NASA Contractor Report 3941

Space Station Architectural Elements and Issues Definition Study

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SPACE STATION ARCHITECTURAL ELEMENTS AND ISSUES DEFINITION STUDY

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SUMMARY

The Space Station will ultimately be judged in the commercial sector by the same economic standards used to evaluate most surface buildings. On the surface, square foot of functional work space and human productivity are the users' criteria for judgement. In orbit similar criteria will be used, but microgravity introduces the opportunity for innovation. Five subject areas were explored for research issues. The topics researched were Cylindrical Shell Wall Characteristics, Interior Arrangements, Utility Routing, Sleep/Personal Quarters and Commercial Work Volume. Each topic was defined, expanded with innovation to produce alternative design solutions, examined for research questions and then the research questions were summarized.

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INTRODUCTION

The study is an innovative look at five selected topics within the future NASA Space Station. These produced new concepts, which were expanded and explored for research issues. The next step is a series of scale models expanding the concepts uncovered.

STATEMENT OF THEORY & PHILOSOPHY

The Space Station will play host to a wide variety of users over a ten year or longer operating life time. These users will have diverse and sometimes conflicting requirements and goals. However, the majority of users will have at least one common goal. That goal will be to use their time onboard the station as productively and efficiently as possible.

Designing a productive work area and work station will require a significant understanding of the user needs and requirements. At this early stage in the station development, significant user requirement information is not available. As the overall station evolves, more user requirements will be established. For the purpose of this study, we have identified some basic needs the majority of users would have and focused on an approach in which flexibility and adaptability are main design drivers.

Projecting some current trends in the development of Earth based work stations may provide an insight into potential problems and opportunities in space based work stations. Historically, technological innovation and change have occurred at a faster rate than economic and social trends. A prime example of this phenomenon can be observed in the business and personal computer industry. A potential user often is faced with a decision not of what to buy, but when to buy. The computer industry is inventing new equipment and programs at an accelerating rate. A computer purchased one year ago may be outdated. The way in which the computer industry and user market is coping with these accelerating changes is by designing and buying modular components that plug into a main system and help keep the overall system updated. This plug in approach can apply to the Space Station design approach.

Technological innovation and dependency also puts a strain on the service systems that support the equipment. Keeping up with the ever increasing demand for more energy, more telephone and computer hookups, new fiber optics and other systems has greatly affected many existing structures and had a significant impact on the current design approach to new buildings including housing. Today, architects and developers are increasingly concerned with providing adequate utility and service space and service expansion space than they were only five years ago.

The commercial user may look at the Space Station as a combination of a research laboratory, office building and hotel in space. The user will be expending a significant investment in the lease of space onboard the station and will expect all the needed services and accommodations.

The office automation revolution is not just technological. It is also influenced by the social and human factors issues which effect the quality and quantity of work performed. Modifying the work environment and the work station toward greater human productivity has taken an increasingly significant role in the planning, design and cost of development strategies. Enhancing human productivity by integrating the technology, the work environment and the training programs has had a positive effect on efficiency and increased the return on investment in many cases.

Continued research in the following main areas is recommended, but outside the current scope of the present contract.

- Marketing studies to further define potential user needs.
- Clarification of the term "human productivity."
- Creation of a Scenario where NASA could take a leadership role in the Human Productivity Trend by performing the research for Space Station and encouraging the dissemination to society. NASA-Ames is located in the "Silicon Valley" geographic area, and an ideal opportunity exists to combine NASA-Ames research, Space Station and Office Automation for the near term benefit of society.

METHODOLOGY USED

Five topics are chosen in accordance with the statement of work, as first priority and budgeted for 80% of the effort. Each topic is researched in a variety of publications dating as far back as Skylab and as near term as the Concept Development Group. The topic is defined as far as possible without being restrictive in the conceptual design stage. The goal of the research is to determine previous work on the topic. The critical issues are listed and expanded. Second and third priority topics are discussed in text and graphic form. These topics are budgeted for 20% of the effort.

The critical issues are explored conceptually from several different perspectives. The conceptual designs explore the areas sometimes overlooked in previous designs. These alternative conceptual designs are compared to previous thinking in the same general topic area to determine the differences and similarities.

The study was broken into the following tasks:

- SELECT 5 EACH FIRST PRIORITY TOPICS FROM S.O.W. LIST AND LITERATURE SEARCH
- DISCUSS AND DEPICT SECOND AND THIRD PRIORITY TOPICS
- IDENTIFY AND DEFINE THE BASIC ARCHITECTURAL COMPONENT/TOPIC
- EXAMINE CRITICAL ISSUES WITH <u>ALTERNATIVE CONCEPTUAL DESIGNS</u>
- DESCRIBE BASIC ADVANTAGES AND DISADVANTAGES OF ALTERNATIVE DESIGN SOLUTIONS
- IDENTIFY QUESTIONS WHICH REQUIRE FURTHER RESEARCH ON TOPIC
- SUGGEST WAYS RESEARCH ON TOPIC CAN BE UNDERTAKEN
- IDENTIFY RESEARCH ISSUES ON TOPIC - FUTURE RESEARCH/DESIGN IMPLICATIONS

Each alternative design is depicted in conceptual drawing form and summarized by listing the advantages and disadvantages of each. Each alternative design is examined and a list of questions which require more research is prepared.

TOPICS SELECTED FOR FIRST PRIORITY

The following specific topics are selected as first priority topics in the broad categories of the Statement of Work:

PRIMARY STRUCTURE CATEGORY

Topic 1. CYLINDRICAL SHELL WALL CHARACTERISTICS

Cylindrical shell wall characteristics of the Primary Structure or Module is chosen as a first priority topic. It is defined as the module exterior shell including the end caps or end structures.

SECONDARY STRUCTURE

Topic 2. INTERIOR ARRANGEMENTS

Secondary Structure of interior arrangements is chosen as a first priority topic. It is defined as the placement of the major functional divisions within the modules to specific interior panels or workspaces.

SUBSYSTEMS

Topic 3. UTILITIES ROUTING AND DISTRIBUTION FROM BERTHING PORTS TO USE POINTS

Subsystems of "Utilities routing and distribution from berthing ports to use points" is chosen as a first priority topic. It is defined as the routing of required services of a utility nature and the distribution of these same services from the berthing ports to the final use points.

HABITABLE SPACES/FUNCTIONS

Topic 4. SLEEP/PERSONAL QUARTERS

Habitable spaces/functions of sleep/personal quarters is chosen as a first priority topic. It is defined as the bedroom and private space of the crewmember.

Topic 5. COMMERCIAL WORKSPACE VOLUME

Habitable spaces/functions of Commercial Work Volume is added as a first priority topic. It is defined as any volume or space in which crewmembers work or perform work functions. It is to be used by any of the many groups of individuals such as NASA, government, foreign, academia and commercial. Commercial appears in the title because it is suspected that the commercial community may ultimately provide the most rigid user requirements.

The first four primary topics are from a list in the Statement of Work and Topic 5 was added at Taylor & Associates request. Other topics on the Statement of Work list will be considered second and third priority topics and mentioned in the text or in graphics.

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PRIMARY STRUCTURE CATEGORY

Topic 1. CYLINDRICAL SHELL WALL CHARACTERISTICS

Most designers assume the containment of pressure is the primary design driver of a module wall. This may be true, but in this study an unconventional approach will be pursued to offer insight into the final Space Station design and also uncover and define research issues.

IDENTIFY - THE PRIMARY STRUCTURE IS MADE UP OF A CYLINDRICAL SHELL WALL AND END CAPS. THIS MODULE WALL HAS CERTAIN CHARACTERISTICS. THESE CHARACTERISTICS INCLUDE:

- TRANSPORTATION VEHICLE PAYLOAD VOLUME SHAPE
- MANUFACTURING TECHNIQUES
- PRESSURE DESIGN CONSIDERATIONS
- MODULE END CAPS

THE DEFINITION OF THE PRIMARY MODULE STRUCTURAL SHELL WALL IS A CYLINDRICAL SECTION OF A VESSEL CAPABLE OF:

1. Containment of pressure at minimum weight
2. Efficient and effective barrier protection from some micrometeoroid/debris penetration
3. Effficient and effective structural attachment via IVA for secondary inside structure
4. EVA compatible structural attachment for external structure
5. EVA or RMS assisted attachment of one module to other modules and the Space Station frame
6. Radiation protection
7. Provide productive interior volume for human use

The shell wall is defined as a cylindrical shell structure between the end caps. The module wall performs specific functions in orbit. It may also perform different and specific functions on the ground prior to orbital deployment. Containment of pressure at the minimum weight is the classical function. Weight has historically been a strong driver, but long term maintenance, repair techniques, internal reconfiguration, refurbishment criteria and growth may diminish weight as a major driver. The modules are volume limited, not weight limited, except for the logistics module.

The wall with some enhancement Barrier shield must provide protection from penetration from outside sources. Some upper limit of protection from a penetration particle size and velocity must be defined.

Attachment to the interior wall should be permitted within limits which permit cleaning, inspection, repair and possibly sensing or monitoring.

