuvers of repositioning body. • Objects carried by hands are awkward when repositioning body.		• Easy access to seats without moving over other diners. • Staging area. • Access to tray pickup point from several directions.	• Easy exit in case of emergency (all members of crew are able to exit at same time).
Dining Area	• Chair-table relationship is comfortable (chair back to edge of table 16"). • Swivel capability not required for dining but necessary for other activities (theater, chapel, etc.). • Dividing panel operation was easy and provided secluded area for study or privacy. • Table bevel, 30 degrees, located tray in good eating position.	• Complete table surface was not utilized. • Chair-chair relationship too close, 6" edge to edge (recommend 12" edge to edge). • Chairs were too close to foot restraints. Foot restraint should be 24" from centerline of a fixed chair. If chair with adjustable height and foot restraint under it is used, 8" from centerline of chair support is recommended.		• No flying over table. • Dual purpose table; flat for conferences with beveled edges to accept food trays. • Multiple usage of room. • Reduce nuisance factors by reducing time and effort involved in reconfiguring area. • Table can be stowed in ceiling divider to provide multiple usage of room. • Lounge area 2 to 4 men.	• Two men required to raise and lower table. • Use of dividing panel secludes study area.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-7 Evaluation of Wardroom Components (continued)

TEST ITEM	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Lounge Area	Table height and design good (30" high x 30" dia.).	Fixed table allows only 3 people to use the area (movable table would allow 4 people to be seated).		Lounge area for 2 to 4 men.	
Visual	• Good visual space in wardroom even with dividing panel down. • With movable chairs, a clear unobstructed view of the screen is available for four people. • The 27-inch opening on either side of the panel extending up 30 inches provided a spacious appearance for the wardroom.	• Dining table supports may provide some blocking of sight (nuisance factor). • Supports in the center of the table would be better for table usage.			
Restraints & Mobility Aids	• Seat belt restraints very positive. • Seat provides a good handhold when getting into position. • Adequate mobility aids with furniture in room, chairs, tables & walls provided all mobility aids required. See Figure IV-57.	• Handholds needed at: tray pickup area, entry to galley, and at center of dividing area. • Foot restraints under tables were located too close to the chairs due to fixed height of chairs.		• A person ascending or descending into a restraint position may maintain contact with a mobility aid at all times. • Swivel & adjustable seat restraint devices. • The feet can be utilized to operate doors in areas where turning around may be limited as shown in Figure IV-59.	
Traffic Pattern	• Design incorporated a large free area (30"x84"x84") which allows multilane traffic patterns depending on which chair the subject wanted to occupy as depicted in Fig IV-58. • Large free area gave direct access to tray pickup area or to exit hatches. • Entering or exiting lounge from wardroom or from above presented no problem. • Emergency exits for all personnel in several directions at the same time.			• Elimination of horizontal aisles by directing traffic to the dining area from above or below.	

