MSC-03909

HABITABILITY DATA HANDBOOK
VOLUME 2
ARCHITECTURE AND ENVIRONMENT

SUPPLEMENT 1

APRIL 1972

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER

PREFACE

This volume is meant to serve as a supplement to the original Habitability Data Handbook, Volume 2 (MSC-03909). Data presented in that handbook is still applicable in all cases as noted. Lighting, acoustics, temperature and color requirements, for example, pertain to either a zero or artificial gravity environment. The original handbook room volume recommendations apply principally to artificial gravity environment. This supplement presents data specifically for a zero gravity environment and does not contradict the original handbook in any way.

2.0 ARCHITECTURAL DESIGN CRITERIA

Crew Area Criteria

Habitability criteria standards for crew areas in zero gravity are identical to those for artificial gravity except for volume standards. Lighting, acoustics, temperature and color standards as presented in Sections 2.1 through 2.4 are generally applicable in zero-gravity situations. Volumetric requirements for specific crew areas in zero gravity are presented in the following subsections.

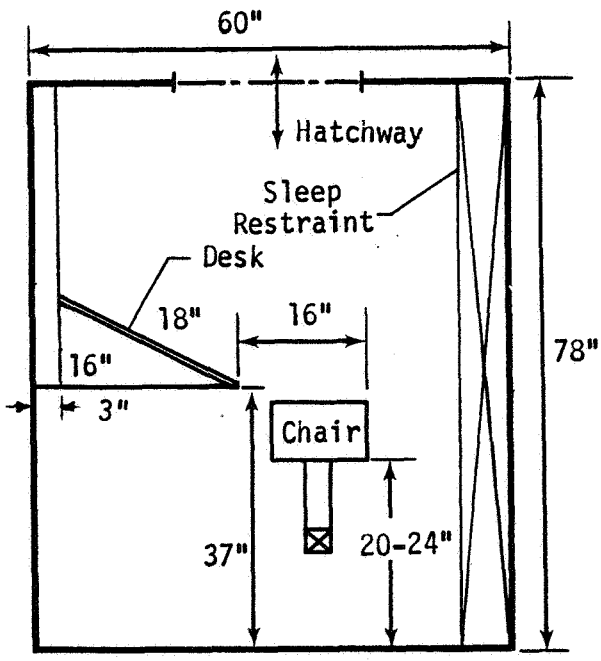
2.1 PERSONAL AREAS

2.1.1 Bedrooms

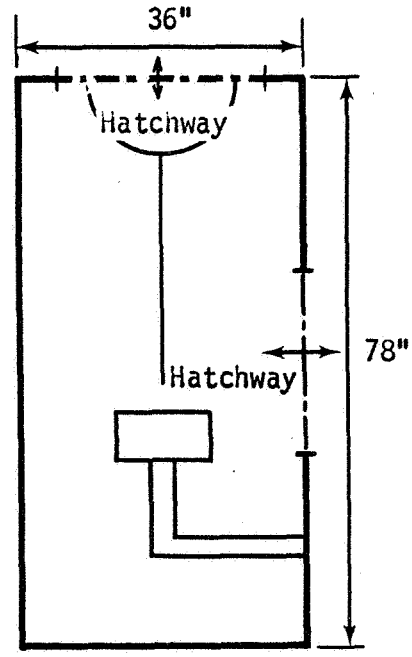
Description: Mode: Restful, mental concentration
Activity: Low
Social Factor: Private

VOLUME

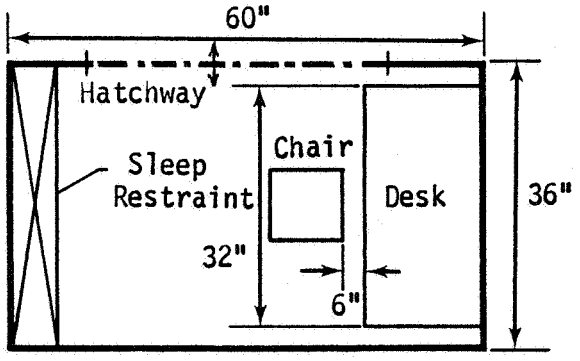
Remarks: The following examples are to be used for general guidance only for the design of a commander's stateroom. This stateroom would be part of a three-room complex including an office and bathroom with shower. The following volume guidelines apply (ft^3): Gross = 122 (25 cu. ft. for storage of clothing, personal items, controls, entertainment supplies), net (chair and table deployed) = 80.0, visual volume from sleep restraint (chair and table stowed, hatches closed) = 76, with office hatch open, visual volume from sleep restraint 163, visual volume from chair with office and hallway hatches open = 182.



Stateroom - Side View



Stateroom - End View



Stateroom - Top View

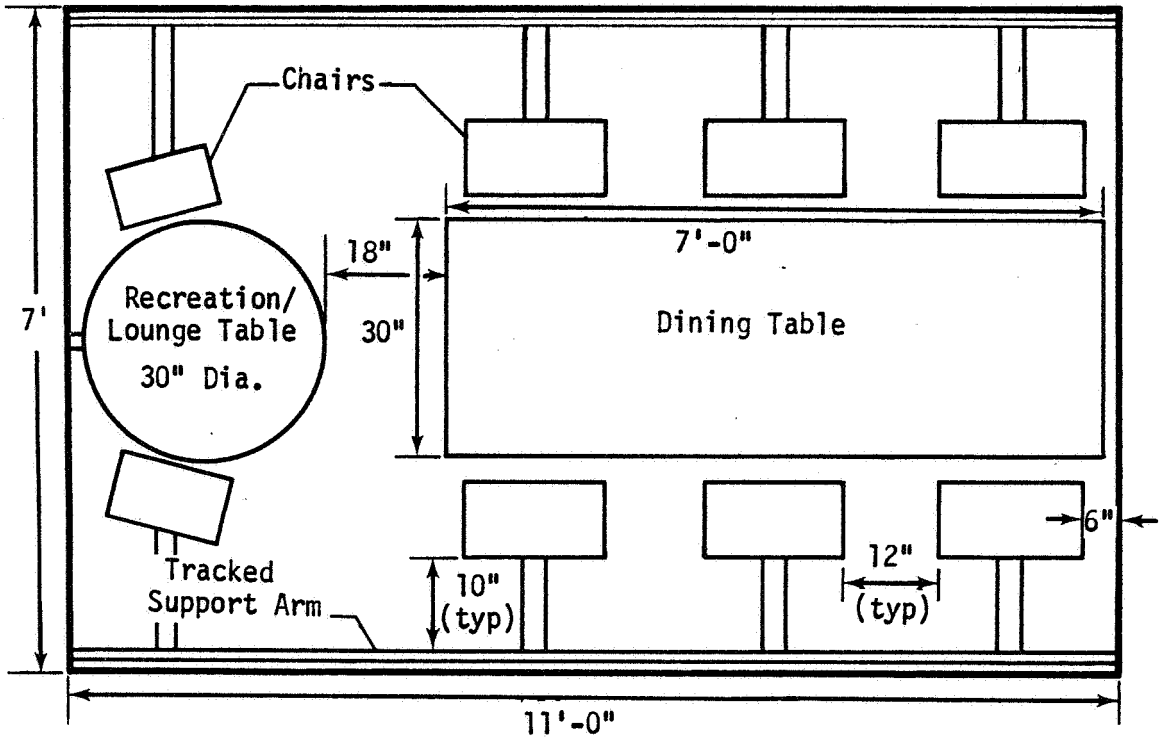
2.2 PUBLIC AREAS

2.2.1.1 Wardroom Complex

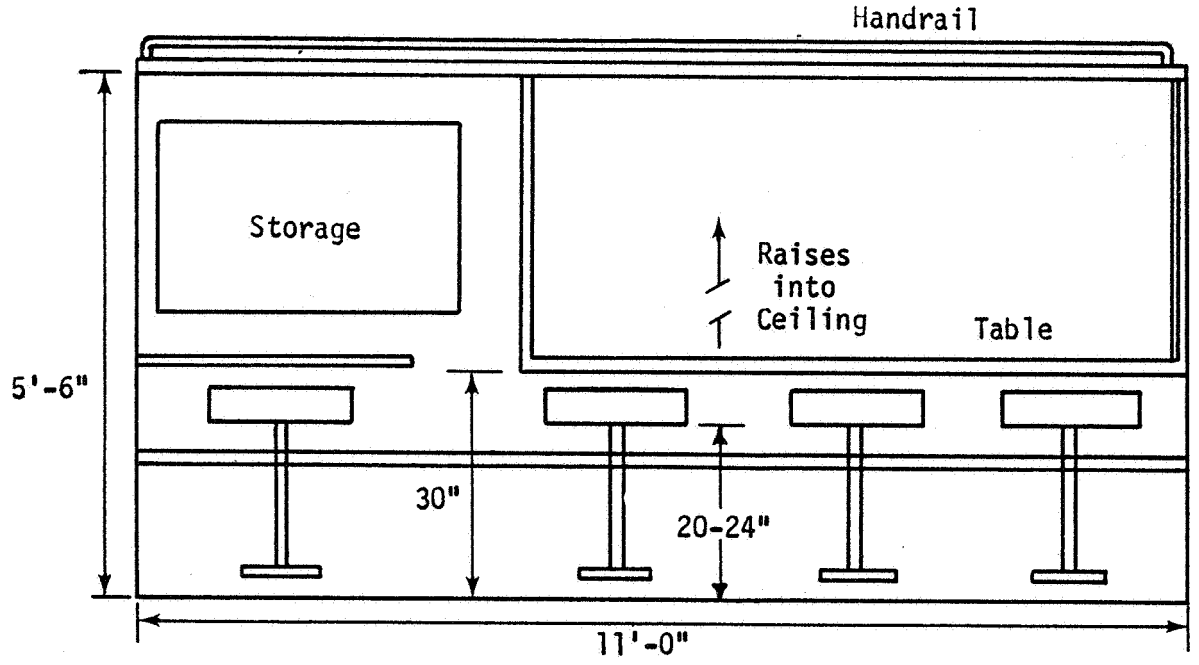
Description: Mood: Restful
Activity: Moderate to low
Social Factor: Public