Attachment to the outside is permitted, but the exterior wall is likely to be masked by a barrier shield and not cleaned, inspected, repaired or sensed from the outside. It is also the outside surface where the module will probably be structurally fastened to the Space Station Keel structure and to other modules.

The primary function of the module wall is sometimes obscured by the above technical considerations. The module is in orbit to provide a maximum of beneficial internal volume for internal activity. In the long term, the module's effectiveness as a structure may eventually be judged as Earth based structures are evaluated economically.

The proposed method of evaluation of a cost per productive internal volume design is to create an evaluation system which includes the life cycle cost of the volume. This includes all the standard factors, such as module costs, interior equipment, training, but also includes the life cycle cost or productivity factor to indicate the human productivity of the volume. The cost impact of an increase in interior productivity by good design could amortize the original cost of the module. Relating this to the interior design is likely to produce a greater awareness of the quality of the productive features of the design.

A secondary functional characteristic of the module wall may be the ability to repair in an emergency, efficient maintenance, unpredicted modifications as required in orbit, and a methodical growth capability in unanticipated directions. These functions are all life cycle related and may tend to get de-emphasized in the initial design.

PRIMARY STRUCTURE - CYLINDRICAL SHELL WALL CHARACTERISTICS

Commercial and user requirements are often given as drivers, but the research may require going beyond the simple asking of questions of a "strawman or perceived" user community. The real Space Station utilization players may not yet be in the loop. This may force the evaluation of modules using a modified Earth based approach such as volume efficiency, functionality, ultimate benefit to the user, etc.

The trend in module configuration seems to be shifting from minimum weight containment to increased module commonality and utilization. One result is a common module with a three fold increase in the number of hatches. Ability of crew interface through the wall of the module seems to lag behind pressure wall and barrier design. In the case of microgravity most experiments can be performed inside the module. In the case of hard vacuum it may be a toss up whether the experiment is to be performed inside the module with the vacuum brought inside or the experiment is done outside with the crewmember using gloves or other methods through the module wall. Inside experiments may be limited by the size of the module interior while outside experiments are not volume limited, but they are reach limited - to about 2 feet. In the case of observation activities the viewer is inside the module, but the quality and dimensions of the window is of importance.

New material process research at Space Station will likely force a wall design different than that now anticipated.

Three of the key issues in the shell wall design which may not get early attention are:

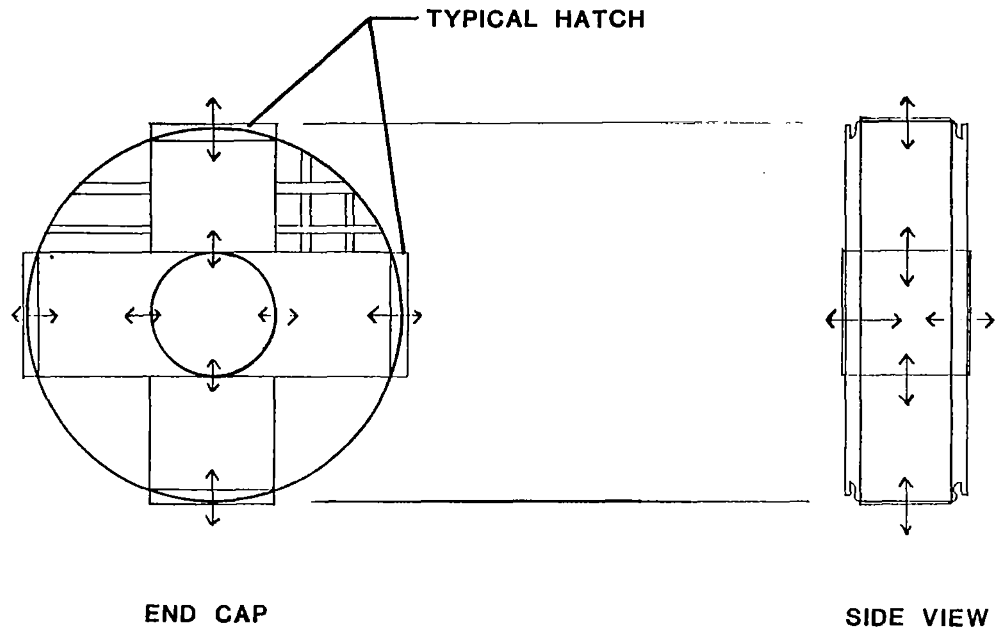
- USEFUL INTERIOR VOLUME AND METHODS TO MAXIMIZE PRODUCTIVE VOLUME
- STRUCTURAL ATTACHMENT OF SECONDARY STRUCTURES TO PRIMARY SHELL WALL
- MAXIMIZE INTERACTION THROUGH THE MODULE WALL

ALTERNATIVE DESIGN SOLUTIONS - CYLINDRICAL SHELL WALL CHARACTERISTICS

Each of the above will be worked into a design in an attempt to uncover and isolate some research issues.

USEFUL INTERIOR VOLUME AND METHODS TO MAXIMIZE PRODUCTIVE VOLUME

The maximizing of the interior volume can mean maximizing the interior diameter and increasing the efficiency of the end caps in such a manner so as to increase the interior volume. Figure 1 depicts an alternative solution called the Max Volume Wall. It uses the maximum diameter possible in the STS Payload Bay. All barriers and other cylindrical material is transported elsewhere. The entire module is the same length as present Common Module designs, but uses a Flat End Cap to maximize the interior volume and solve some utility routing problems. The Flat End Cap comes in four varieties each using variations of the same basic hardware. Figure 1 shows the Flat End Cap which is a structural frame capable of distributing the 3 G launch loads from the entire interior structure to the Shuttle Payload Bay. The best aspect of this approach is the elimination of the radial port segment "traffic zone." The key is that the interior loads are never passed to or through the module cylindrical wall at



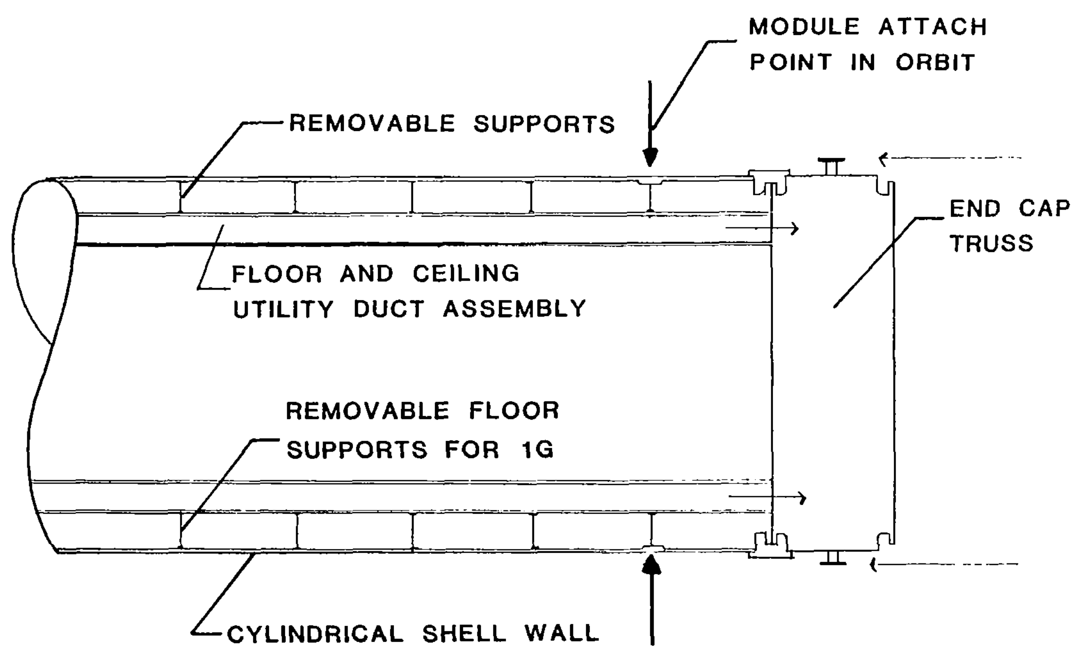


Figure 1 Flat End Cap - Maximized Interior Volume

anytime. The interior secondary structures are supported on beams in the floor and ceiling frame which transfers the load directly to the Flat End Cap and to the Payload Bay. The end result is a complete transfer of almost all functions possible from the cylindrical wall to the end cap. This permits the module wall to contain pressure, be clear of attachments and obstructions for inspection, perform no other functions and maximize the interior diameter.

The four variations of the Flat End Cap design include the same basic hardware design including an outer pressure wall, an interior load transfer frame or truss, end cap pressure wall (2 each), utility "pass throughs" in the end cap pressure wall and at least one hatch. The four basic designs include a one hatch unit, a five hatch unit, Docking unit and a mid module unit. Figure 2 depicts the four general variations of the basic design. Figure 3 depicts the concept in perspective. The Single Hatch Flat End Cap design includes the utility transfer provisions to connect to the adjacent module and a single hatch.