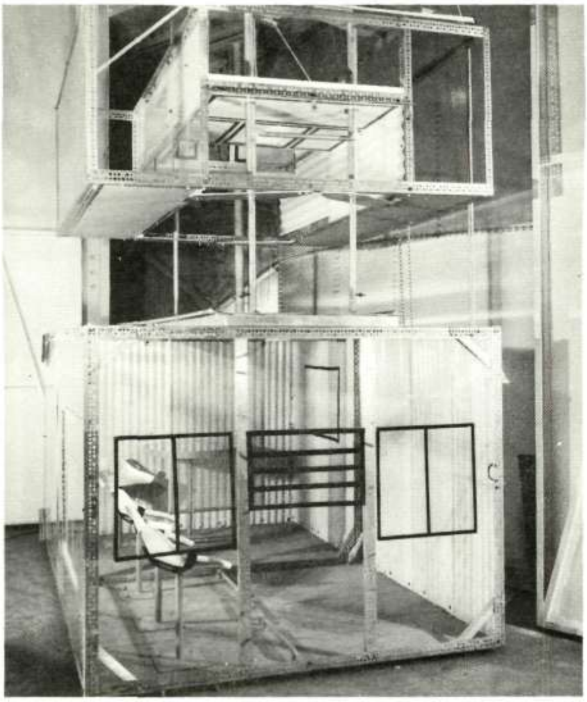


Figure IV-54 Wardroom with Table Raised

Figure IV-55 Elbow Interference While Dining

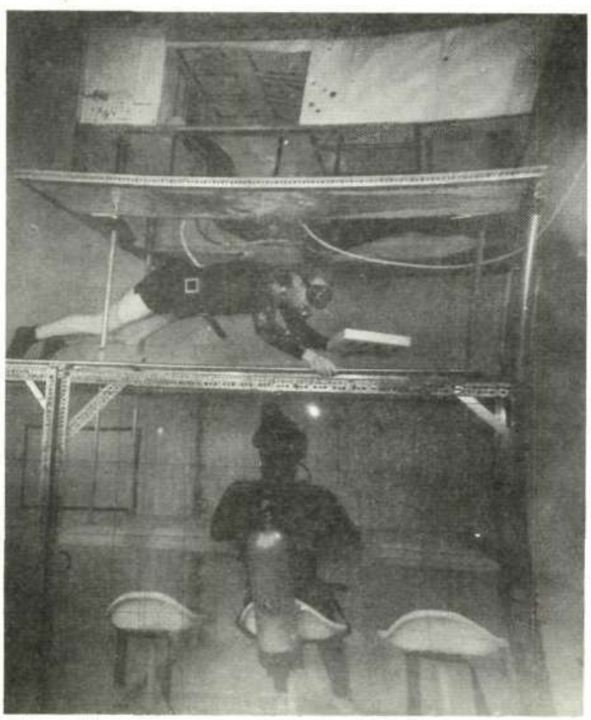


Figure IV-56 Access to Wardroom with Tray

Figure IV-57 Chair as Mobility Aid

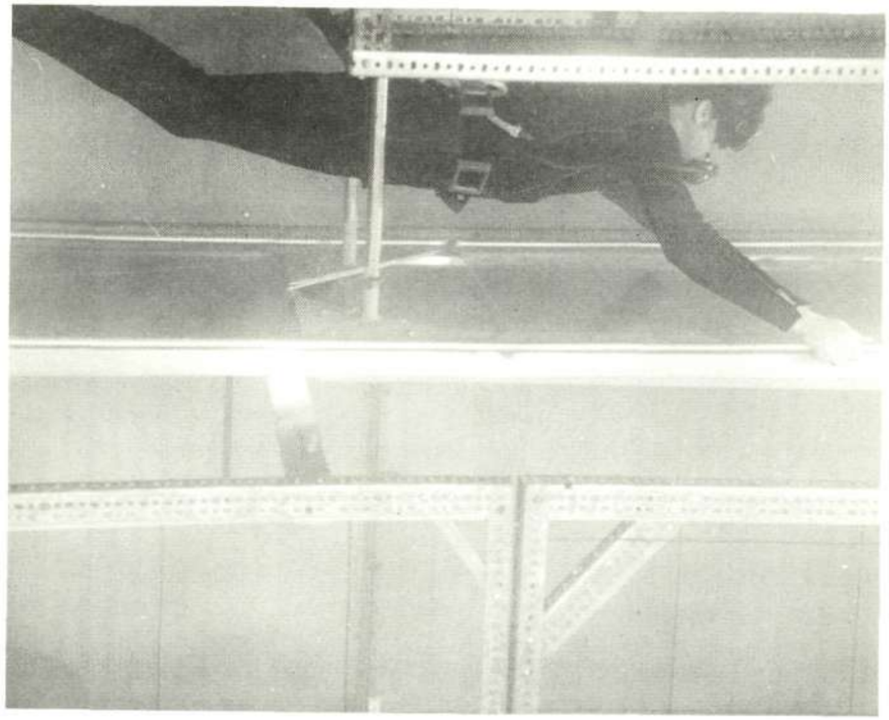


Figure IV-58 In Passageway Above Wardroom

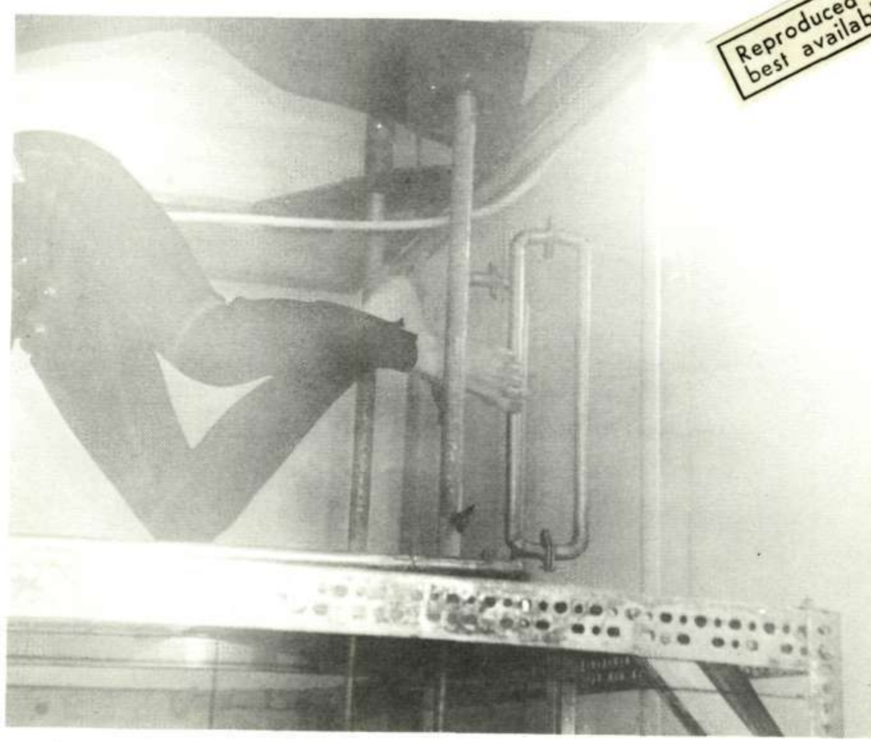


Figure IV-59 Closing Door with Feet

OLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-8 Evaluation of Orientation and Traffic Patterns

ROOMS CONSIDERED	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Stateroom to Office	• The astronaut is positioned at the 90° roll orientation by the operation of the doors. • Direct access to the sitting restraints when entering feet first. • When entering feet first, the astronaut can use his hand and the chair seat lip to position himself.	• Commander had to fly over the waiting crewmen at the table. • The console was in the main traffic pattern as tested controls could be inadvertently activated in this condition.	N/A	Change room orientation direct access from stateroom hatch to chair.	
Stateroom to Bathroom	• Similar orientation results in very easy transfer. • The bathroom could be rotated 180° with no apparent problems since there is room in the stateroom to flip and the long doorway into the bathroom provides easy access.		N/A		
Stateroom to Hallway	With adequate mobility aids in the hallway, the astronaut can maneuver out of the stateroom in the desired direction.		N/A		
Office to Stateroom	• Door operation requires 180° flip by astronaut if entering stateroom head first. • When entering feet first, he is oriented with the stateroom.		N/A		
Office to Bathroom	• Abundance of free space in office permits proper body positioning to be oriented with the bathroom on entering. • No problems occurred when the test subject did a 90° roll.				
Office to Hallway	• The oversized doorway provided ample room to maneuver into the hallway regardless of the orientation. • Door handles provide a mobility aid.	Mobility aids are required to control direction immediately outside the doorway.			
Bathroom to Stateroom	Regardless whether the astronaut exits feet or head first, the same orientation and ample room in the stateroom, even when desk and chair are deployed, results in easy transfer.				

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-8 Evaluation of Orientation and Traffic Patterns (continued)

ROOMS CONSIDERED	MERITS	DEFICIENCIES	APPLICABILITY & RELIABILITY	DESIGN CONCEPTS	OTHER FACTORS
Bathroom to Office	The 90° roll orientation is an advantage, in that the room needed to maneuver is above the table and chairs yet the table provides a mobility aid during transfer. The door size, 30"x 60", dictates the slide direction as does the room orientation.				
Bathroom to Hallway	This mode was not tested, however, the 30"x60" door would provide adequate access to a hallway. When the bathroom is adjacent to the stateroom, an outside or hallway door could be put in the top of the bathroom. For this entrance, a feet first access to the bathroom and a head first exit is recommended. However, a head first entry into the bathroom is possible but requires the crewman to flip 180° once in the room.				
Galley to Center Passageway	It is necessary to flip 360° when entering from the tray dispensing end head first & 180° roll on leaving the area. The 30-in. separation between the galley & wardroom allows these maneuvers. When entering from the floor end, only a 180° roll is required and that only if the person is facing the wardroom.				
Passageway To Wardroom	Easy access even with food tray or study material due to the 27" x 132" opening on both sides.	Objects carried in hand caused some trouble when maneuvering body through openings.			
Wardroom to Passageway	On exiting the chair restraint provides a good push-off point with the feet while the handrails are used to control direction.	A mobility aid in the center of the passageway floor would provide a more controlled translation when holding an object in one hand.			
Wardroom to Lounge	Direct point-to-point translation is possible by using furniture items as mobility aids.				
Lounge to Passageway	Using the chair or wall as a push-off point with the feet while the handrails are used to control direction.				