VOLUME

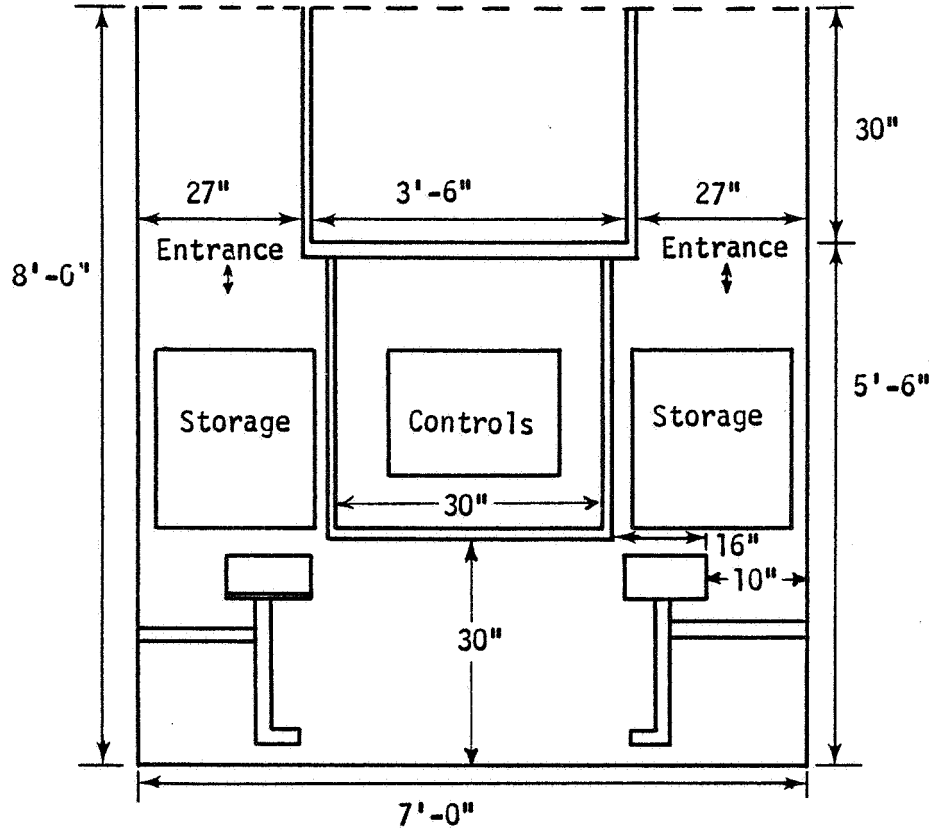
Remarks: The following example of a wardroom complex is based on a six-man crew with the wardroom serving as a dining area, lounge, recreation room, library, study and chapel. The wardroom gross volume is 444 cu. ft. (20 cu. ft. for storage of recreation equipment, conference and worship materials and controls). The net volume for dining (eight chairs and two tables deployed) is 312 cu. ft. The lounge configuration net volume (dining table raised into ceiling) is 356 cu. ft. The recreation, library, chapel, and study configurations are identical to either the dining or lounge configuration.



Wardroom - Top View



Wardroom - Side View



Wardroom - End View

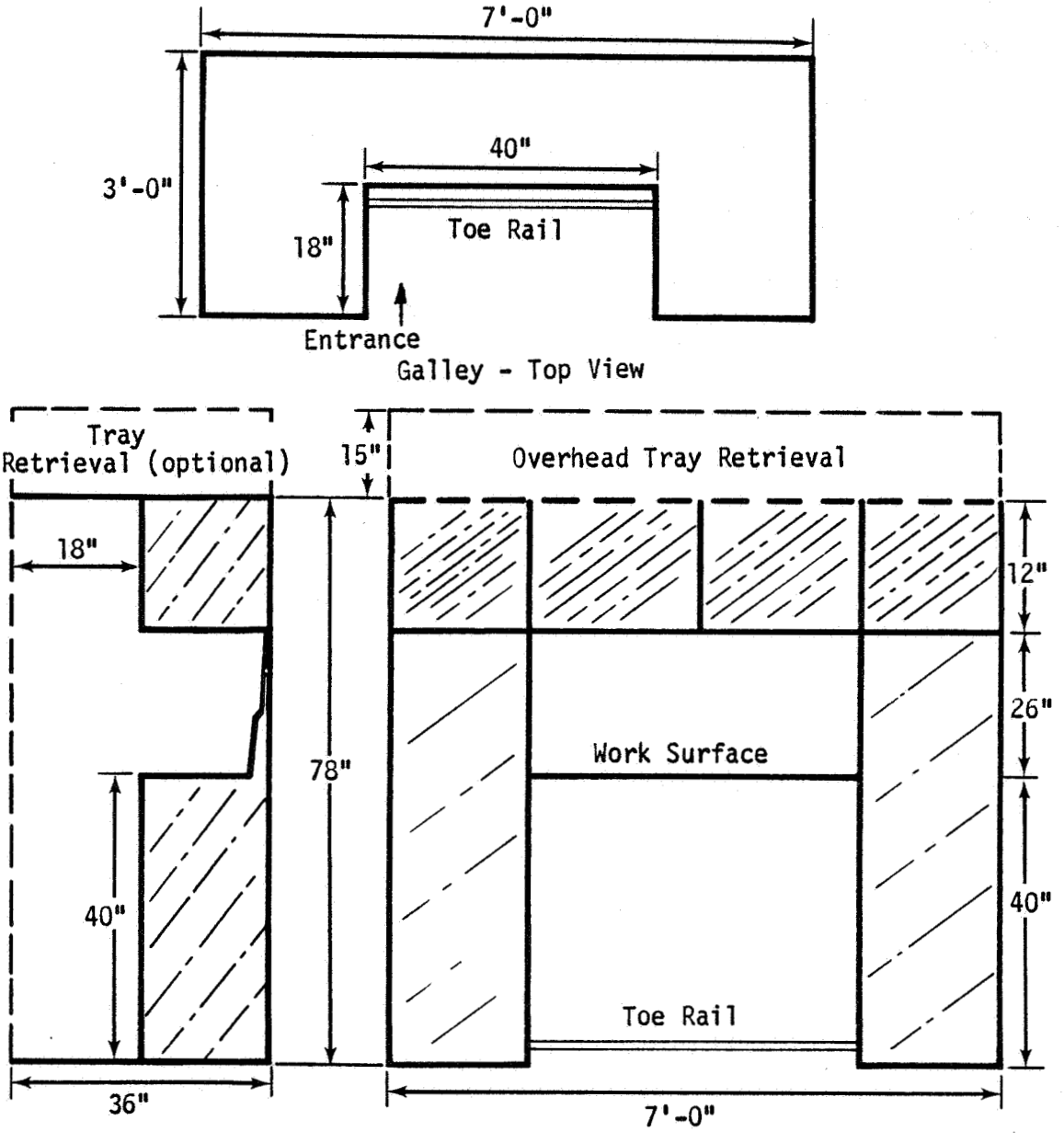
2.3 SERVICE AREAS

2.3.1.1 Galley

Description: Mood: Physical activity
Activity: Moderate
Social Factor: Public

VOLUME

Remarks: An example of a configuration for a galley in a zero gravity environment based on the premise that one of a six-man crew act as galley attendant during food preparation and cleanup after meals is given below. Individual crewmen would pick up their prepared trays at a retrieval point accessible from outside the galley, then transfer to the dining area. The following volume guidelines apply (ft^3): Gross = 137, net = 41. Space for food storage, ovens, refrigerator, housekeeping equipment, water system, etc. (96 ft^3) is available. This volume is sufficient for 84 man-days of supplies (6 men-14 days).

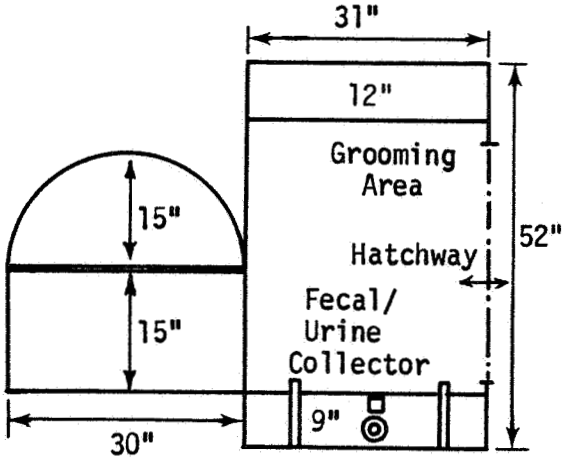

7'-0"
3'-0"
40"
18"
Toe Rail
Entrance
Galley - Top View
Tray
Retrieval (optional)
15"
Overhead Tray Retrieval
18"
12"
26"
78"
Work Surface
40"
40"
Toe Rail
36"
7'-0"
Galley - Side View
Galley - End View

2.3.3 Bathroom

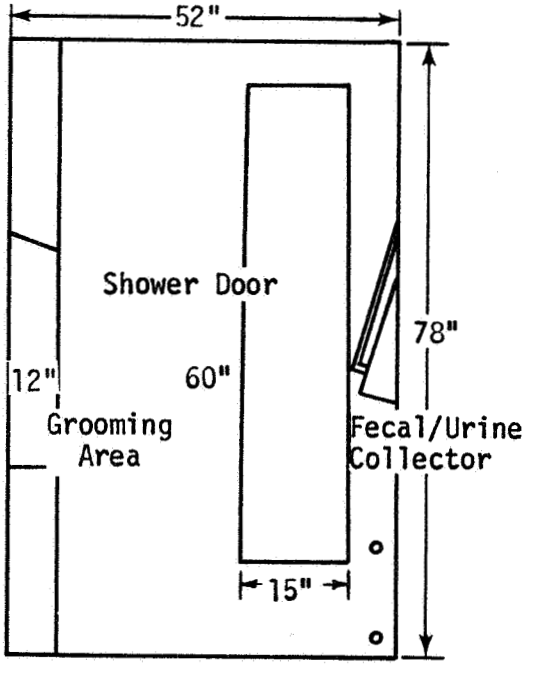
Description: Mood: Restful
Activity: Low
Social Factor: Very private

VOLUME

Remarks: The following example configuration is for the design of a bathroom which would be one room of a three-room commander's complex (see Sections 2.1.1 and 2.4.10 of this supplement). The following guidelines apply (ft^3): Gross = 109 (including 36 ft^3 for shower), net = 91 (including 36 ft^3 for shower).