The Five Hatch Flat End Cap includes the provisions to handle five hatches with utility transfer provisions. The utility connection volume between the inner pressure boundary and the outer shell boundary is a pressure volume outside the normal crewmember connecting tunnels, but protected from the hard vacuum by the outer wall of the Flat End Cap. This permits utility connections to be performed, repaired, monitored and updated in a volume isolated and protected from the crewmember volume. This minimizes internal contamination from utility repair and maintenance operations. The access to the volume is through "Quick Opening Panels," but full pressure bulkhead panels in the tunnel walls easily isolate using the air locks and hatches in the Flat End Cap Design. The "Quick Opening Panels" are defined as man sized access through the cylindrical or rectangular passage for purposes of utility interface. The Advanced Mid Module Unit Design uses the same basic hardware to create a center of the module capable of increasing the interface with the outside including visual, experiments, arms, etc. It uses telescopic and other techniques to increase the interior crewmember's interface with the exterior experiments through visual and mechanical means.

The connection of the Cylindrical Shell Wall to the Flat End Cap is a design detail which can be explored, but requires additional load analysis and conceptual research. An early solution is depicted in Figure 4. It provides an outside connection ring, which is placed over two flanges to form the connection. An inner bolted connection can be also used as shown. The key is the fact that neither the structural or the utility connections in the ground test operations or in orbit are at the end cap to module interface, but inside the Flat End Cap volume. This moves the problems associated with each to inside the Flat End Cap volume where both of these problem areas can be handled in a different manner than the conventional Apollo/Soyuz Docking Port Method which concentrates these potential problem areas into a narrow