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table IV-9 Parametric Analysis

	ZERO-GRAVITY	CREW SIZE 3-12 Min.	DURATION 30 Days	TECHNOLOGY AVAILABLE 1975-1985	VOLUME 6K - 30K ft^3
Galley	Design of the serving tray preparation and dispensing area adaptable only to zero-g. Tasks performed in the galley dictate the same orientation. Simple handholds and toe bars provide adequate restraint and mobility aids while in the galley. Man's interface with the equipment will accommodate the 5 to 95 percentile man.	Adaptable for either individual or an assigned galley attendant to prepare meals. Designed to prepare for a maximum of six at one time, therefore larger crew would necessitate two preparation and clean-up activities.	Design of 96 ft^3 would accommodate 3 men for 30 days. Larger crews would require additional storage space for the food. For a 360 man-day mission an additional storage volume of 204 ft^3 is required.	Oven, refrigerator & freezer, water chiller & heater, food storage units, compactor, food trays, and waste eliminator will be available by 1975 (used on Skylab).	The design could be incorporated into any habitable area of 2500 ft^3 or more with consideration given to crew size and mission duration as limiting factors.
Wardroom Dining Lounge Conferences Study Theater Chapel	Design is for zero-g only since entry and exit is through a passageway above the seated positions. Orientation between the lounge and dining area is the same due to the multi-use of both areas. The low center section (66") is acceptable in zero-g since very little translation is performed in an erect position. Also the cove on both sides provides additional visual volume and easy access to all areas of the wardroom. The zero g allows point-to-point translation due to the soaring capability.	This size room is only feasible for a crew of 6 or more. Smaller crews could utilize the space, however, requirements of the mission will dictate the amount of volume for this area of habitability.	This design will accommodate up to 6 men at one time for eating. This will give crewmen the opportunity to sit in different locations. Allows a very flexible area for long-duration missions in providing an area the crewman can change to fit their needs.	Chairs, audio visual, tables & storage units, etc. require development and could be available by 1975.	Spacecraft with a volume of approximately 30,000 ft^3 is needed to make a room of this size feasible. Smaller spacecraft can utilize other areas for eating and the other activities.
COMMANDER'S STATEROOM COMPLEX					
Stateroom	Tasks performed in two orientations to utilize the volume available. Zero-g allows smaller hatchways for entry and exit.	1 man only, no socializing.	Provides a comfortable personal area for a 30-day mission or longer.	Sleep restraints, desk, chair, storage containers available by 1975.	Gross Volume = 98 ft^3 - Extended mission may require additional storage (clothes & personal). This volume is adaptable for the larger spacecraft where the volume is not such a high premium.
Bathroom	• Tasks performed in same orientation. • Fecal collecting device is 60° off horizontal to provide maximum volume utilization.	• 1 man for normal hygiene activities. • 2 men can use bathroom if necessary or if one man in shower (recommended emergency situation only).	Commander's bathroom - 1 man for 30 days (extended duration would require extra space for waste storage). Shower may not be deemed necessary for the 30-day mission but it is desirable.	• Fecal & urine collector available early 1975. • Shower available by early 1975-1985. • Personal grooming station available by 1975.	Gross Volume = 103 ft^3 - Additional waste storage for extended mission. The bathroom without a shower could be incorporated into any habitable area of 2500 ft^3 or more. The area for a hygiene facility is a requirement for all manned missions.
Office	Activities to be performed in this area dictate the same orientation. Access is possible from above the chair restraints as in the wardroom for dining.	3 men (commander's chair and two guests in a formal orientation) is the maximum the room can comfortably provide space and restraints.	Same volume and orientation regardless of duration.	Table, chairs, console, storage units available by 1975.	Gross Volume of 182 ft^3 for an office may be an area considered for the larger spacecraft. Although some command area must be made available in all spacecraft.

V. DOCUMENTATION

A. STUDY PLAN, MSC-03775

The study plan outlines Martin Marietta Corporation's approach, milestones, anticipated results, and workload allocation for Neutral Buoyancy Testing of Architectural and Environmental Concepts of Space Vehicle Design. This DRL Number T-628 Line Item 6 was submitted to NASA-MSC and approved by Clarence Council, Technical Monitor, NASA-MSC in June 1971.

B. BIBLIOGRAPHY/SYNOPSIS REPORT, MSC-03771

The bibliography synopsis report contains the results of an extensive search of available material pertaining to architectural and environmental concepts for long-term space missions. The report utilizes a subject index to categorize each of the 76 documents researched and cited in the report into one or more of six subjects. The six subject areas are: Extraterrestrial Habitability Concepts, Terrestrial Architectural Concepts, Neutral Buoyancy Testing, Mobility/Restraint Concepts, Astronaut Performance/Task Evaluation, and Cross-Cultural Architectural Concepts. The data were obtained from government documents, professional societies, books, trade journals, Martin Marietta documents, corporation contacts, recent professional conferences, and personal contacts with several NASA astronauts.

C. MONTHLY PROGRESS REPORT, MCR-71-219

In addition to other reports, a monthly progress report of all work performed during each month of the contract has been submitted. The reports are in narrative form, brief, and informative in content. They include the information specified in the format by Data Requirement Description MA-179T.

D. TEST PLANS

Test plans for the following neutral buoyancy testing have been coordinated with the Technical Monitor and received his approval: GFP Restraint Evaluation; Preliminary Neutral Buoyancy Tests of Volumes, Tasks, Furniture Items, and Mobility/Restraint Devices; Chair and Table Prototype; Commander's Stateroom Complex consisting of the stateroom, office, and bathroom; and Galley/Wardroom Complex. The last three plans are included in this report as Appendices A, B, and C.

E. MID-CONTRACT REPORT, MSC-03772

This report contained a summary of the progress and an evaluation of the effort through the first half of the contract. The contract portions covered in the report were the analysis studies, final conceptual design developed, and the neutral buoyancy testing and evaluation summary up through the prototype chair/table testing.

F. TEST FILM AND PHOTOGRAPHS

During the neutral buoyancy testing, significant results are recorded on 16 mm movie film, video tape, and still photographs. For all the tests conducted, approximately 5200 feet of movie film, 4500 feet of video tape, and 180 still photographs were taken and submitted to NASA-MSC. The schedule of when the film and photographs were presented to NASA-MSC is as follows: GFP Chair Restraints, August 2, 1971; Preliminary Neutral Buoyancy Testing, October 12, 1971; Prototype Chair and Table, November 15, 1971; Commander's Stateroom Complex, January 13, 1972; Galley/ Wardroom Complex, February 10, 1972.

G. A/E HANDBOOK AND RATIONALE SUPPLEMENTS, MSC-01530 & 01532

The A/E Handbook Supplement is intended to update the Habitability Data Handbook, Volume 2, MSC-03909 Architecture and Environment in a zero-gravity environment. The data supplied in the supplement will provide designers with pertinent information in the design of habitability areas and furniture items for use in zero gravity.

The rationale supplement provides the rationale for the information supplied in the A/E Handbook Supplement. References are made to the neutral buoyancy movie film and photographs to substantiate certain aspects of the design as indicated in the handbook.

H. SUMMARY REPORT, MSC-03774

The summary report is submitted in conjunction with this final report and will not exceed 10 pages. The report contains an introduction, study scope and objectives, relationship to other NASA efforts, method of approach and principal assumptions, basic data generated and significant results, study limitations, implications for research, and suggested additional effort.

VI. SUMMARY OF A/E DESIGN FOR ZERO GRAVITY

This section is included to present a summary of the applicability to space vehicles and the effects of zero gravity upon architectural/environmental design as determined by efforts of the contract. The Architectural and Environmental Handbook Supplement, NASA/MSC document 01530, is considered a part of this section as specific criteria for zero gravity.