Bathroom - Top View



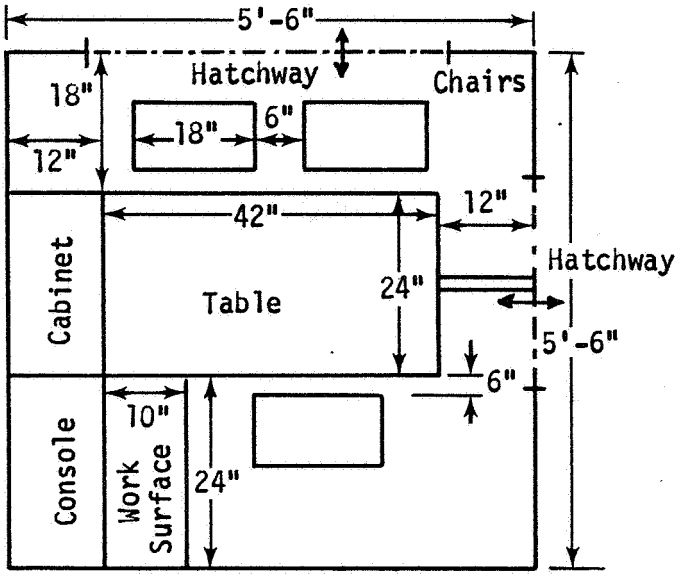
Bathroom - Side View

2.4.10 Offices

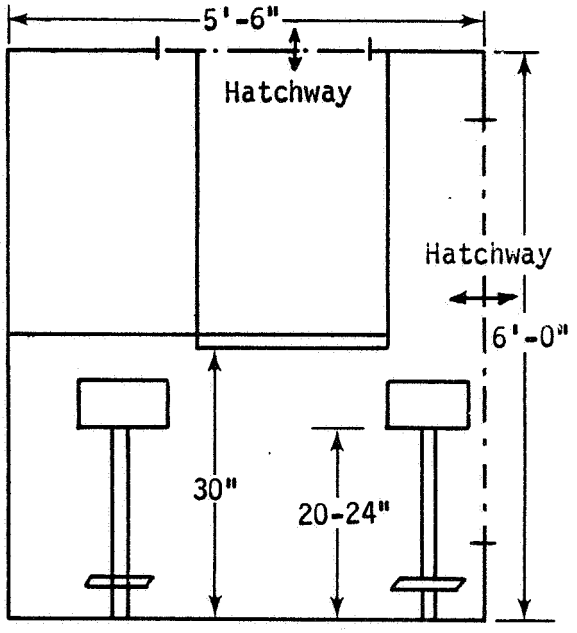
Description: Mood: Mental concentration
Activity: Moderate
Social Factor: Public

VOLUME

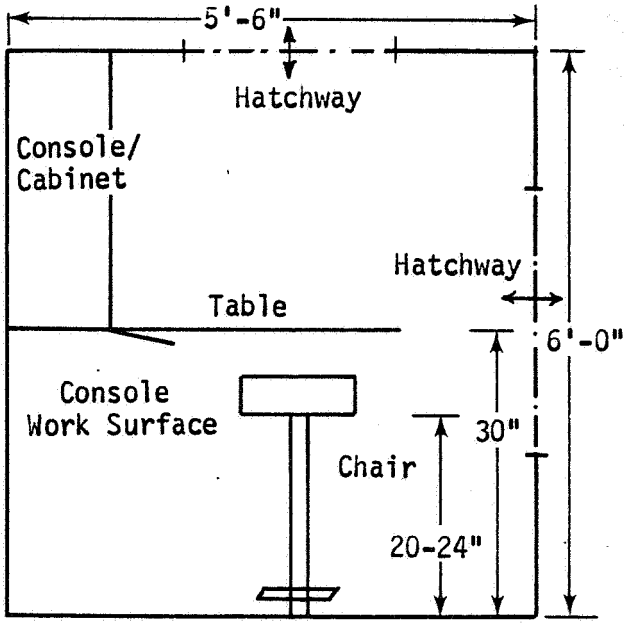
Remarks: The following example for an office configuration is for the design of a three-man office (commander and two guests) which is part of a three-room complex (see Sections 2.1.1 and 2.3.3 of this supplement). The following volume guidelines apply (ft^3): Gross = 182, net = 127, visual (from commander's chair, stateroom and hallway hatches open) = 225.



Office "D" - Top View



Office "D" - Side View



Office "D" - End View

3.0 SPECIFIC ENVIRONMENTAL ELEMENTS

3.5 VOLUME (Zero Gravity)

3.5.1 Requirements. This section defines the volume requirements for specific activities and tasks performed in zero gravity. Consideration of individual tasks, whether they are related or unrelated to each other, and the fact that they are performed in zero gravity are major factors in determining volume standards. A zero gravity environment lends itself very readily to maximum utilization of volume. Because of the freedom of movement possible, the entire available room volume can be utilized; that is, no space need be wasted and a relatively small volume will seem more spacious in zero gravity than in a one-gravity environment. Changes in body orientation within a room may be desirable or necessary; the volume requirements for such changes, and the method and ease of point-to-point transfer must also be considered. All of these items, with the zero-g environment being the basic controlling factor, must be combined to formulate specific standards for extraterrestrial habitats in which the average person can work, sleep, eat and relax comfortably and efficiently over long periods of time.

3.5.2 Definitions.

Gross Volume - Gross volume is that volume which would be available if all furniture items, storage modules, controls and control panels, and equipment were removed from the room leaving the room frame only.

Volume per Man - Volume per man refers to the numerical figure obtained by dividing the gross volume of a space by the number of occupants the space is designed to hold.

Net Volume - 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, controls and equipment are in place.

Visual Volume - Visual volume is the amount of space which is visually perceived as usable from a specified position within a room. Within any given room the visual volume is a fixed figure; portions of other rooms visible through open hatchways add to the visual volume total for a specific position.

Orientation. An individual's body position in relation to the furniture, equipment, or task around him defines his orientation. A change in orientation requires a change in the position of the body as a whole.

Task-Related Requirements - Volume requirements are based in whole or in part on the specific task being considered. Unrelated tasks can be performed in different orientations and can utilize part or all of the same volume since they would not be performed simultaneously. Related tasks require that no change in orientation occur during their performance; dual utilization of volume for these tasks may not be possible.

3.5.3 Engineering Data.

3.5.3.1 Gross Volume. Gross volume specifies the total room envelope, that is, the space within which the room must be placed in relation to an outer vehicle shell and other rooms. Table 3-37 gives the gross volume requirements for the individual rooms. The gross volume requirements for a specific room are determined by a series of analyses as follows.

All activities and tasks which are to be conducted within a given room are defined and the required volume for each is determined. The equipment and hardware, along with their volumes, required for the individual tasks are also established, as well as storage volumes for clothes. The maneuvering and orientation changes required in the performance of the tasks must then be identified. If a room is designed for multiple orientations in order that maximum volume utilization occur, sufficient space must be provided to allow for the changes in orientation to be accomplished. The volume interface requirements between man and the furniture or equipment are then identified; that is, access dimensions are specified.

Table 3-37 Room Height, Volumes in Zero Gravity

Habitability Unit	Ceiling Height (ft)	Gross Volume per Man (ft^3)
Bedroom-One man	6.5	122
Bedroom-One man with office and bath	6.5	292
Bathroom-One man, with shower	6.5	109
Bathroom-One man, without shower	6.5	73
Office (commander and two visitors)	6.0	61
Galley (one man-attendant)	7.0	137 (84 man-days)
Wardroom (serves as dining room, lounge, conference room, recreation area, etc.)	5.5	74

These individual requirements are not necessarily additive but the interrelationships must be identified so that gross room volumes can be determined. As an example of such an analysis, the stateroom defined in Section 2.1.1 of this supplement is considered.

The major activities in the stateroom are sleeping and relaxing in bed, private recreation, personal work, limited grooming and dressing. Table 3-38, referenced in Section 3.5.4 below, gives the dimensional requirements for individual tasks. For instance, sleeping requires an envelope of 36" x 36" x 78". The 36" x 78" plane fixes two of the three orthogonal dimensions for the stateroom. A 95th percentile man's height is 73 inches and approximately five additional inches are provided to establish the 78-inch dimension. The sleep restraint width is 36 inches, thus fixing the second dimension. Other activities such as changing clothes, reading or working at a desk, and limited personal grooming can all be accomplished within this envelope. In order to maximize volume utilization, the room is designed for two orientations, with don/doffing taking place in one orientation and all other activities being accomplished in the opposite, heads-up position. Table 3-38 reveals that 48" is required in two dimensions for a tumbling maneuver; this fact sets another minimum room dimension. The furniture items required in the room are a sleep

Table 3-38 Volume/Task Requirements

Task	Dimensions, in. Depth	Width	Height	Remarks
Don-Doft Clothing	30	30	78	
Hygiene				
Fecal	40	30	69	Required minimum of 40" width perpendicular to hygiene facility
Urination	30	30	73	
Handwash	30	30	73	
Sleeping	6 (front to back)	36 (optm) 30 (min)	78	More than adequate, 30-inch width is the minimum acceptable width.
Food Preparation	36	18	78	On condition that 18" width is a free dimension
Exercise (simple, one-position)	72	36	78	Good for simple, individual exercises.
Exercise (dynamic, mobile)	96	72	78	Better for more active and dynamic exercises.
Maneuverability (one plane)	48	24	48	Adequate for tumbling in one plane only.
Maneuverability (all planes)	48	48	48	Adequate for all tumbling & turning maneuvers - all planes.
Sitting	18-40	24	58-62	
Standing	18	24	73	Zero-g relaxed position reduces height
Soaring	30	24	78	

restraint, chair and desk. Figure 3-29 illustrates the access envelopes for all furniture items, storage units and equipment items. The minimum internal room dimensions determined from the analyses of the task and orientation requirements for the stateroom are 36" x 48" x 78". When the required access envelopes for the stateroom items are considered, the minimum internal dimensions specified in the example are 36" x 60" x 78". (See Section 2.1.1 of this supplement). The 60-inch dimension ensures adequate space for all activities, with several access envelopes overlapping for unrelated tasks.

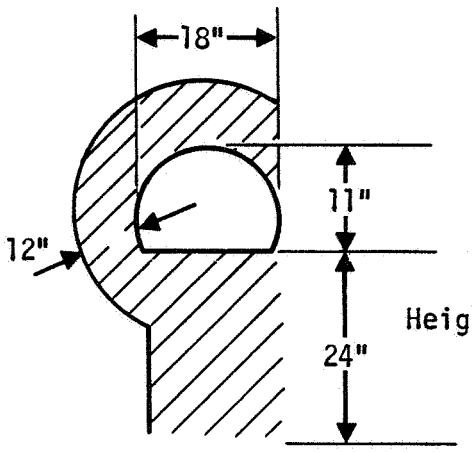
3.5.3.2 Volume per Man. Since this figure relates to the number of occupants a space is designed for, it is useful in figuring volume requirements for public rooms and other areas in which the number of occupants determines the spatial requirements of the room.