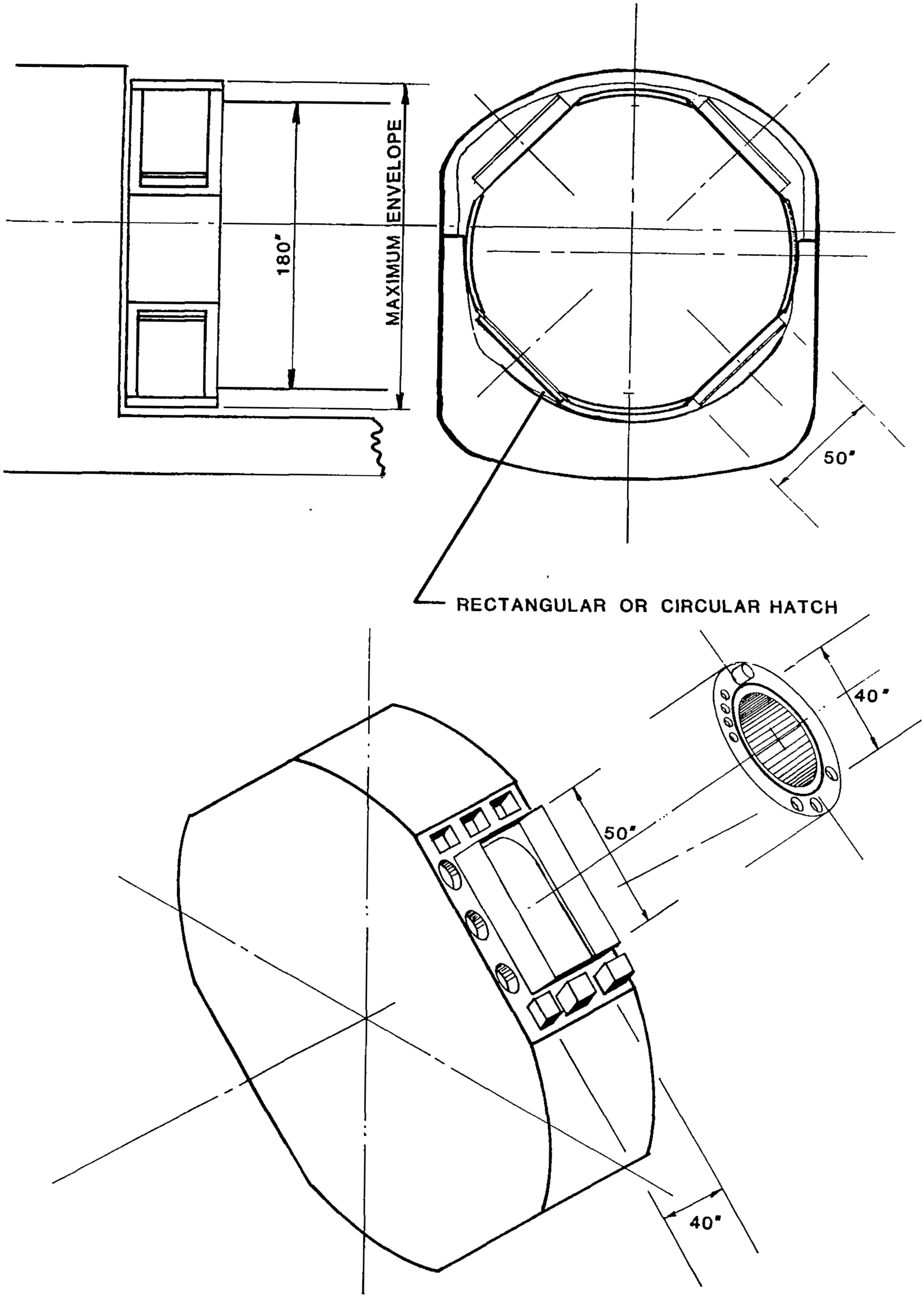


Figure 2 Flat End Cap - Conceptual

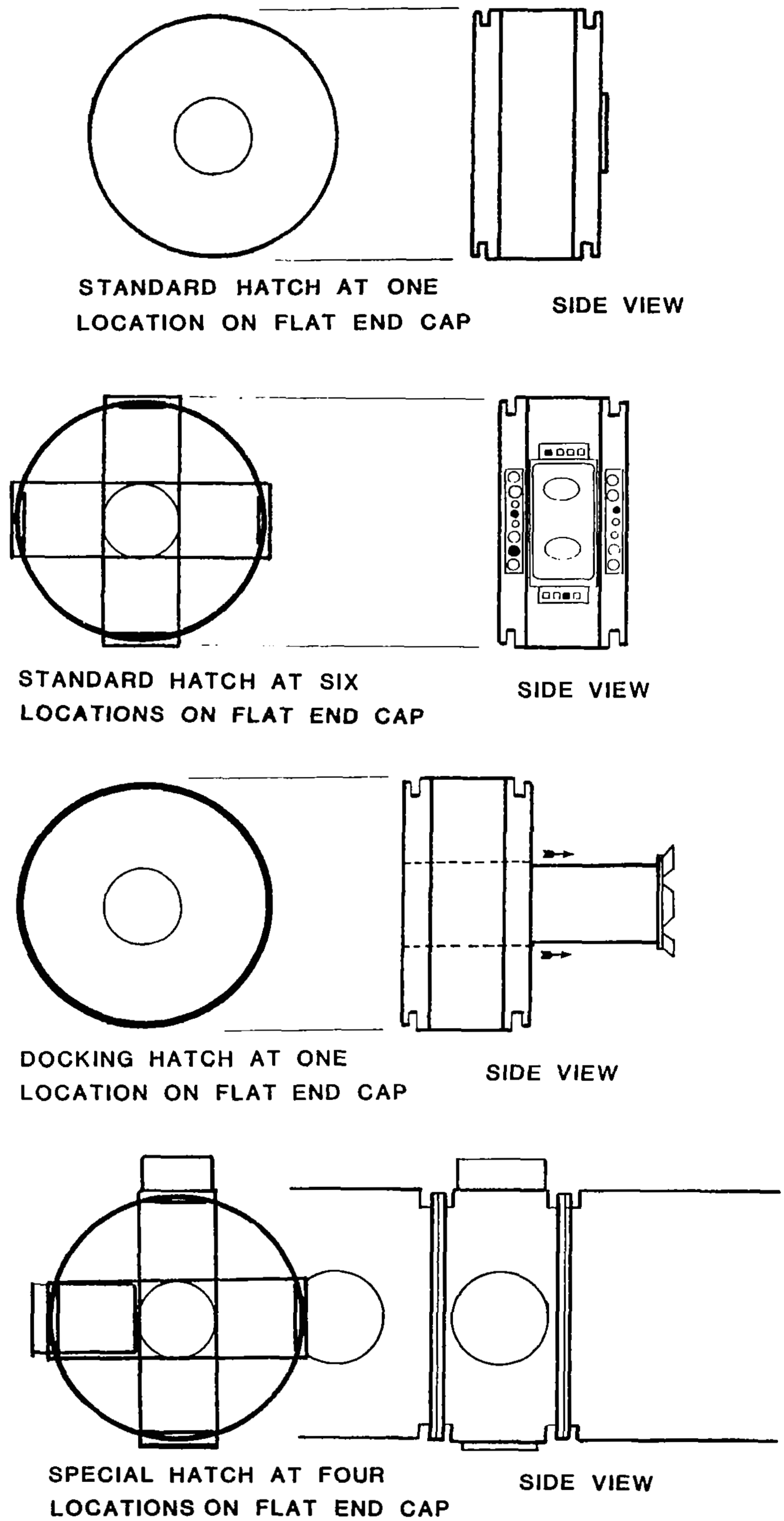


Figure 3 Flat End Cap Variations

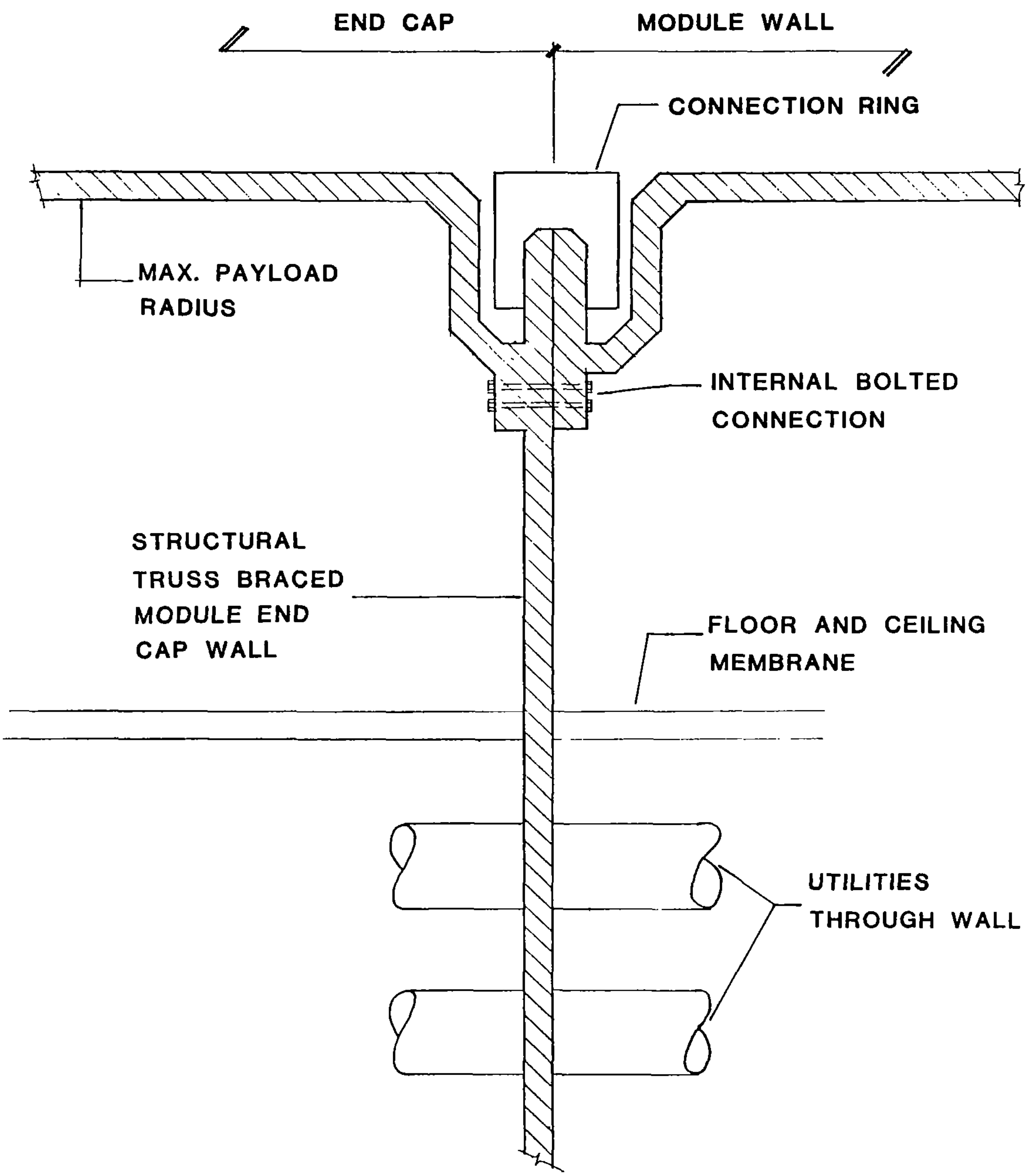


Figure 4 Flat End Cap to Module Connection

interface neck. (Reference Marc Cohen's work in the Tri-Tet studies). This concept transfers utility connections to a pressurized volume outside the module interior, but inside the control pressure volume of the end cap. All connections, most control valves, bleed down mechanisms, some storage and most maintenance problems are confined to this volume.

The Flat End Cap interface volume for structural and utility connections parallels a concept used in Alaska by the author to join two previously fabricated process units together using an interstitial volume.

STRUCTURAL ATTACHMENT OF SECONDARY STRUCTURES TO PRIMARY SHELL WALL

The structural attachment of secondary structures to primary shell wall will have an effect on the interior design and load carrying structural design. The approach in the Flat End Cap Conceptual Design is to transfer much of the load carrying ability to the end caps and maximize the cylindrical diameter as much as possible. The transport of the deployable barrier shield may reduce this diameter by some as yet undefined amount, but the barrier could be transported to orbit in some other location. The interior end cap wall of the Flat End Cap design in the proposed alternative design is not subject to the penetration repair specification and becomes a major load carrying structure plus a utility "Pass Through" surface. This also fits the vertical nature of the Space Shuttle load carrying payload bay. The utility routing is covered later in a different section.

Some load bracing and load attachment is likely to be needed for the attachment of secondary structures to the Cylindrical Shell Wall. The suggested alternative solution is a structural thickening of the shell wall at selected locations. These locations are probably required for other reasons such as the thickening shown for the adjacent module load transfer shown in Figure 1. The research into this structural thickening detail requires specifics on the wall design, but a rough conceptual design is shown in Figure 5. The thickened section has a minimum of wall material which is not violated and special repair And access procedures. It may be possible to eliminate all connections to the Cylindrical Shell Wall by the use of the Flat End Cap Design.

The structural attachment between modules can be researched and a movement away from the traditional capsule docking solutions can lead to less repeatability in the connection and undocking aspects of the hardware solution which is more sensitive to the utility interface. Figure 6 suggests several other load carrying/ connection locations other than the traditional docking module approach. Actually three separate locations exist for the transfer of structural load in orbit as shown in Figure 6. Unfortunately, the structural loads in orbit are minimal and the location used will probably be a function of convenient access