A. APPLICABILITY TO SPACE VEHICLES

The data obtained for habitability during the contract can be applied to either a very large volume space vehicle or a more condensed vehicle where areas must serve multi-functions. This is illustrated in both the commander's stateroom complex and the galley/wardroom complex where for the larger space vehicles the entire complexs could be accommodated but for smaller vehicles only portions of the complex would be used. Therefore, it can be summarized to say that the specific function, task, and furniture to support the function or task of the mission determines the amount of space to be allocated to habitability areas. Although for all missions, provisions must be provided for food preparation and hygiene facilities and the tasks of eating, sleeping, relaxing, and performing manual tasks will be performed. To support these areas the data generated during the contract is directly applicable for the galley, the bathroom without the shower, and the performance of the related tasks in a zero-gravity environment. An example of a space vehicle which would require galley and hygiene capabilities and the access envelope for life sustaining activities would be the projected shuttle orbiter vehicle. The design concepts for these two areas and the data relating to the activities could be incorporated directly into this vehicle.

B. EFFECTS OF ZERO GRAVITY ON A/E DESIGN

The effect of zero gravity on A/E design is to increase the options available to the designer by, as previously stated, taking advantage of all wall surfaces for mounting equipment, requirement for smaller openings between rooms, and the ability for point-to-point transfer. The major result of these options is the requirement for less volume than a normal gravity situation and the subjective feeling of spaciousness by the person in the environment.

The optimum volume required for a one-man stateroom for a 30-day mission in a zero-gravity environment was determined and verified by neutral buoyancy testing to be 122 cubic feet, of which 25 cubic feet is for storage. This volume provided a comfortable space for sleeping, personal relaxation, and a private office. Access to the room was via two sliding doors, one 30" x 42" between another room and one 42" x 44" into a passageway. The furniture items, sleep restraint, desk, and chair provided ample restraint and mobility aids when deployed. With the furniture in the stowed configuration, the walls and door handles provided the restraint and mobility aids necessary to perform general habitability tasks of housekeeping, retrieving and stowing objects, and translation through the room. The minimum volume to be allowed per man in a six-man crew is approximately 49 cubic feet. This volume would provide for sleeping and changing clothes immediately in front of the sleep restraints and is arrived at by the 36" x 78" sleep restraint and the 30" access room in front of the sleep restraint. With a six-man crew, there would be a minimum of 37.5 cubic feet of additional visual volume for each individual stateroom. This is determined by a 30" x 36" x 60" passageway for access to the room. A stateroom for four or more men will reduce the volume per man requirement down to approximately 40 cubic feet (60" x 60" x 78"), not including storage, for a 30-day mission. For longer missions up to 180 days, a volume of approximately 68 cubic feet (72" x 84" x 78"), not including storage, per man is required in a four-man stateroom. These multi-man staterooms were not tested, however, the data applicable to a multi-man stateroom can be determined by knowing the equipment required to support the sleep function and the access volume required for this equipment. It must be noted that access volume can be shared with more than one function as long as the functions occur at different times. These statements can be applied to any area of habitability and is not confined specifically to a stateroom.

The effect of zero gravity on furniture design is not as drastic as on volume, however, there are ways to incorporate zero gravity required devices into furniture. In zero gravity means must be provided to control body movement at all times, even when relaxing or sleeping. The sleeping-bag type sleep restraint mounted vertically on the wall is the farthest departure from one-gravity furniture. It is even more important in zero gravity to observe the general design criteria of MIL-STD-1472A in regard to sharp edges and all other safety requirements. This is due to the fact that man can utilize all parts of a volume and the ease in which the body can achieve a velocity that could be detrimental when contact is made with an object. The furniture item should incorporate handholds or other restraint and mobility aids that are required for man to interface with the item. An example of this is a lip of at least 3/4 inch radius on chairs, desks, tables, and cabinet faces to allow for a handhold or serve as a push-off point. Other features are that belts or other restraint devices should not be placed on a body positioning muscle and a two-point contact must always be maintained. Some furniture items will be designed for specific functions or tasks although the basic design features as mentioned above still apply. For instance the support for a sitting restraint may vary greatly for different tasks as well as the need for a foot restraint.

Another aspect of architectural design for zero gravity is the method of locomotion of man in zero gravity. Man's primary mode of locomotion is to translate in a stretched-out head-first manner and if possible, maintaining contact with some surface with either his hands, feet, or other parts of his body. As he approaches doors or furniture items, he orients his body with respect to the task of opening the door or interfacing with the furniture item by using either specific mobility aids, which are not required in most areas, or any surface that is in the area. Therefore, since all surfaces in a volume may become hand, feet, or other parts of the body contact points, controls such as switches, push buttons, etc. must be protected to prevent inadvertent actuation. Also because of the freedom available in zero gravity for maneuvering, the feet can be utilized to a greater extent as operators rather than just as means of locomotion or stabilizing points. To take advantage of this capability the architectural design can employ features in zero gravity that are not possible in a normal gravity environment. However, when the feet become operators, the hands or the trunk of the body must provide the stability points as the laws of mechanics still apply in zero gravity.

C. BASIC DATA GENERATED AND SIGNIFICANT RESULTS

Basic data generated during this contract was design criteria applicable to a manned spacecraft in a zero-gravity environment. This criteria was published as a supplement to the "Architectural and Environmental Handbook", NASA-MSC Document 03909. This criteria included development of concepts for a commander's stateroom complex consisting of a bedroom, bath and office and a galley/wardroom complex. In addition, a prototype chair and table were developed. A brief description of each is provided in the following paragraphs.

C.3

1. Stateroom Complex

a. Bedroom - The bedroom concept is shown in Figure VI-1 and has a gross volume of 122 cubic feet which includes 25 cubic feet for storage (clothes, personal items, supplies, and controls). The net volume totals 80 cubic feet with the chair and table deployed and has a visual volume from the sleep restraint of 76 cubic feet with all doors closed and 163 cubic feet with the end door open.

The tasks associated with the stateroom are sleeping, changing clothes, personal entertainment, writing, housekeeping, and relaxation. These tasks require both the standing and sitting position in addition to the need to maneuver in and out of the room and reorient to the different task oriented design.

b. Bathroom - The bathroom concept selected is depicted by Figure VI-2 and has a gross volume of 104 cubic feet. This volume includes 36 cubic feet for a whole body shower and 13 cubic feet for storage for a net volume of 55 cubic feet in the hygiene area. The fecal and urine collector are located opposite the handwash personal grooming area for aesthetics purposes and volume utilization. The 30 degree slope of the fecal seat from the vertical positions the man in a desirable position somewhat normal to earth use and yet makes maximum use of the volume available. Visual volume is the same as net due to the door being normally closed for functions of the bathroom.

The tasks to be performed in the bathroom consist of personal hygiene functions, body waste elimination, personal grooming, changing clothes, full body showering, and housekeeping. The tasks all require a single orientation of the body which is consistent with the design of the bathroom.

c. Office - The office concept as tested contained a total volume of 215 cubic feet, which was determined to be too large for the functions performed in the room and the location of the furniture items. A gross volume, as shown in Figure VI-3 of 182 cubic feet will support the functions of an office. Of this volume, 55 cubic feet occupied by furniture items thereby leaving a net volume of 127 cubic feet. The visual volume is increased to 225 cubic feet by leaving the larger 42" x 44" door to the hallway and the 32" x 42" door to the stateroom open.