3.5.3.3 Net Volume. This figure indicates the space available in a specific room for body movement and transfer within the room, ingress to and egress from the room, and for the performance of tasks in the room. Volumes of furniture items, equipment, storage modules, consoles, etc. are not considered to be part of the net volume. Access dimensions for each item are still considered part of the net volume.

3.5.3.4 Visual Volume. The visual volume is the amount of space available for viewing from a specified location. It helps indicate the degree to which the monotony of the environment can be alleviated by opening connecting hatchways, changing positions, etc. Visual volume is a net figure; that is, the usable room volume perceived from the observer's position is the value specified.

3.5.4 Room Volume Requirements Determination - Summary. The method of determining the volume requirements for a given room (see example, Section 3.5.3.1 above) can be summarized as follows:

- Specify type of room (e.g., office).
- Determine tasks to be performed in the room. Specify required volume for each task (see Table 3-38).



NOTE: 12" chair access required only at either side or back

Chair
Height 20-24" (seat to floor)

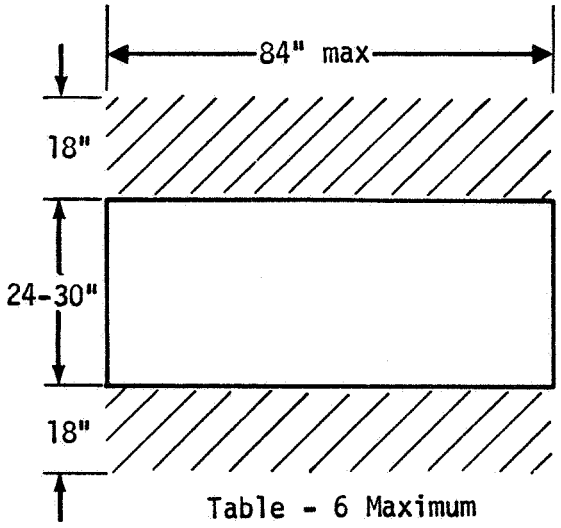
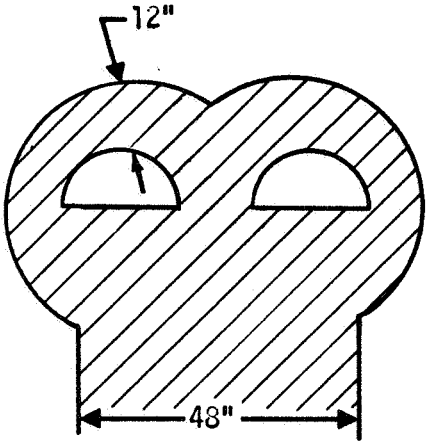
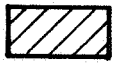


Table - 6 Maximum
Height 30"

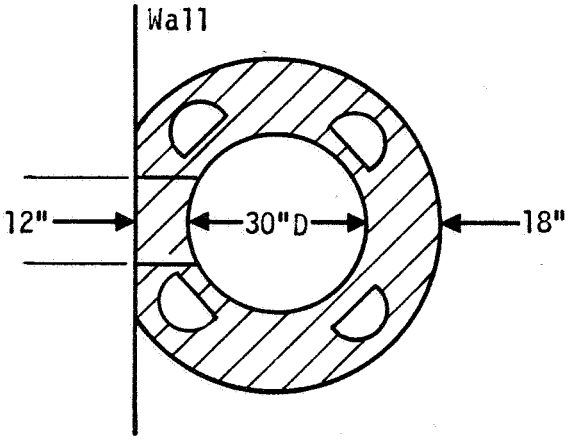


Chairs - Dining Arrangement
Side-by-Side

Item

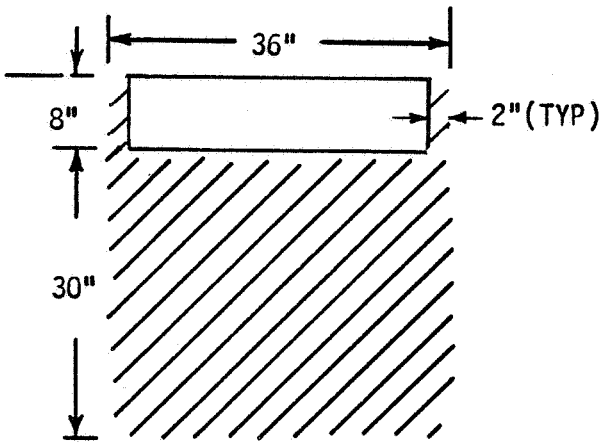


Access Space

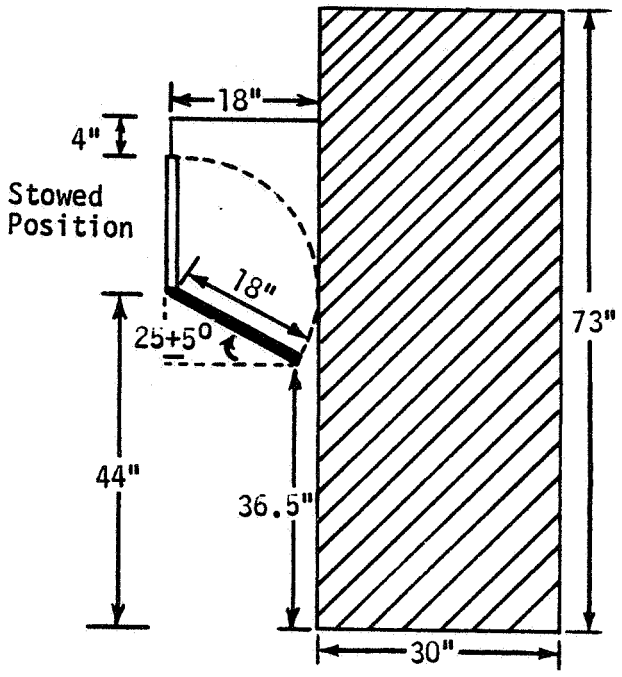


Lounge Table for 4 Maximum
Height 30"

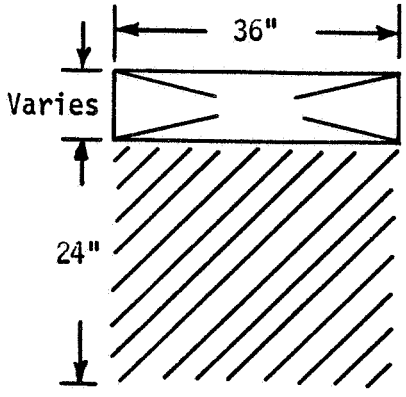
Figure 3-29 Access Envelopes - Furniture Items



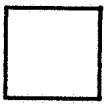
Folding Desk - top view
Height 62" (front edge)
(Stowed Position)



Folding Desk (side view)



Sleep Restraint
Zero-G Only
Height (Restraint & Access) 78"



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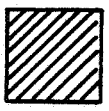
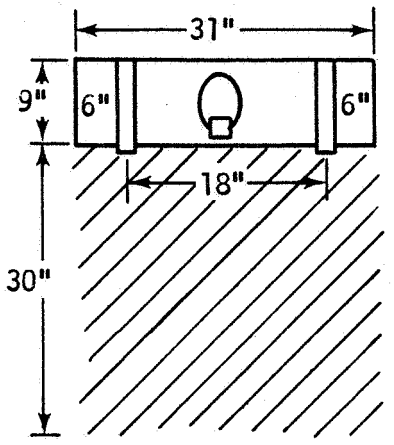
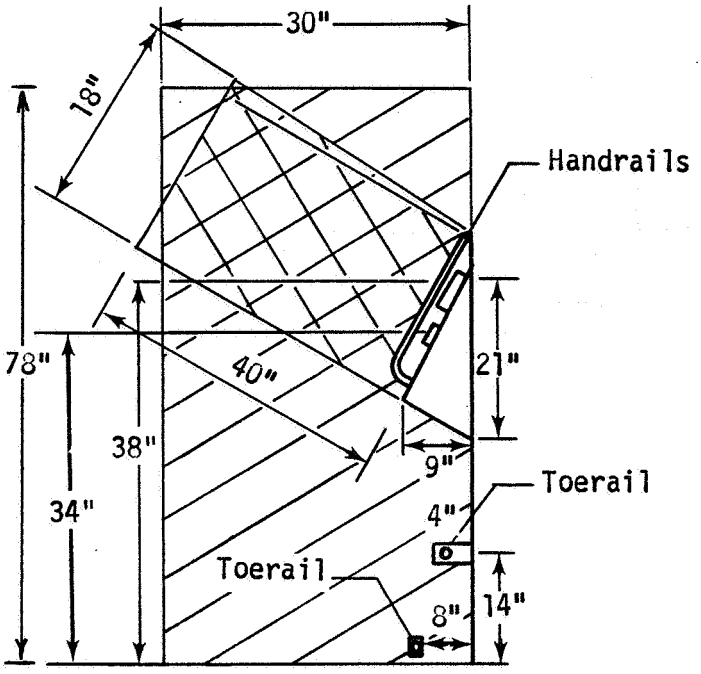


Access Space

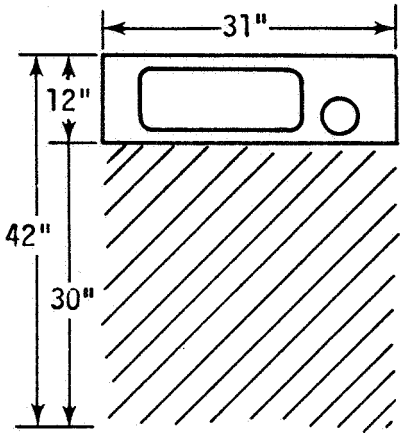
Figure 3-29 Access Envelopes - Furniture Items



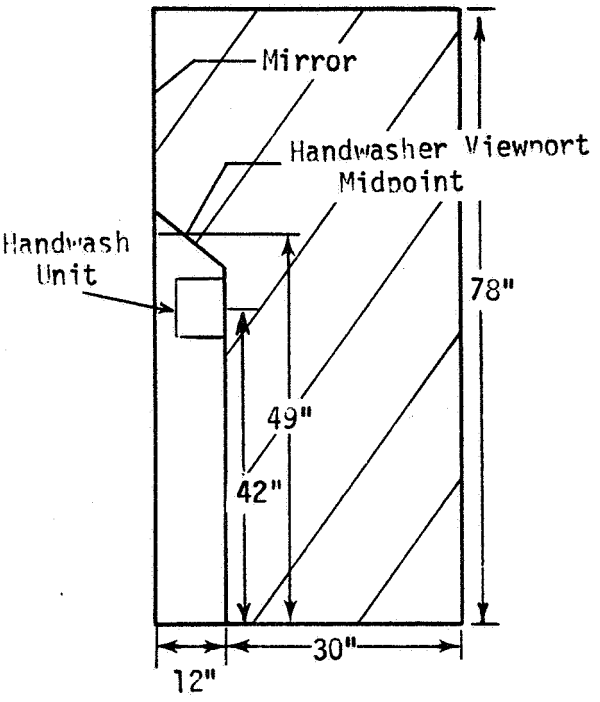
Hygiene Unit - Top View
Height 78" (Access)