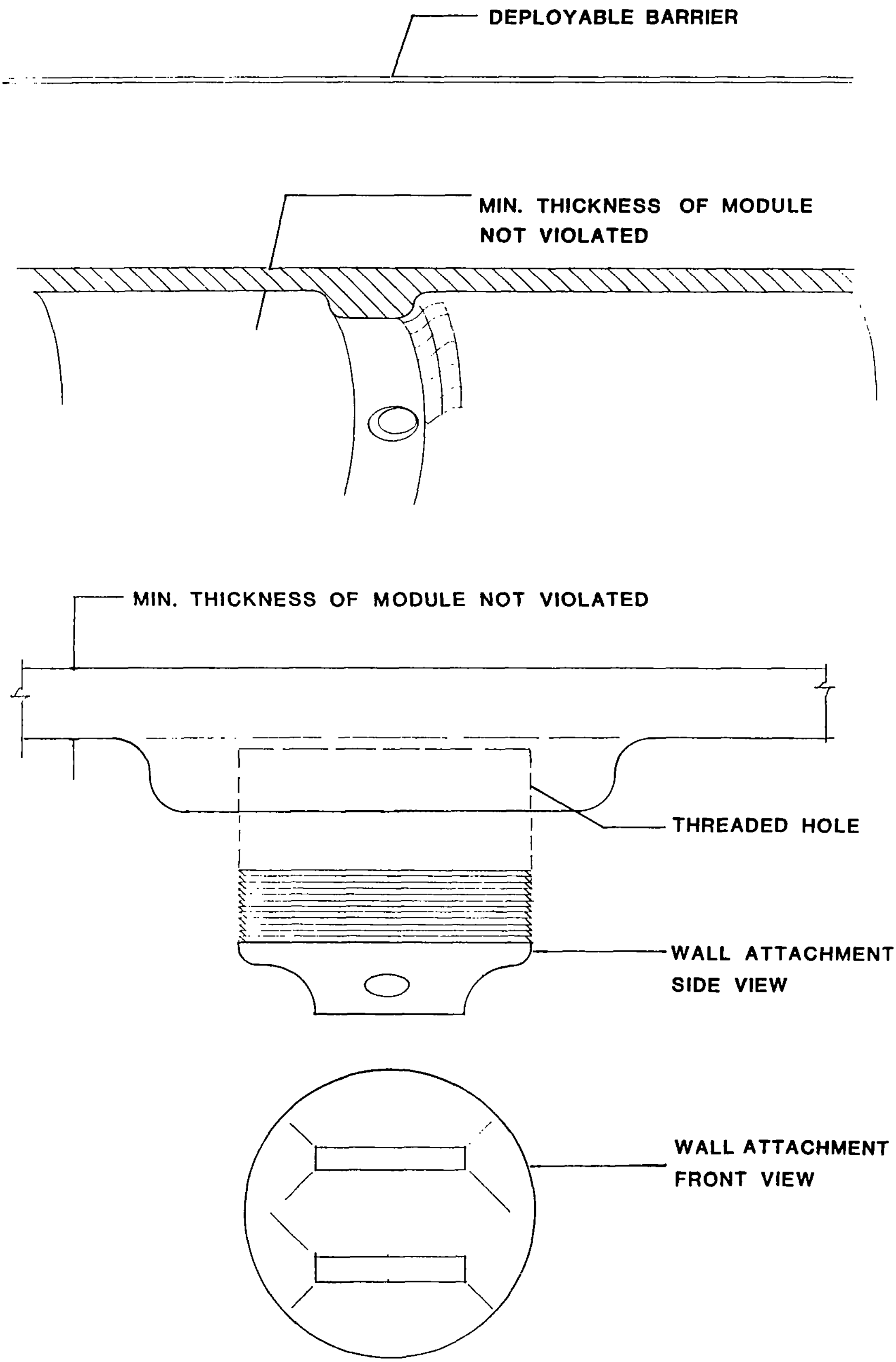


Figure 5 Wall Attachment Details

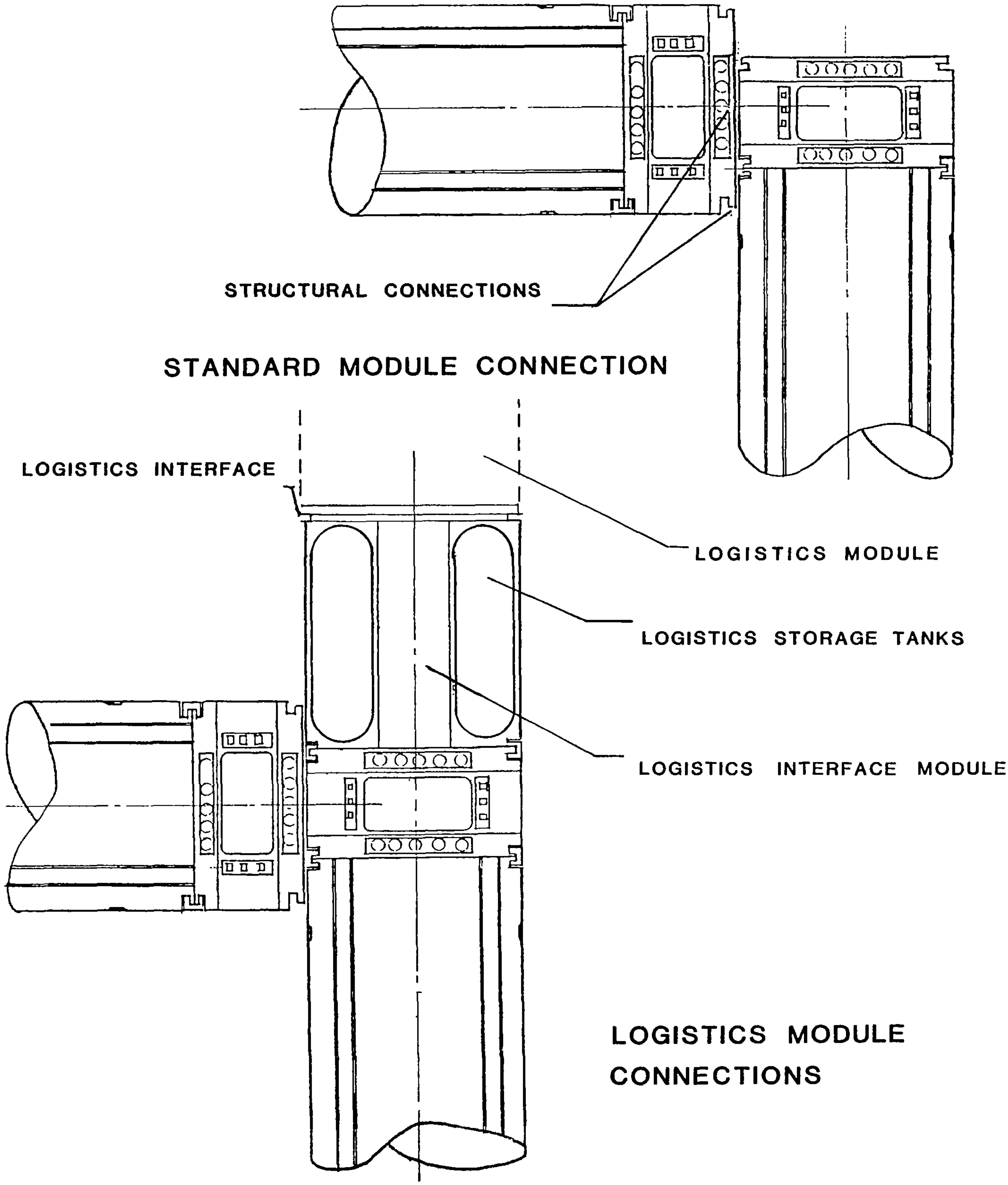


Figure 6 Module Interface

from an EVA crewmember point of view rather than any other reason. The three structural locations are:

1. Outer Rim of the Hatch Structural Frame
2. Joint of the Flat End Cap as it intersects the similar unit approximately 3 feet from the centerline
3. Outer rim of the Flat End Cap as it intersects the Cylindrical Shell Wall (a likely location for a thickened section in the module wall)

The fourth structural location is the intersection of the Collision/Micrometeoroid Barriers, but this is not considered a good location for connection even if it is the most accessible from the exterior.

The utility interface is a different situation. Much utility interface will occur in a restricted interface area and it will require considerable research to find the optimum method. One utility alternative design solution is shown in Figure 7. It is probably an area which will always be short of sufficient volume to make connections and requiring an estimated 30% spares for growth and flexibility for repair. Figure 7 suggests a rectangular hatch and possibly a rectangular tunnel design, both of which require much more full scale mock-up research before any decision.

The concept suggested by this proposed max volume/diameter module conceptual research is the transfer of most of the complexity of the cylindrical shell wall and interior of the module to the Flat End Cap hardware. This complexity includes, but isn't necessarily limited to the following items:

- Utility connections
- Structural strength for launch
- Structural support for the interior loads
- Hatch design and frames
- Windows
- Penetrations through the shell wall
- Possibly the difficult to repair portions of the ECLSS equipment

The advantage and disadvantages of the "Maximum Diameter Cylindrical Shell Wall" are yet to be fully researched, but it does permit the module wall to be maximum diameter and provides a relatively simple aluminum design concentrating on pressure containment and maximized volume without the complications of windows, hatches, attachments (interior and exterior) and may have some advantages not isolated at this time. It has some advantages in the ground assembly and outfitting of the module.