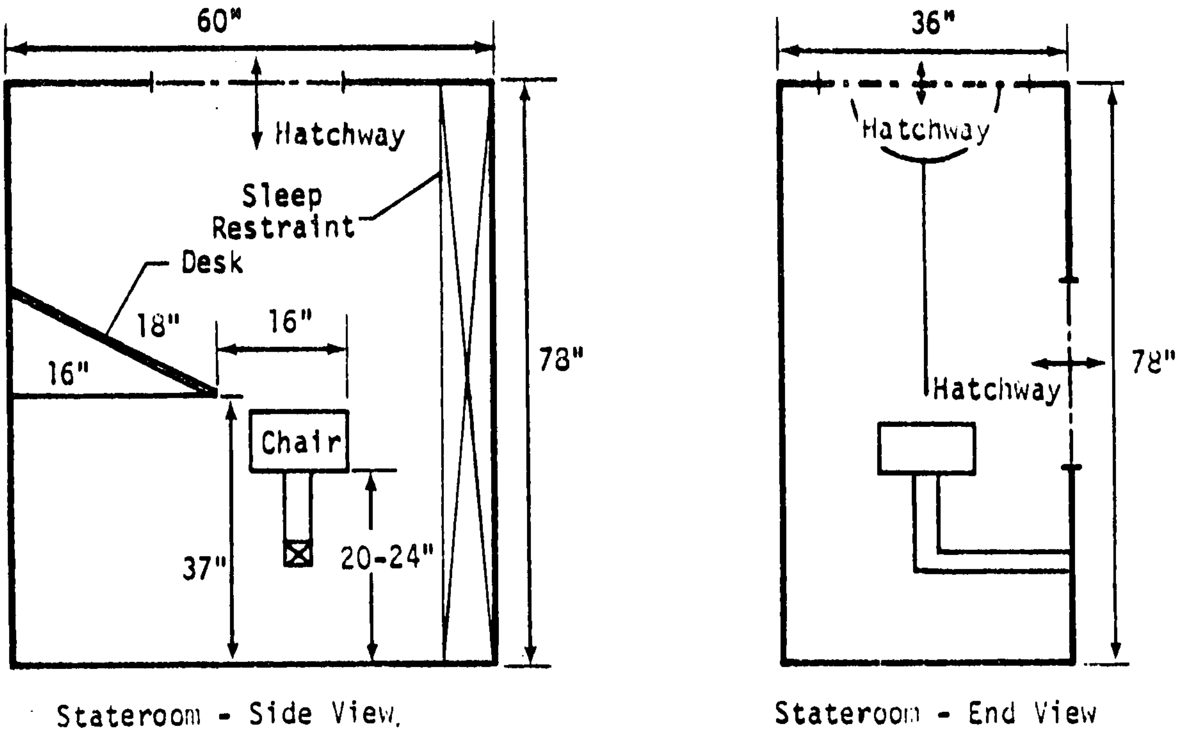


Figure VI-1 Commander's Stateroom

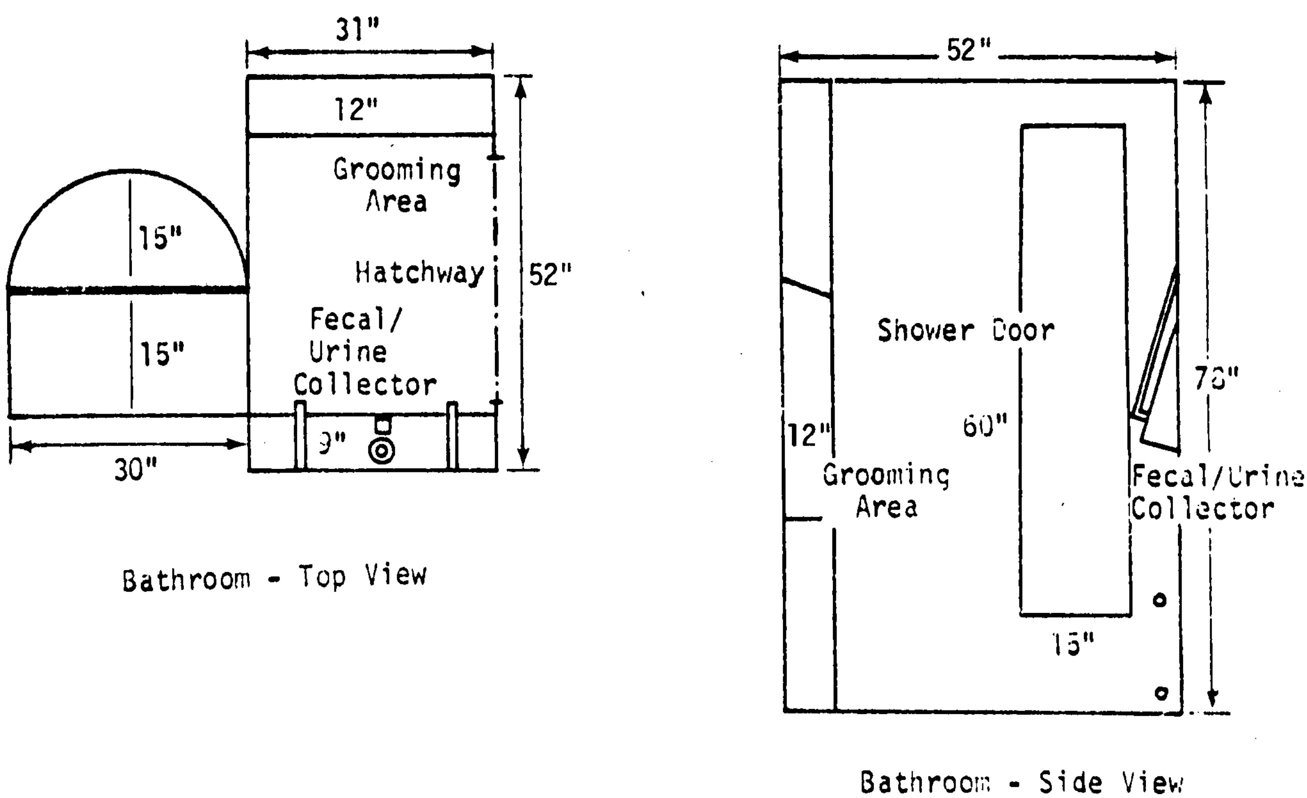
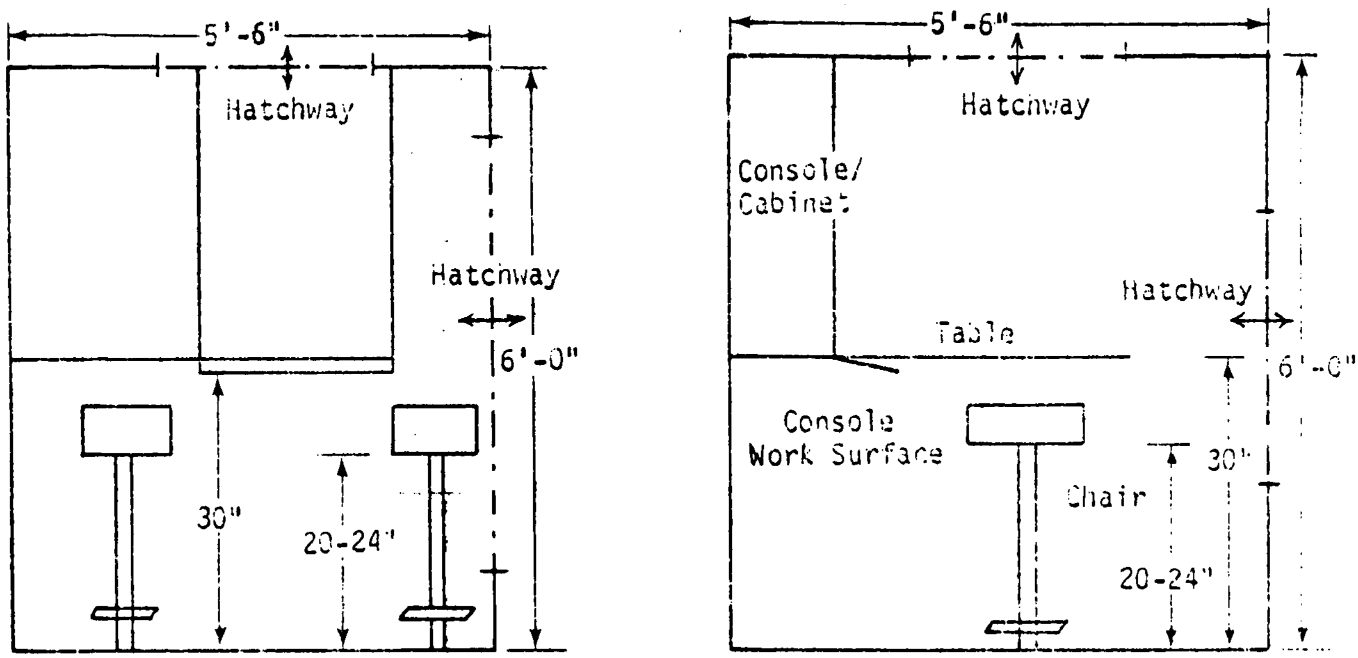