Hygiene Unit - Side View



Handwasher Unit - Personal Grooming
Top View
Height 78"



Handwasher Unit - Personal Grooming Area
Side View

Figure 3-29 Access Envelopes - Equipment & Storage

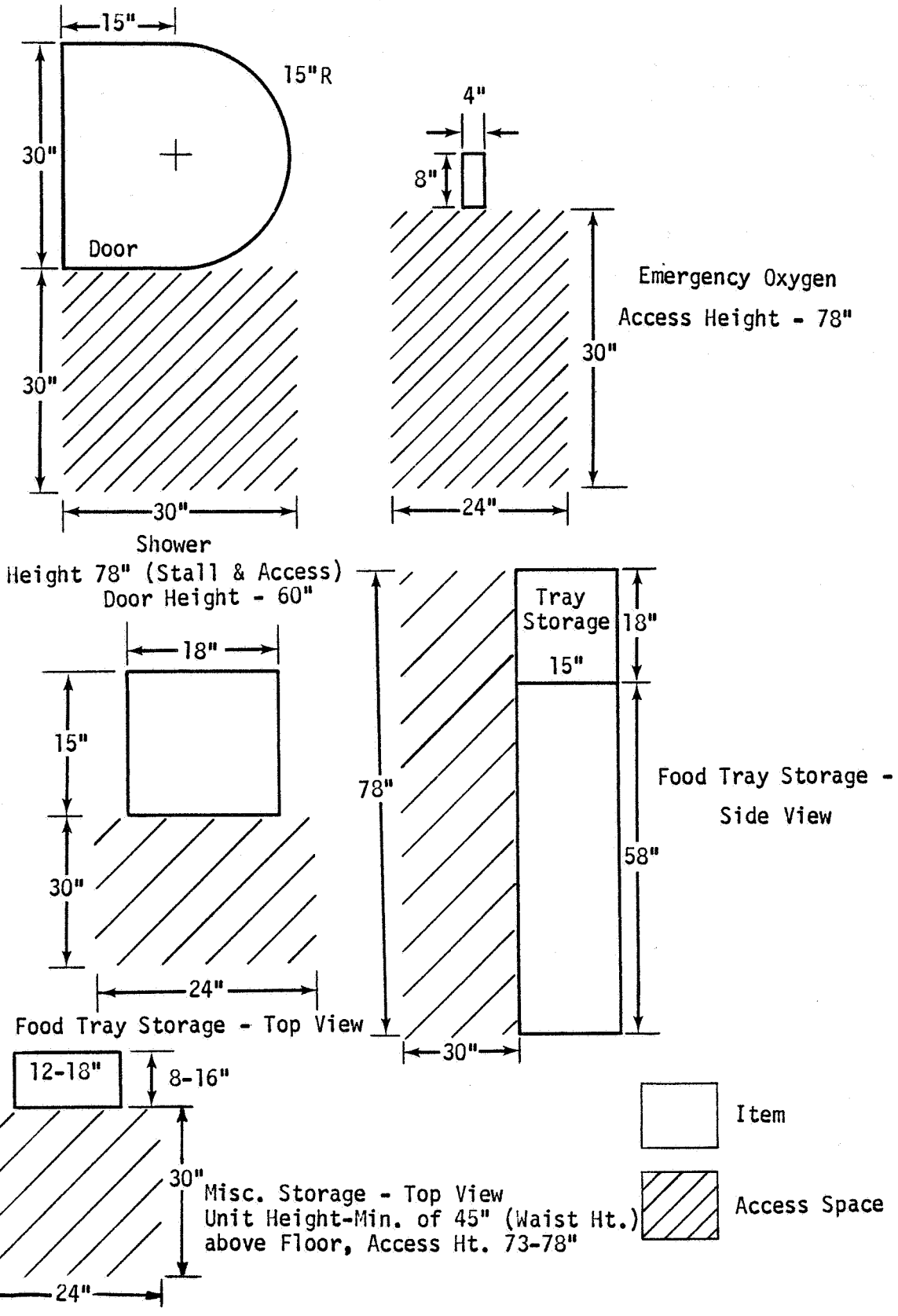
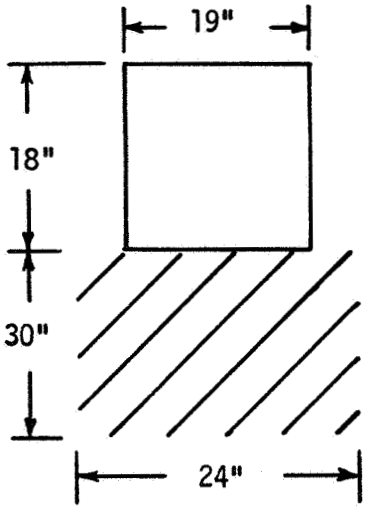
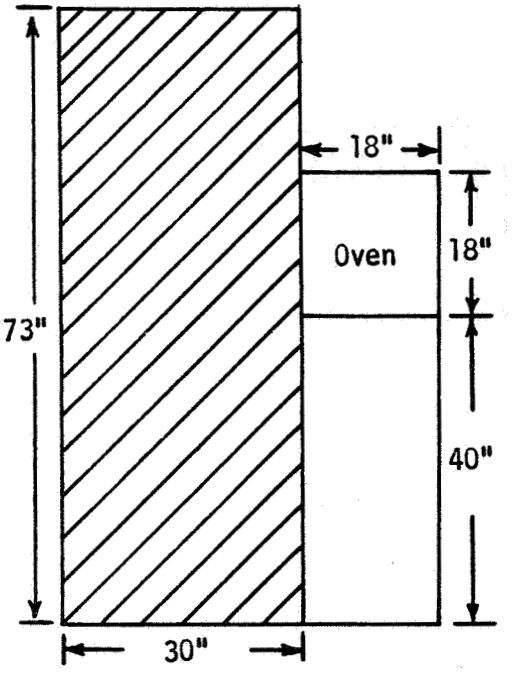


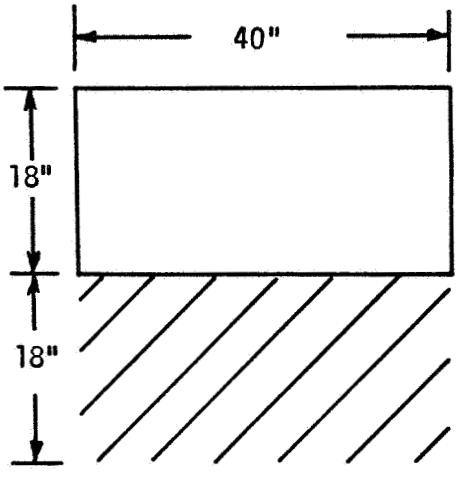
Figure 3-29 Access Envelopes - Equipment & Storage



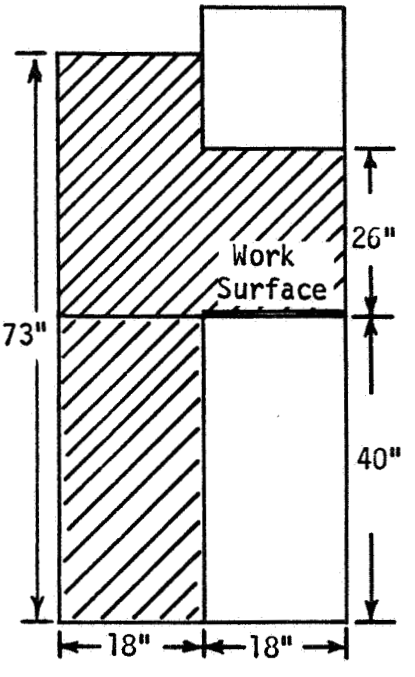
Oven - Top View



Oven - Side View

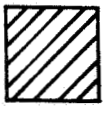


Food Preparation - Top View



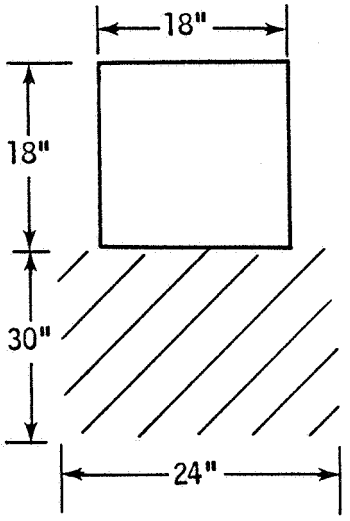
Food Preparation - Side View

Item

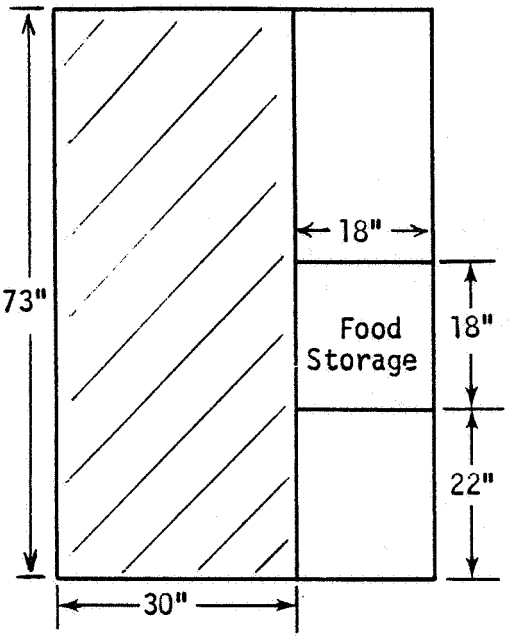


Access Space

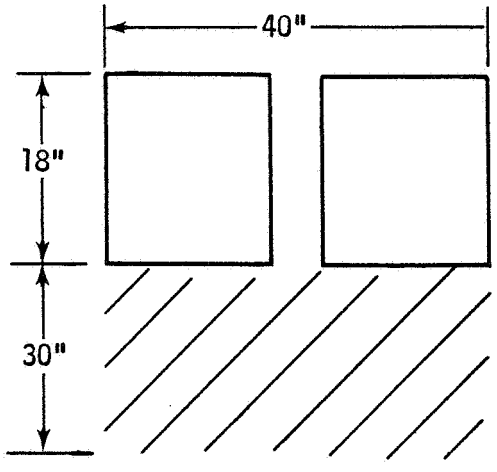
Figure 3-29 Access Envelopes - Equipment & Storage