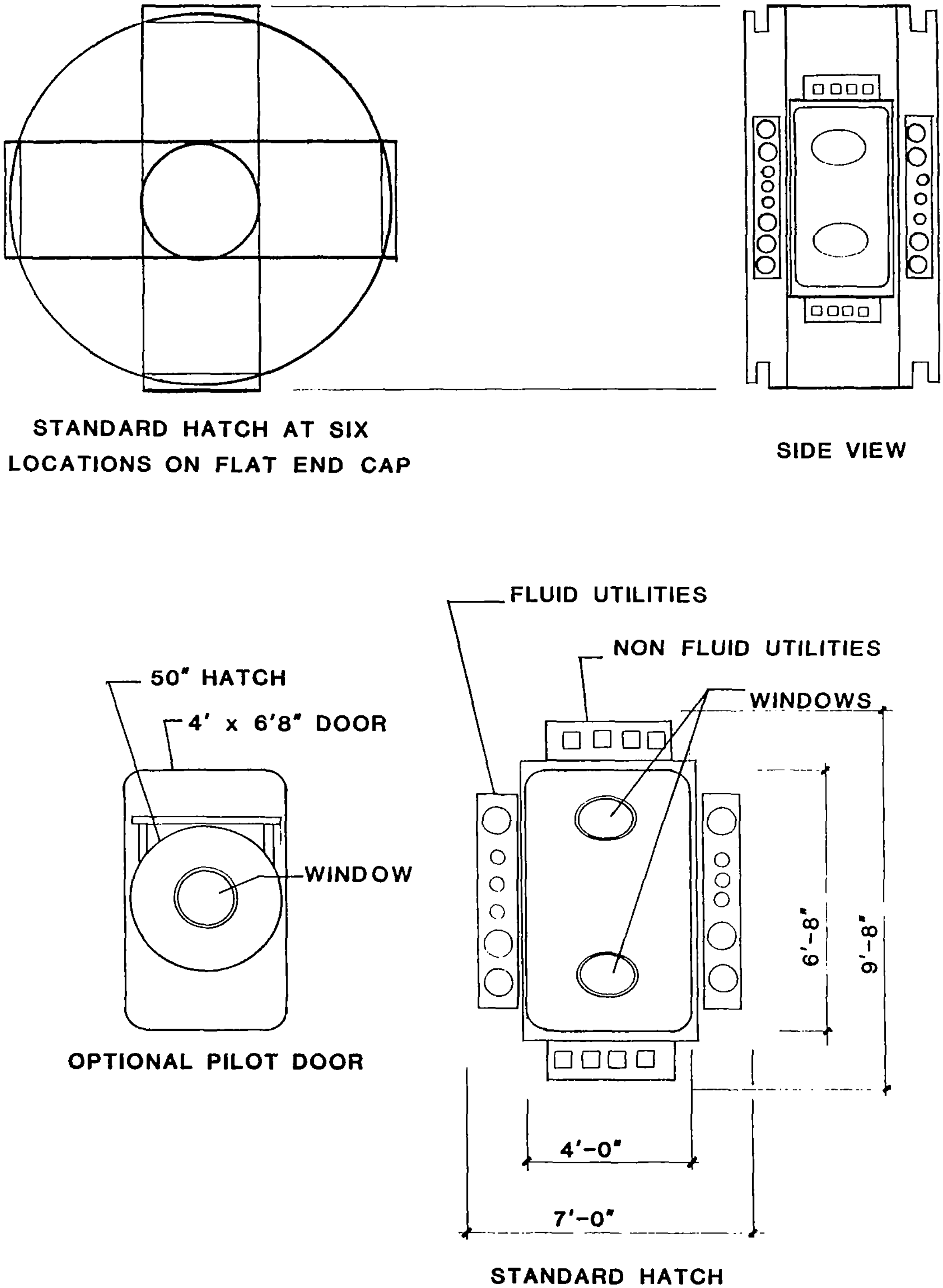


Figure 7 Utility Interface

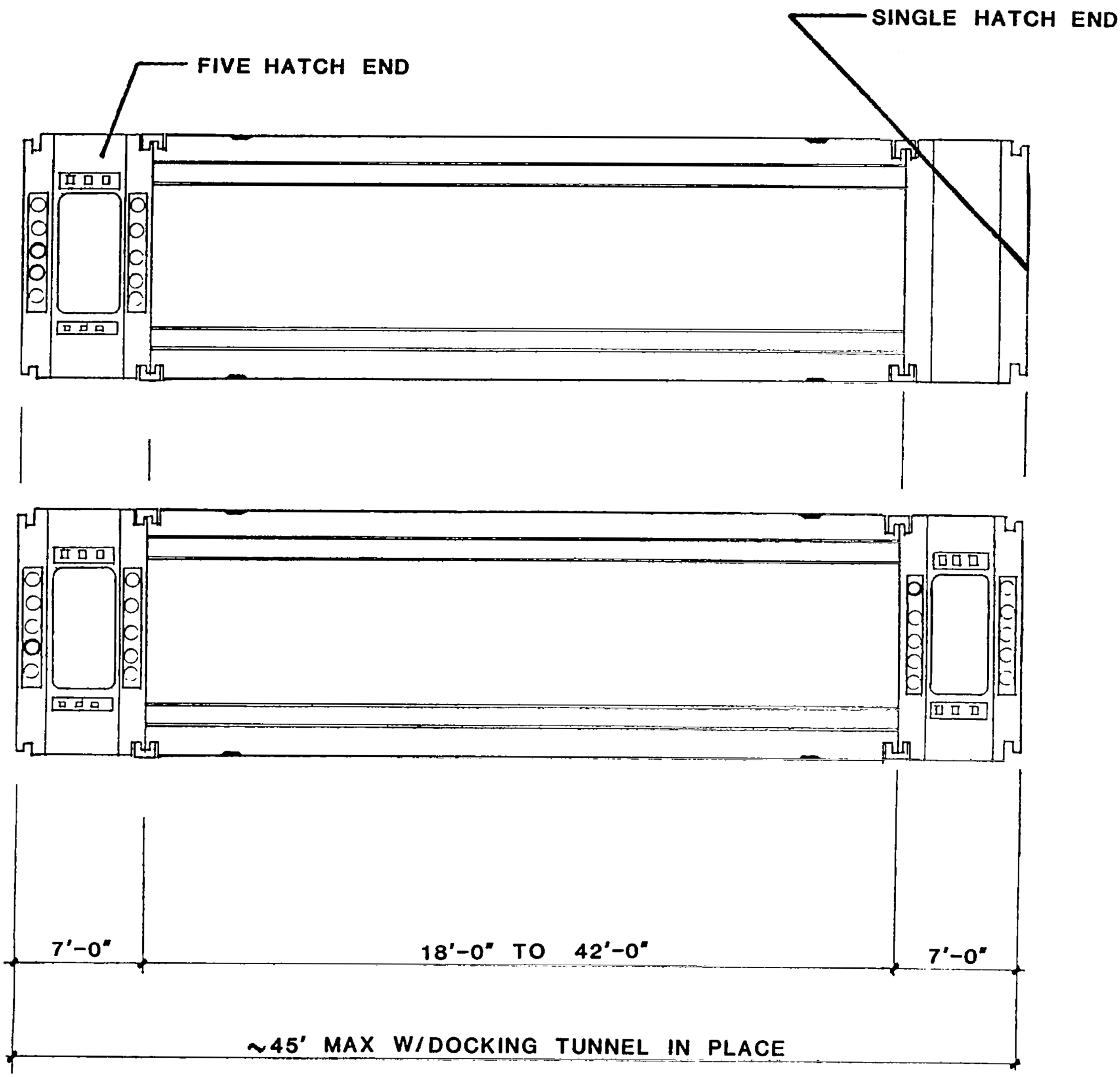


Figure 8 Common Module - Flat End Cap

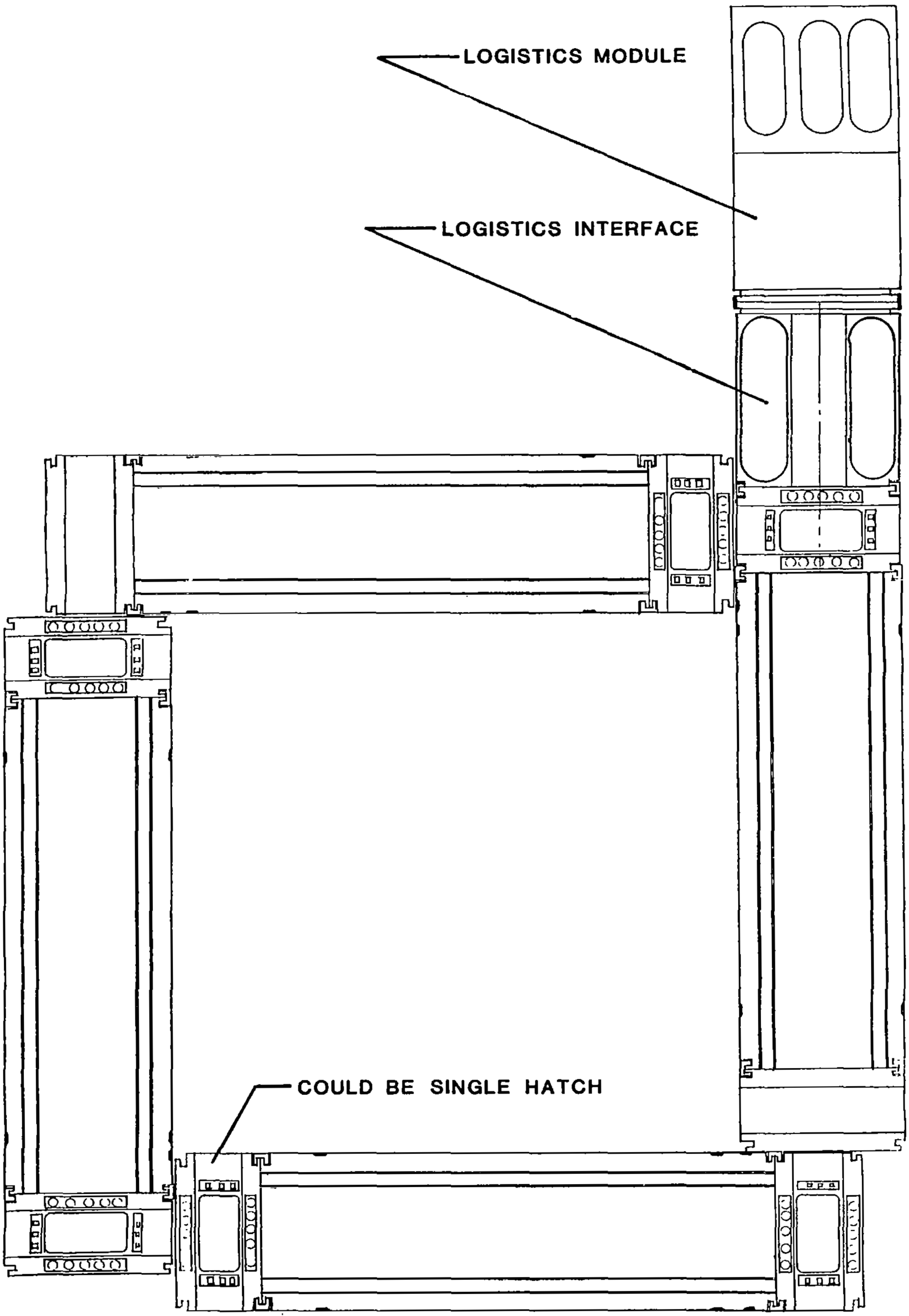


Figure 9 IOC Reference Layout

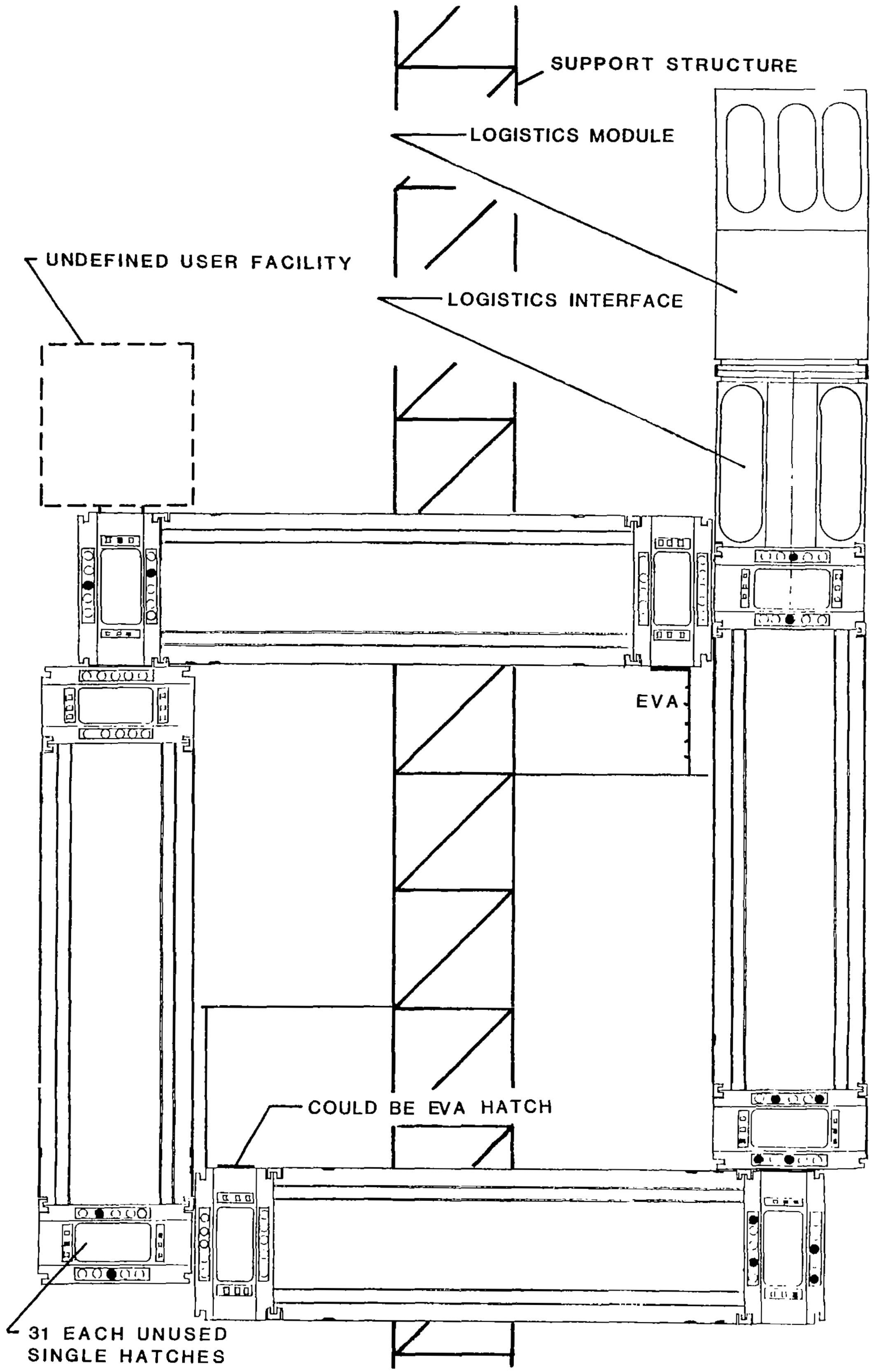


Figure 10 IOC Reference Layout - Expanded Exterior Interfaces

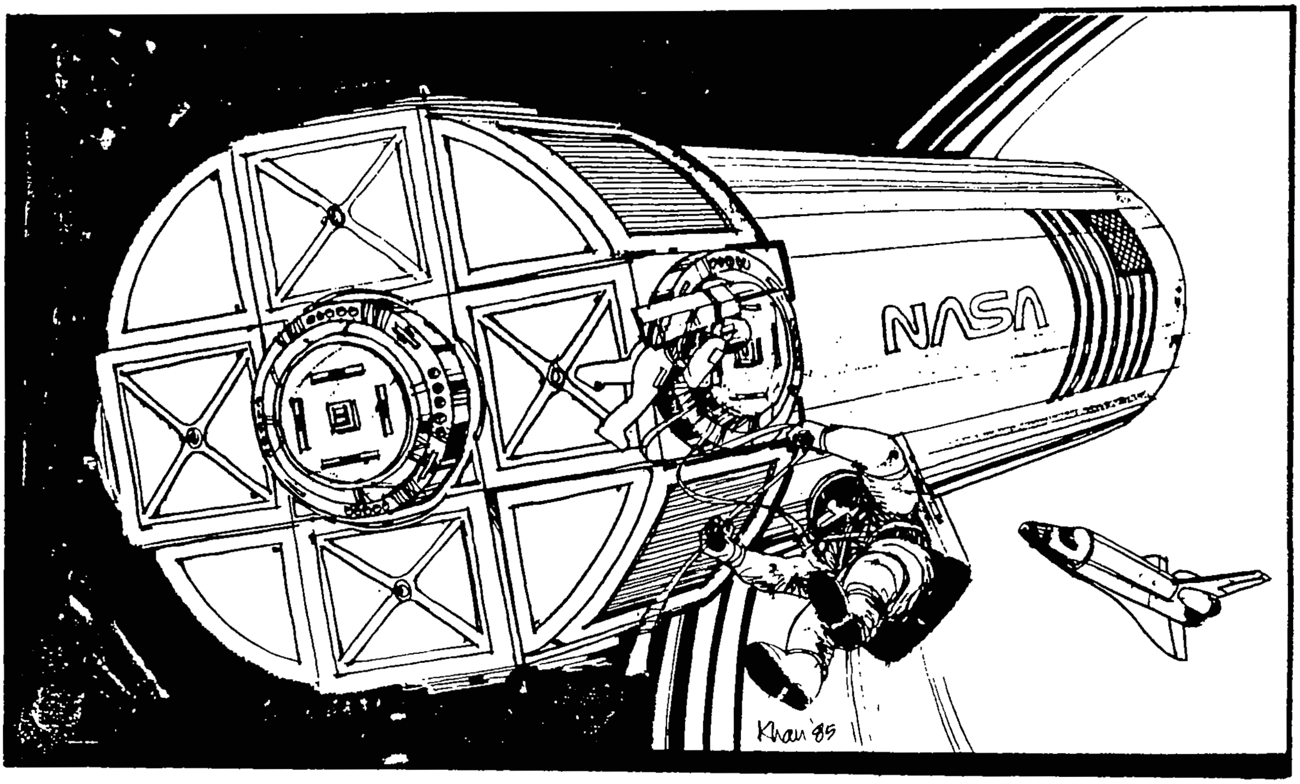


Figure 11 Future Application of Flat End Cap

One disadvantage is the flat end wall supported by an internal truss isn't necessarily the most efficient method of containing the end cap pressure. This may be less of a problem when one considers the IOC is volume limited and not weight limited.

The impact of the Flat End Cap and the Minimized Cylindrical Shell Wall can be seen in Figure 8. Assuming a 6 foot wide end cap design, the resulting 56 foot long common module would provide approximately 44 feet of interior length and approximately 6773 cubic feet.

The impact on the IOC can be seen in Figure 9. Figure 9 depicts a simple 5 Hatch/Single hatch IOC layout. Figure 10 depicts a 5 Hatch Flat End Cap at each end and expanded interfaces with the exterior environment for docking other vehicles, EVA work platforms, exterior experiment racks, interface with the L.S.S. equipment, etc. The resulting four modules with 32 each exterior hatches as shown in Figure 10 may be excessive and a combination more appropriate. A 16 exterior hatch IOC configuration would result if one end cap has one hatch and the other has five hatches, the same number as the current common module.

Future evolution of the Flat End Cap could produce either circular or rectangular hatch standards. Shown in Figure 11 is a conceptual depiction of a future module application of the Flat End Concept.

MAXIMIZE INTERACTION THROUGH THE MODULE WALL

A concept which further modifies the Flat End Cap Concept and creates a common module compatible hardware concept is also possible. Figure 12 depicts the concept in rough form. It uses the basic hardware from the Flat End Cap to create a mid-module insert specifically designed to address interaction through the module wall. This interaction could include:

- EVA
- VISUAL OBSERVATIONS
- EXPERIMENTAL INTERACTION
- EXPANDED TUNNELS
- TELESCOPIC DOCKING TUNNELS
- RESCUE/RE-ENTRY EQUIPMENT

The insert hardware is placed between two end caps and also provides utility "Pass Throughs" plus another structural load transfer location to the Shuttle Payload Bay. The concept has 2 to 6 hatch or hatch like modifications.