Figure VI-2 Bathroom



Office "D" - Side View

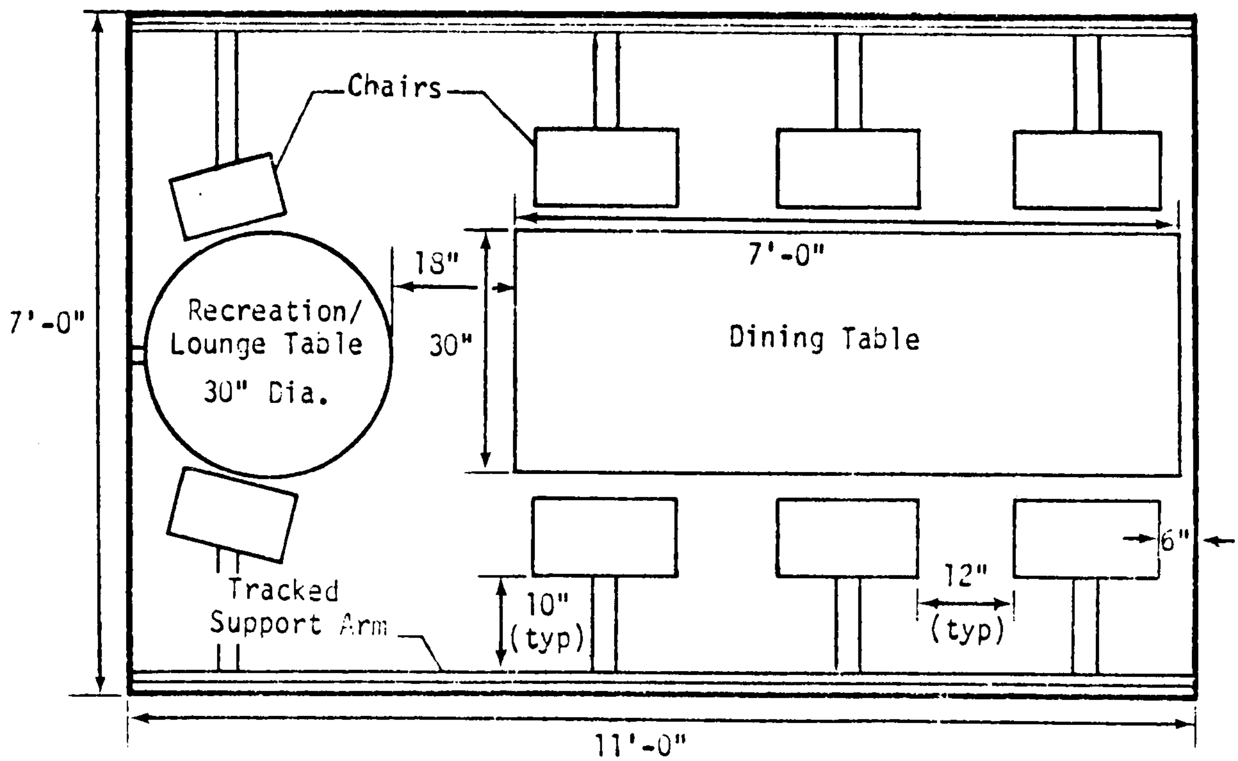
Office "D" - End View

Figure VI-3 Commander's Office

The tasks performed in the office consist of either the commander working individually or in conference with one or two guests. The furniture arrangement offers a business-like atmosphere by separating the commander from his guest by the table. Being the largest room in the three-room complex, this room serves as a focal point and must provide room to maneuver to the adjoining smaller rooms. The orientation within the room is in one direction only since all tasks performed in the room are related. The orientation with respect to other rooms is not important since ample room for maneuvering within the room is available.

2. Wardroom/Galley Complex

a. Wardroom - The wardroom designed and tested is shown by Figure VI-4. The gross volume of the wardroom is 444 cubic feet with the eight chair restraints and two tables requiring 132 cubic feet when deployed for a net volume of 312 cubic feet. The wardroom was designed to accommodate a six-man crew for a 30-day mission. The major furniture items consisted of a 30" x 84" dining/conference table for six men, 30" diameter lounge table for four men, eight chair restraints, and a dividing panel to separate the dining and lounge areas. The wardroom design provided the capability to serve as a multi-purpose room with two functions carried on at the same time. The crew areas that the wardroom must satisfy are: dining room, lounge, recreation, library, study, conference, and chapel.