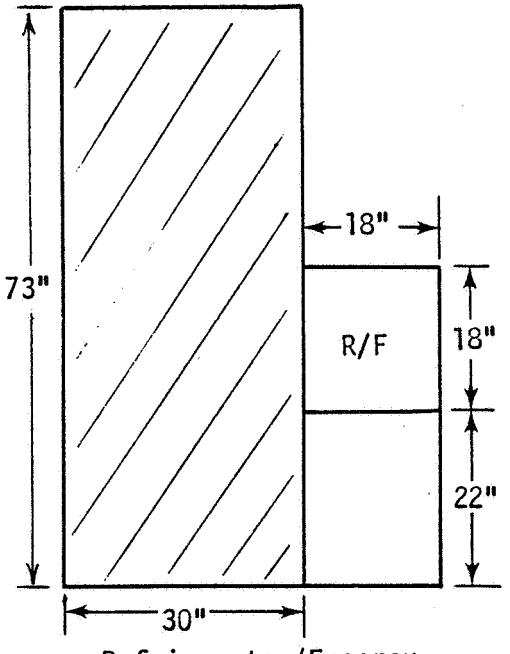
Food Storage
Top View



Food Storage
Side View



Refrigerator/Freezer
Top View



Refrigerator/Freezer
Side View

Figure 3-29 Access Envelopes - Equipment & Storage

- Determine furniture/equipment/storage requirements. Specify required volume for each item and its access dimensions (see Figure 3-29).

- Determine optimum orientation of room from above requirements, considering shared access for unrelated tasks, hatch placement and traffic locomotion patterns. Determine gross, net and visual volumes.

Table 3-37 presents minimum room volumes in zero gravity for five specific rooms. The commander's stateroom complex includes a stateroom (bedroom), office (two visitors) and a private bathroom. The galley is designed for use by a single attendant and the wardroom provides dining, recreation, lounge, conference and worship facilities for six crewmen. Refer to Section 2.0 for examples of specific room configurations.

3.5.5 Application. Specific zero gravity room volumetric standards are given in Section 2.0 of this supplement. To aid in the development of graphic layouts, selected pieces of furniture to be used in the stateroom, office, bathroom, wardroom and galley are illustrated in Figure 3-29, with acceptable standard dimensions given where appropriate. In addition to the furniture dimensions, the related access dimensions for each item are shown.

3.6 EQUIPMENT DESIGN FOR MOBILITY AND RESTRAINT AIDS

3.6.1 Requirements. This section defines the design criteria developed for mobility and restraint aids for use with the furniture items and equipment defined on an architectural basis. Volume 1 of this handbook, MSC-03909, Mobility and Restraint gives data applicable to all habitability areas. Data presented here are consistent with the design criteria given in Volume 1 as applied to specific architectural areas in a zero-gravity environment. The number and location of mobility aids and restraints in specific rooms are defined by general guidelines, task requirements, and by overall room design.

3.6.2 Definitions.

Restraint - A restraint is any device which serves to keep an individual at a specific location for a desired period of time. The amount of body movement possible while a restraint is in use varies with each restraint. A given restraint can be attached or applied at one or several points on the body; restraints can also be used in combination if necessary. Restraints can also serve as mobility aids.

Mobility Aid - A mobility aid is any device which facilitates movement by an individual from one point to another. Mobility aids enhance the individual's locomotion, orientation, control and stability. Certain types of mobility aids can also serve as restraints.

Locomotion - Locomotion is the ability to move from one point to another. In zero gravity direct, point-to-point transfer is often possible and desirable.

Orientation - Orientation refers to the ability to determine body attitude with respect to some reference system.

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

Stability - Stability refers to the ability to maintain a desired orientation.

3.6.3 Engineering Data.

3.6.3.1 General Guidelines. The following general guidelines, in addition to those given in Volume 1, must be considered in the equipment design of restraints and mobility aids for use in zero gravity.

- Furniture items should be designed with rounded edges, 3/4" radius lips, and smooth surfaces which can be used as handholds or mobility aids.
- Handholds must be within reach from any given location.

- Toerails and handholds must be of sufficient length to allow easy access without searching.
- Zippers used on sleep restraints must be usable from both inside and outside.
- Chair restraints must not restrict head and upper torso movement.
- Chair seat must swivel (30 lb. force to activate) and have vertical adjustment.
- Lap restraint or toerails must not place undue stress on any muscle of the body.
- A minimum of two contact points are required to maintain body position and control.
- Simple specific restraints must be provided for such items as clothing, towels, writing materials, and food trays.
- Feet are usually used to provide propelling force; hands are used to control direction.

3.6.3.2 Task Requirements. Restraint and mobility aid designs are determined in part by the specific tasks which must be performed within a given series of rooms. Table 3-39 shows the restraints and mobility aids which are required for individual tasks. The toerail is favored over foot restraints in most applications since it requires less searching and allows more flexibility of position. Specific handholds are placed only at task stations such as hatches and the hygiene unit and where non-specific aids (e.g., furniture items) are not within reach. The actual number and location of specific mobility aids and restraints are affected by the specific rooms in question, and their location and orientation with respect to each other. Hatch positions between rooms and on hallways determine methods of ingress and egress, which in turn set mobility aids requirements. In general, all furniture items, cabinet edges and shelves should have a built-in lip which can serve as a mobility/restraint aid; this minimizes the number of specific aids required and reduces weight, clutter, etc. Hatch handholds also serve as mobility aids and, as in the case of relatively small, single occupancy rooms, may be the only specific handholds required in the room. Similarly, mobility aids required in a single occupancy, multiple orientation room differ from those required in a multiple occupancy,

Table 3-39 Restraints/Mobility Aids and Furniture Accessories for Each Task

Task Element	Restraint/Mobility Aid
Sitting	Lap belt, toe restraint or foot restraints.
Standing	Foot restraint or toerail, handhold or rail.
Sleeping	Sleep restraint with adjustable belt at chest.
Stowage	Various restraint aids such as velcro strips, bungee cords & snaps.
Don/Doff Clothing	Wedging in small room (obtaining support from two parallel walls), handhold & toerail.
Hygiene Tasks	Handholds & toerail for fecal & urine collector. Handhold & toerail for standing up to mirror. Lap belt on fecal collector seat.
Maneuvering or Translating	Various handholds such as hatchway opening, hatchway handles, chairs, tables, other available objects.
Entering or Exiting Chair & Table	Lip on chair, chair seat or top, toerail & table.

single orientation room. The former is relatively small with a minimum of furniture items and may require mobility aids to facilitate orientation changes when furniture items are stowed. The latter room is more spacious with more complex furniture configurations; non-specific mobility aids such as tables and chairs may be used to a greater extent in such rooms.

3.6.3.3 Restraints/Mobility Aids Definition. Testing in a neutral buoyancy environment revealed that for the tasks and rooms considered two specialized restraints were required and two types of non-specialized restraints/mobility aids (interchangeable) were necessary. Non-specific mobility aids (chair seat lip, table edge, etc.) are also required. A lap belt for use on the chair seat and a sleep restraint were the specialized devices; the non-specialized devices were a handrail or handhold and a toerail. Table 3-40 gives the specific definition of each of these devices. The recommended restraints/mobility aids are very simple; nevertheless, their applicability and effectiveness have been completely verified for the crew areas identified in Section 2.0 of this supplement. Little or no maintenance of the devices would be required. Figures 3-30 through 3-32 depict the approximate reach envelopes for the toerail, handhold and chair restraint.

Table 3-40 Restraints/Mobility Aids Definition

Restraint/ Mobility Aid	Dimensions	Location	Remarks
Foot	1" dia - Rectangular 8" x 18", 4" above floor surface.	At chair base	Configuration of feet can be changed often, with restraint.
	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° 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.

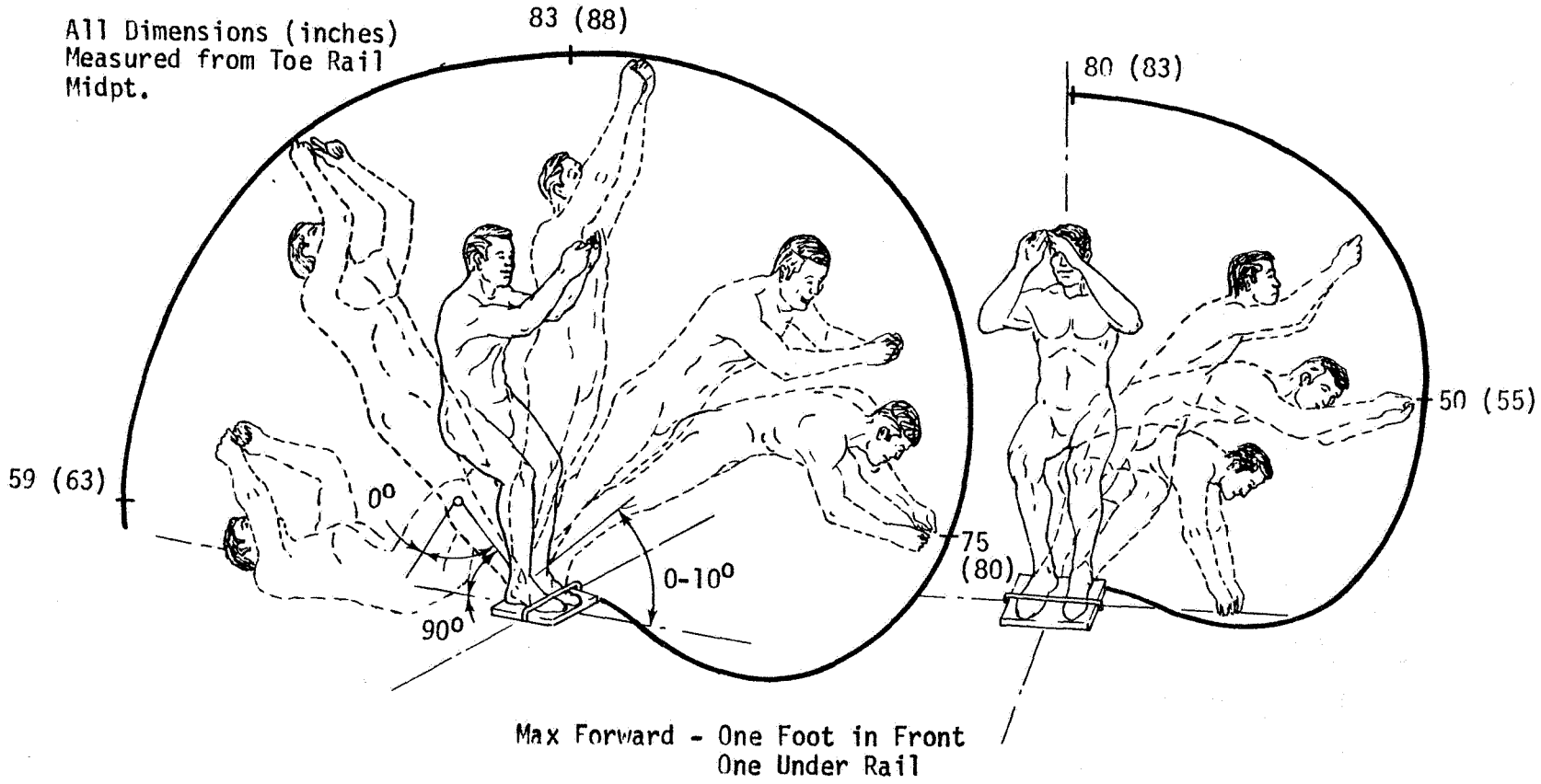


Figure 3-30 Toe Rail Functional Reach - 50th (95th) Percentile Man

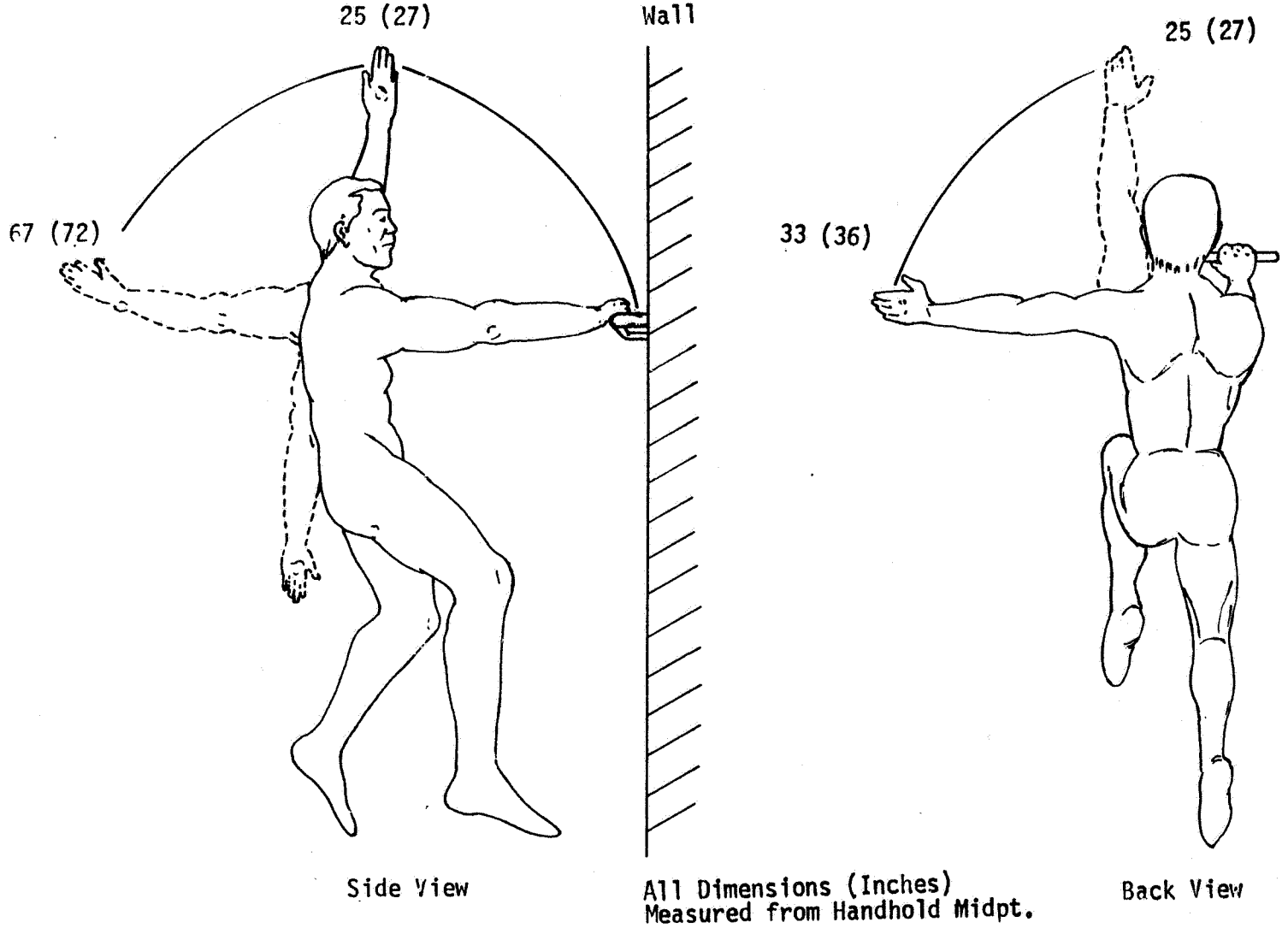


Figure 3-31 Handhold Functional Reach - 50th (95th) Percentile Man

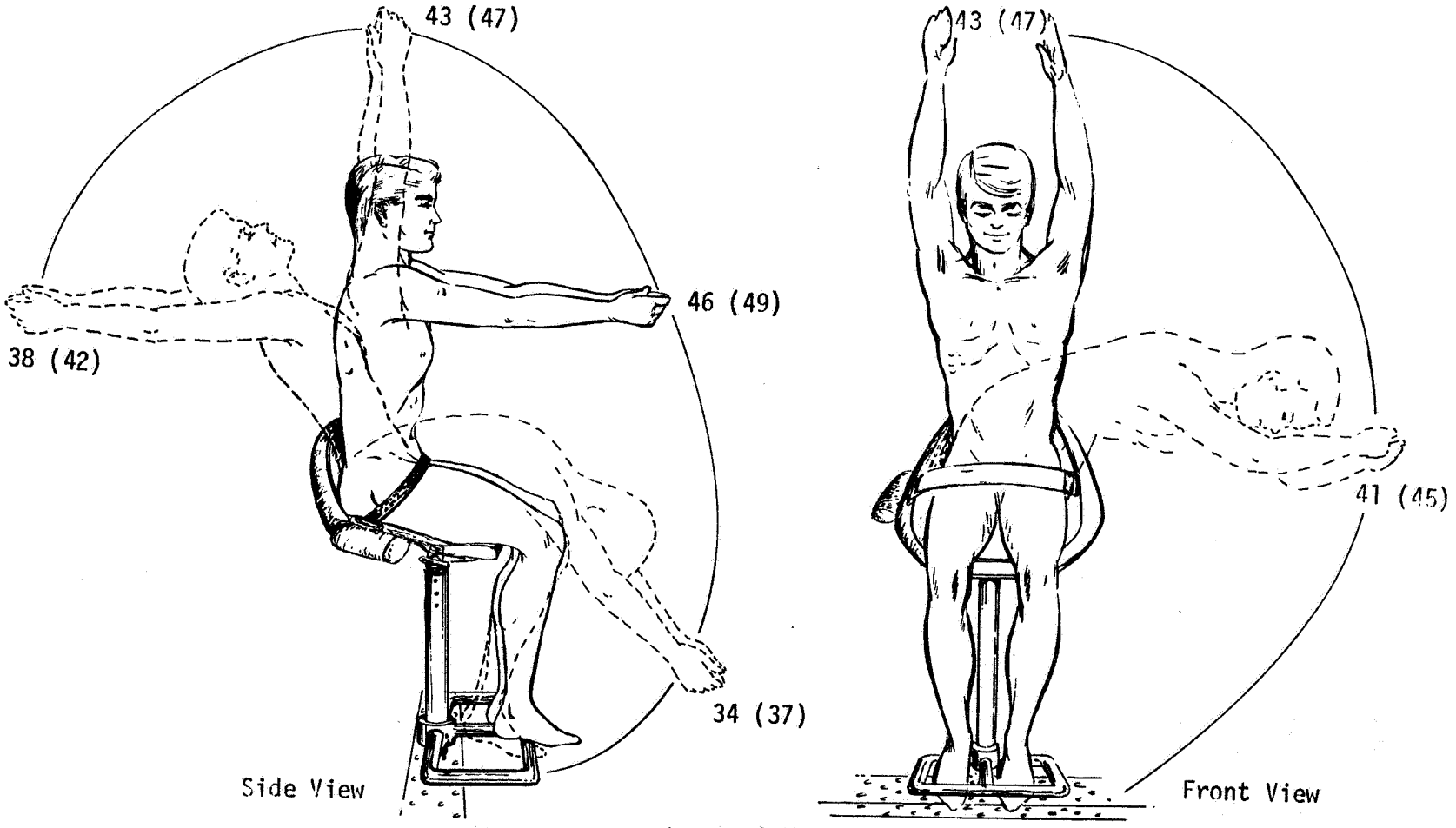


Figure 3-32 Chair Restraint (Lap Belt + Toerail) Functional Reach - 50th (95th) Percentile Man

3.7 SPECIFIC ZERO GRAVITY DESIGN CONSIDERATIONS

Several areas exist where specific design criteria for zero gravity environments have been identified. Those criteria are presented in the following paragraphs along with a brief discussion of each area.

3.7.1 Locomotion. Movement from one point to another in zero gravity affects and is affected by actual room design. The method of transfer is different from normal one-gravity locomotion in that relatively large periods of time can occur when the body limbs are not in contact with any surface. A means of maintaining control over the rate and direction of movement must be provided. The soaring position normally assumed in zero-g transfer (see Figure 3-25) leaves both the hands and the feet free to be used to initiate, control and terminate a transfer sequence. Direct point-to-point transfer is the most preferred method in a zero gravity environment especially when transporting objects in one's hands.

The following design criteria apply:

- All furniture items, cabinets, walls, surfaces and storage spaces, besides specific handholds and toerails, should be designed for use as mobility and restraint aids. All edges and corners should be rounded to provide safe surfaces for grasping. Any and all surfaces will be used by crewmen for stabilization and control, although deployed furniture items are always preferred to flat surfaces such as walls.