Wardroom - Top View

Figure VI-4 Wardroom Concept

The primary tasks in the wardroom are performed while sitting in the chair restraints. These include eating, study, conferences, watching movies, playing sedementary games, relaxing, and conversations. Therefore, the chair restraint and its location and capabilities are of prime importance in providing a comfortable habitat. The chair also serves as a mobility aid during locomotion and as a temporary handhold when performing tasks such as housekeeping.

b. Galley - The galley selected and tested is depicted by Figure VI-5 and has a gross volume of 137 cubic feet. Of this volume, 96 cubic feet is required for food storage, tray storage, ovens, refrigerator, housekeeping equipment, and water system for a 84 man-day mission. The remaining 41 cubic feet is considered net volume for the galley attendant to perform his duties. The

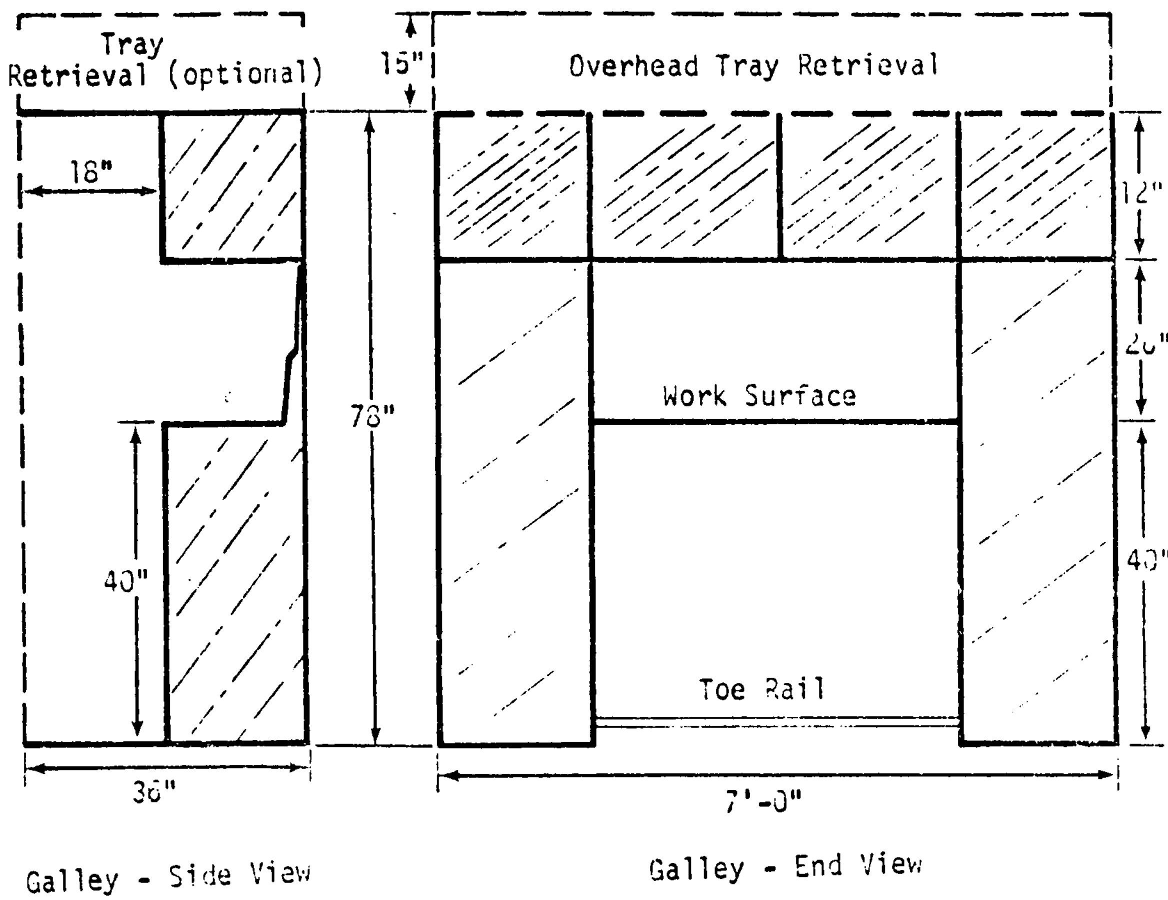


Figure VI-5 Galley Concept

wrap-around design allows the attendant access to all areas in the galley while standing in one position. Therefore, the only special restraint required is a toe bar across the width of the work area. Handhold restraints can be incorporated into the design of the furnishings such as a lip on the front of the tray preparation area and handles on the storage area.

The only tasks in the galley are those associated with food preparation, scullery functions, and general housekeeping tasks. For this reason the galley was designed solely to satisfy the functional requirements and the interface with man.

3. <u>Prototype Chair/Table</u>

a. <u>Prototype Chair</u> - The chair restraint developed satisfied the functional requirements for a sitting restraint and provided additional features to serve as mobility aids. The primary functions of the device provided the stability of controlling the body and maintaining body position while performing tasks in a particular place. The chair design incorporated a retracting lap belt, chair seat swivel, vertical height adjustment, moveable foot restraint and mobility/restraint aids.

b. <u>Prototype Table</u> - The table developed served primarily to determine the table top surface angle, table height, and interface requirements with man and a sitting restraint. Therefore, the features of vertical height and lateral adjustment were required for testing but probably will not be required in a spacecraft. It was found during testing that the table surface angle was not too critical but an angle of approximately 25 degrees was deemed satisfactory for all different sized men.

4. <u>Habitability Design Criteria</u>

The following is a summary of zero gravity habitability design criteria that was generated for specific areas:

a. <u>Ease of Locomotion</u>

1. The soaring position normally assumed in a zero-g environment leaves both the hands and the feet free to be used to initiate, control and terminate a transfer sequence.

2. Locomotion is accomplished utilizing available furniture items, cabinets, walls, surfaces and specific mobility aids.

3. Simple mobility aids on furniture are preferred over specific aids such as handrails.

4. It is difficult to maneuver sharp turns or corners with objects such as food trays or writing surfaces in one hand.

5. Direct point-to-point transfer required when transporting object in hands.

6. Coupling moments (by use of other hand or portions of body) are necessary to maintain a straight point-to-point transfer when propelling force is by use of one hand.

7. Feet are used to provide propelling force with the hands used to control direction.

8. Locomotion patterns or routes should not go over seated people or control panels.

b. <u>Mobility and Restraint Usage</u>

1. Habitability tasks require relatively light forces to stabilize and maintain body position and control.

2. Simple specific mobility and restraint aids (toe bars, handholds) are preferred over special aids (harnesses, magnetic shoes, locking shoes).

3. Specific mobility and restraint aid definitions are shown in Table VI-1.

4. Non-specific mobility and restraint aids should be designed into furniture and equipment items (3/4-inch radius lip on chairs, tables, shelves and counter edges).

5. Specific mobility and restraint aids should be located in the volume only where non-specific aids are not available.

6. A minimum of two contact points are required to maintain body position and control.

7. Simple specific restraints must be provided for miscellaneous items such as removed clothing, personal hygiene kits, wash cloths, towels, writing materials and food trays.