- Direct transfer is always desirable. Furniture and equipment within rooms should be placed so as to minimize interference along preferred transfer routes.

- Methods for carrying small objects (food trays, books, personal Items) while leaving the hands free should be provided.

- Limitations on direct transfer, such as prohibiting soaring over the dining table, can be established in specific situations, but the basic guideline should be to allow freedom of path selection wherever possible.

- Two points of mobility aid creating a coupling moment are sometimes necessary to maintain straight point-to-point transfer.

- Handholds and toe rails should be designed for complete interchangeability; that is, any toe rail should be capable of serving as a handhold.

- Specific mobility and restraint aids should be located only where non-specific aids are not within reach. In many cases, for example, formed 3/4" radius lips on shelves or cabinet edges can be used in lieu of specific handholds.

3.7.2 Zero Gravity Man. Design of rooms or areas which are to be inhabited by man in a zero gravity environment requires a knowledge of the dimensional envelope man occupies during various tasks (see Table 3-38). For many tasks the man model for zero gravity is identical to that for a one-gravity environment; orientations may differ but the envelope is the same. Sleeping in zero gravity, for example, could be accomplished on a wall rather than in a one-g orientated floor mounted bed.

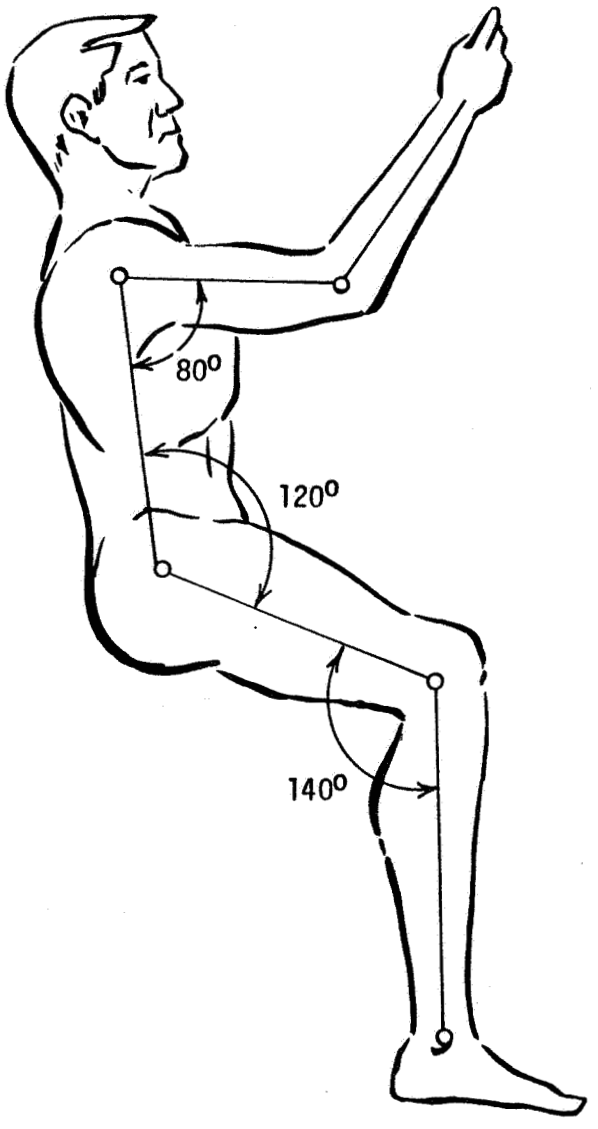
Some tasks are not performed in the same manner in the two environments. For example, walking in one-g becomes soaring in zero-g. The overall envelopes are similar but walking is performed in one orientation while soaring can be accomplished in any orientation relative to room furnishings.

Figure 3-33 shows the relaxed position assumed in a neutral buoyancy simulated zero-gravity environment. This position, applied to true zero-g conditions, is theoretically independent of local orientation.

The man/task definition establishes guidelines which should be used to formulate total volume estimates. An analysis of task requirements for each room, which includes the man model envelopes, can be used to establish room dimensions.

3.7.3 Door/Hatchway Design. The design of doors and hatchways for zero gravity use is impacted primarily by the soaring method of transfer and the ability of crewmen to use both hands and feet for maneuvering. The cross sectional area which a man in a soaring attitude presents to a hatchway is much smaller than that for a walking man in a one-g doorway. Either a head-first or feet-first method can be used.

Sliding door hatches utilize minimum volumes, as opposed to hinged doors which swing out into some portion of the room. Specialized requirements, such as for a shower stall, may dictate the use of a hinged doorway, how-



- No Points of Contact Between Body and Any Surface
- Air Capacity of Face Mask and Chest Cavity Tends to Elevate and Straighten that Portion of Body to Normal "G" Configuration During Simulation in Water

Figure 3-33 Neutral Buoyancy - Relaxed Position

ever. In those cases, space reductions must be sought in other areas. For example, the shower stall is always entered and exited by a man in the same orientation, and the dimensions for the shower door are 60" x 15". The following design criteria apply:

- Simultaneous two-man access is required in all hatches except for single-occupancy rooms. Minimum hatch dimensions are 30" x 30" (single passage) and 30" x 48" (double passage).
- Hatch handholds should be at least 18 inches long to facilitate the use of either hands or feet without searching.
- Hatches often serve as pivot points for reorientation between rooms; that is, reorientation is accomplished during passage through the hatch.
- Doorways can be utilized to increase visual volume by being larger than required for entry and exiting. Visual volumes for single occupancy rooms can be significantly increased by using large doorways.
- Size and location of doorways is also dictated by room orientation. Hatchways utilize valuable wall space but economies can be maintained by using ceiling hatches, for example, whenever possible.
- Sliding door hatches should be oriented so that the normal method of operation would be to slide the hatch to either side.
- All hatches and main passageways must accommodate a pressure-suited crewman for emergency situations (min. 30" x 30").
- Hatches and hatch handholds should be designed to act as cues to room orientations. Any required reorientation will normally be accomplished as passage through the hatch is performed.

3.7.4 Furniture Design. The design of specific furniture items for zero gravity is based on anthropometric considerations, functional requirements of the item, and the interfaces between man and the furniture item and between different furniture items. Access dimensions for a given item are determined in part by its design; overall room dimensions are affected by these access requirements. The following design criteria apply:

- The chair seat height above the floor should be 20-24 inches.
- Two points of restraint on the body should be provided for a chair restraint-lap belt and toe rail.

- Table height should be 30 inches.
- Desk height should be 42 inches.
- The distance between the vertical portion of the chair back and front table or desk edge should be 16 inches.
- Chair seat slope should match man's relaxed position in zero gravity (approx. 20^{o} below horizontal).
- Maximum volume utilization in zero-g may be obtained when the man/furnishing interface takes advantage of the diagonal dimensions in a given room (e.g., fecal collector 30^{o} off vertical).
- Chair backs and table edges should have rounded 3/4" lips to facilitate their use as mobility aids.
- The sleep restraint should have an internal restraint to be applied to the chest, if required by the crewman.
- Zippers, such as might be employed on the sleep restraint, should be operable from both the inside and the outside.
- Chair height should be adjustable (8 lb. force to activate).
- Fold-away or swing-out designs for chairs, tables and desks should be considered for maximum volume utilization.
- Chair should swivel as required; toe rail should swivel with chair (e.g., spring-loaded ball, 30 lb.).
- In a desk/chair combination the desk should be adjustable (surface angle, distance to chair) from a restrained position in the chair.
- Swing-out doors used in storage cabinets or work areas must be above knee level (22") from the floor if a toe rail restraint is used at that position.

3.7.5 Related Design Factors. The following design criteria, although not directly applicable in any of the above areas, are presented as meaningful extensions of the data developed.

- Point-to-point transfer routes are especially desirable when a crewman is carrying an object, since his hands may not be free to provide the guidance and control required for a change of direction.

- Proper access dimensions can be critical in such areas as the dining room; interference during eating can be very disturbing. Minimum distance between chair sides for dining table is 12 inches.

- During don/doffing of clothing crewmen frequently require two points of contact with the surrounding room (e.g., one foot in toe rail and one hand on wall), and this should be considered in room design and restraint placement.

- Shoe design should include reinforced upper surfaces and toes to reduce wear.

- If a sleeping bag type of sleep restraint is used, an interior chest restraint is required to restrain the upper body (see Section 3.1 above).

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

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

- Arrangement of furnishings, coupled with use of cove-type ceilings, divider screens, windows where feasible, large radiused corners and proper placement of hatches all should be used to increase the volume visually perceived.

4.0 RELATED ENVIRONMENTAL ELEMENTS

4.4 GRAVITY

4.4.3.2 Artificial Gravity. In the performance of psychomotor tasks in artificial gravity (eye and hand coordination) the greater the range or speed of arm motions, the more accuracy declines, the more difficult the task becomes and the greater is the affect of fatigue. Increasing rotational rates increase the task difficulty; radial orientation with respect to the axis of rotation provides the best performance (1).

Both radial and tangential locomotion can be readily accomplished at rotational rates of 3, 4 and 5 rpm during simulated artificial gravity (2). Tests revealed (2) that tangential locomotion and cargo transport was relatively easy at 40, 60 and 70-foot radii on a flat floor. Body control was somewhat difficult to maintain, however, at the 40-foot radius at 3 rpm due to a lack of traction and the tendency of the flat floor to seem tilted.

No preference for either the pro- or anti-spin direction was exhibited during ascent or descent in the radial direction; climbing effort can be reduced by progressive spacing of ladder rungs (greater spacing close to center of rotation).

REFERENCES

NOTE

The primary source of data for this Supplement was Reference 1. Artificial gravity data was taken from References 2 and 3.

1. "Neutral Buoyancy testing of Architectural and Environmental Concepts of Space Vehicle Design," Martin Marietta Corporation Report MSC-03773, March 1972.

2. "Some Aspects of Locomotion and Cargo Handling in Simulated Artificial Gravity," by Green, J.A., Piland, W. M., Stone, Jr., R. W., AIAA Paper No. 71-886, Reprint from AIAA/ASMA Weightlessness and Artificial Gravity Meeting, Virginia, 1971.

3. "Initial Assessment of Various Human Behavior Capabilities in a Rotating Environment," Peacock, J.L., Green, J.A., AIAA Paper No. 71-888, Reprint from AIAA/ASMA Weightlessness and Artificial Gravity Meeting, Virginia, 1971.