8. Restraint aids should not place stress on any muscle of the body.

Table VI-1 Restraints/Mobility Aids Definition

Restraint/ Mobility Aid	Dimensions	Location	Remarks
Foot	1" dia - D-ring around base, 4" above floor surface, 8-10" radius from chair base.	At chair base	Configuration of feet can be changed often, around D-ring.
	1" dia - 2" clearance from floor surface, length determined by table length.	Below table	Straight rail along centerline of table.
	1" equilateral traingle, corners 0.3" radius, 2" clearance from floor surface, runs entire length of corresponding facility (e.g., entire dia. of shower stall).	On floor below hygiene facility, in shower stall, below mirror & handwasher, below sleep restraint.	Flattened surfaces provide better contact & more comfort for restraints used in stress-applied situations, such as reaching, etc.
Hand	1.25" x 0.62" with 0.31" radius on edge, length determined by specific use.	Hatches, doors, at sides of hygiene unit, on office wall behind chairs, on shower door (latch 8" long).	Handholds must be within a man's reach from any position in any given room.
Combination Foot/Hand	Universal short-term interchangeability.	Total of above.	------------
Lap Belt	2" wide, pulls across to stationary catch, push-button release, mounted @ 45^{o} to horizontal.	Chair seat, fecal collector seat.	Lap belt provides restraint to sides and forward, leaves upper body free.
Sleep Restraint	78" x 36", zipper entrance, internal waist, chest restraints.	Stateroom wall.	------------
Mobility Aids	Non-specific	Chair seat lip - 3/4" radius, chair top, table edge, all foot & handholds, hatchway opening, walls, all surfaces.	Mobility aids must always be within reach from any location.

9. Restraint aids should be designed so that the pressure exerted on any portion of the body is distributed over a large area to avoid a feeling of sharpness and discomfort.

10. Mobility and restraint aids should be designed to be continuous and have two points of contact to avoid catching clothes and prevent injury to the crewman.

11. Handholds and toe bars should be designed for interchangeability for usage with either foot or hand.

12. Length of handholds and toe bars should be long enough to be utilized without searching.

c. <u>Performance in Volume Utilization</u>

1. Table VI-2 gives the dimensional requirements for various individual tasks.

2. Unrelated tasks can utilize part or all of the same volume provided they are not performed simultaneously.

3. Multiple-orientation rooms require volumes sufficient for reorientation maneuvers.

4. Don/doffing clothes is best accomplished when the crewman can easily reach two parallel surfaces 36 inches apart at one time (with hands or feet); thus, a smaller volume can be more efficient than a larger volume.

5. Reorientation between rooms is usually accomplished during passage through the hatch; that is, volume in two rooms can be utilized to perform this task.

6. All hatches should be designed to accommodate simultaneous passage of two crewmen, except where single passage occurs exclusively (e.g., commander's stateroom to bathroom).

7. Maximum volume utilization in zero gravity may be obtained when the man interface with the furnishings takes advantage of the diagonal dimensions in a given room (having the fecal collector 30 degrees off the vertical in the bathroom).

Table VI-2 Volume/Task Requirements

Task	Dimensions, in. Depth	Width	Height
Don-Doft Clothing	30	30	78
Hygiene			
Fecal	40	30	69
Urination	30	30	73
Handwash	30	30	73
Sleeping	6 (front to back)	36	78
Food Preparation	36	18	78
Exercise, simple	72	36	78
Exercise, dynamic	96	72	78
Maneuverability (one plane)	48	24	48
Maneuverability (all planes)	48	48	48
Sitting	18-40	24	58-62
Standing	18	24	73
Soaring	30	24	78

8. On pad service operations for equipment should be considered in the definition of volume and orientation requirements.

9. All main passageways and volumes must accommodate a pressure suited crewman for emergency situations. A 30" x 30" or 30" dia. hatchway is the minimum size required for passage of a suited crewman.

10. Fold-away or swing-out designs for chairs, tables and desks should be considered for maximum volume utilization.

11. Retractable or sliding doors are preferred over hinged swing-out doors for maximum volume utilization.

12. A zero-gravity environment enhances man's movement for maximum utilization of the total room volume.

d. Accessibility Performance

1. Each item of furniture, equipment and storage space requires a specific access envelope which defines the volume needed around a given object for efficient utilization of that object.

2. Access space can be shared if the items and tasks involved are unrelated or, if related, the normal task procedure precludes interference.

3. Chair access should be 12 inches on either side and a minimum of 2" at the back (chair height is 20-24 inches), and 24 inches at the front. Chair may also be mounted from directly above.

4. Chairs situated side-by-side (e.g., for dining) should have 12 inches between them (shared access) and 2 inches at the back.

5. Sleep restraint access from the front (sleeping bag type) should be 24 inches.

6. Access space at conference or dining tables should be 18 inches at each side of the table. Of course, chairs placed around the table are within this space.

7. Access in front of a folding (into wall) desk should be 30 inches from the stowed position; height should be 73 inches.

8. Front access for all storage units should be 30 inches. Access envelope width is a minimum of 24 inches, or the width of the unit itself. Access height is 73-78 inches.

9. It is desirable that storage units be placed at waist level or above (45 inches above floor) to facilitate access.

10. Access to the urine collector, the personal grooming area, and the shower should be 30" x 30" x 78".

11. The access envelope for fecal collection is 30 inches wide, 78 inches high and 40 inches in depth along a line perpendicular to the fecal collector surface.

12. Food preparation area access should be a minimum of 36 inches wide, 18 inches deep and 78 inches high. Space above the work surface (36 x 18 x 26 inches high) is also available for use.

13. Sketches of these access envelopes are contained in MSC-03909, Volume 2, Architecture and Environment.

e. <u>Performance Due to Arrangement/Orientation</u>

1. Arrangement of furniture items in various orientations within a volume does not affect performance if tasks are not related.

2. Related tasks should be oriented in same orientation.

3. Arrangement of furniture items in adjoining volumes does not affect performance if orientated differently.

4. Direction of door operation (locating handles on sliding doors) can aid in orientating entering crewman to a particular task within a volume.

5. Aesthetic considerations should be given to placement of equipment in bathroom.

6. Arrangement of furnishings within a volume should make maximum utilization of visual volume.

f. <u>Visual Perception in Zero Gravity</u>

1. Cove type ceilings and divider screens adds to the volume of a space through visual perception.

2. Visual perception of a volume is increased by locating furniture/equipment so that crewmen can view through open hatchways into other volumes or hallways.

3. Design all volumes with walls that flow from one to the other by large radius corners, lighting effects, selected pictures, and color patterns.

4. Hatchways should be made as large as possible to create illusions of more space.

5. Windows where feasible will add to the visual perception of a volume.

g. <u>Nuisance Factors During Performance</u>

1. Hatches should be placed so crewmen can avoid contact or interference with console units during ingress or egress through the hatch.

2. Access space in dining areas is critical; interference during eating must be avoided.

3. Traffic patterns should avoid overhead routes above eating tables and conferences.

4. Swing-out doors in storage units (e.g., galley) must be above knee level (22 inches from floor) when foot/toe restraints are utilized at the unit.

5. Overhead tray retrieval, storage or equipment in the galley must be placed so as to avoid interference with the crewman over the food preparation counter.

h. <u>Furnishings Comfort</u>

1. To incorporate human comfort into furnishings used in a zero-gravity environment, the designer must be knowledgeable of the relationship between man and the equipment.

2. A sleep restraint that provides flexibility in the degree of restraint, options of amount of covering, options of bed accessories, and access/egress considerations.

3. Sitting restraints must fulfill the primary functional requirement to maintain body position and control while performing tasks. Related requirements are:

a. Fit anthropometric dimensions of man.
b. Do not apply pressure to a body support muscle.
c. Height of restraint dependent on type of foot restraint and slope of seat.
d. Seat slope to match man's relaxed position in zero gravity.