The Second and Third Priority Topics of this study include:

2nd Priority - Module End Cap Geometry has been discussed with the "Cylindrical Shell Wall" discussion.

3rd Priority - Window types and locations is identified as an area of further research with these comments. The window in orbit becomes a source of enjoyment, recreation, potential privacy and social gathering. The IOC may initially provide enough window viewing locations (up to 64 each if each module has a "Mid Module Insert Hardware"). If these windows were sufficient size in the standard hatch hardware and enhanced in some manner to increase the viewing enjoyment, then the existing hatch locations could provide a variety of window locations.

Window utilization is expected to be different than on Earth for several reasons. First, no Earth window has the view from orbit. Second, each window in orbit carries with it an element of danger and maybe should be isolated in some fashion such as being within a hatch frame and the airlocking capability of the hatch volume. Third, the view according to past experience in orbit is so enjoyable that it may not be suitable from a "glance from the work location" point of view. Fourth, the view may be a personal experience instead of a group enjoyed experience. Each may impact the window design in some way.

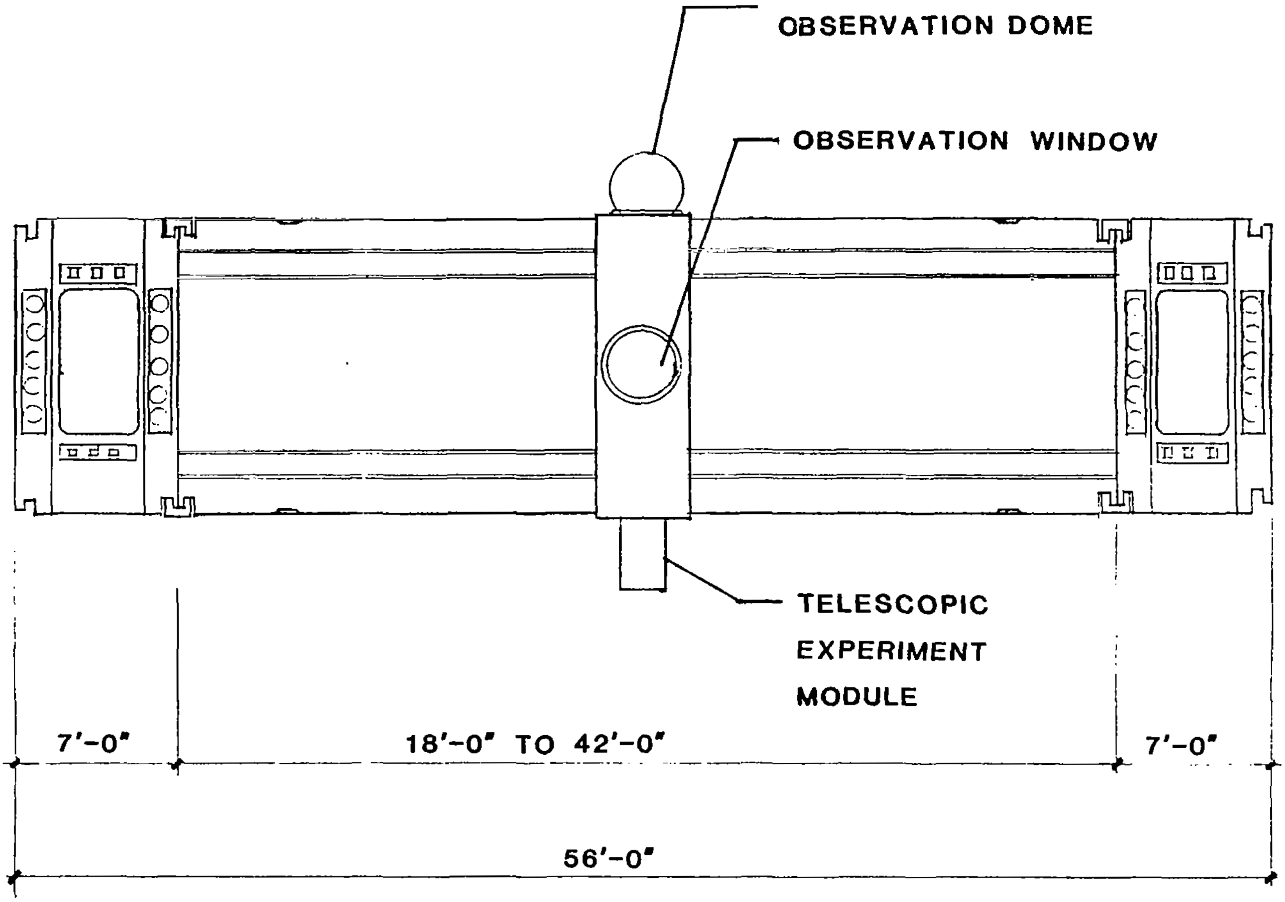


Figure 12 Mid Module Wall Interface Hardware

The result of the conceptual research is a concept which if explored further may result in some useful research issues and could result in a research program leading to a Cylindrical Shell Wall Design providing a more productive interior volume.

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SECONDARY STRUCTURE

Topic 2. INTERIOR ARRANGEMENTS

The arrangement of the items within the pressure boundary of the module is considered the area of coverage of this topic. It includes the placement and arrangement of the work spaces, functional volumes of the station, the floors and ceiling, the location of the utilities in relation to the other items in the module and crewmember interface with these items in such a manner so as to maximize human productivity within the module.

The interior volume of the module is defined as the volume of coverage of this topic. It has both surface and orbital based requirements.

IDENTIFY - THE BASIC ARCHITECTURAL COMPONENT/TOPIC

The secondary structure is the frame and other structure that supports the interior equipment, floors, utilities, crewmembers and all other objects within the interior. The interior arrangement of these items is identified as the topic Interior Arrangements.

DEFINE

All items within the module are defined as the Interior Arrangements basic architectural component or topic. The definition of the interior arrangements is the location within the Space Station module volume capable of use. This activity or work is expected to be the evaluation criteria for the effectiveness of module design and fabrication, but the surface based fabrication and development work also must be considered. The work volume is expected to be driven by technical, scientific, human productivity, cost and commercial requirements.

ALTERNATIVE CONCEPTUAL DESIGN - END SUPPORTED INTERIOR

The end supported interior uses the concept as described in the previous Cylindrical Module Wall Conceptual Design. The floor and ceiling (if they can still be referred to as floor and ceiling in a microgravity environment) are fully supported in orbit by the structural strength of the floor and ceiling members. The utilities and small structural loads are transmitted to the end caps through this secondary structure. Figure 13 depicts the general interior arrangements using this method. The floor and ceiling arrangements are the subject of mock-up research, but a type of arrangement is shown in Figure 14. It tries to combine the

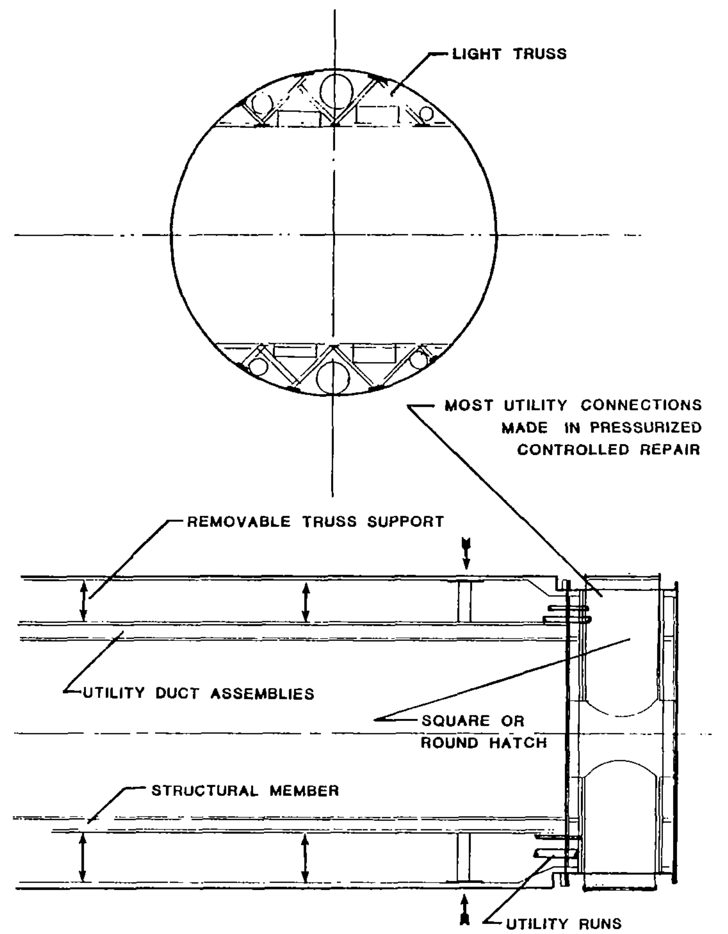


Figure 13 Floor and Ceiling Arrangements

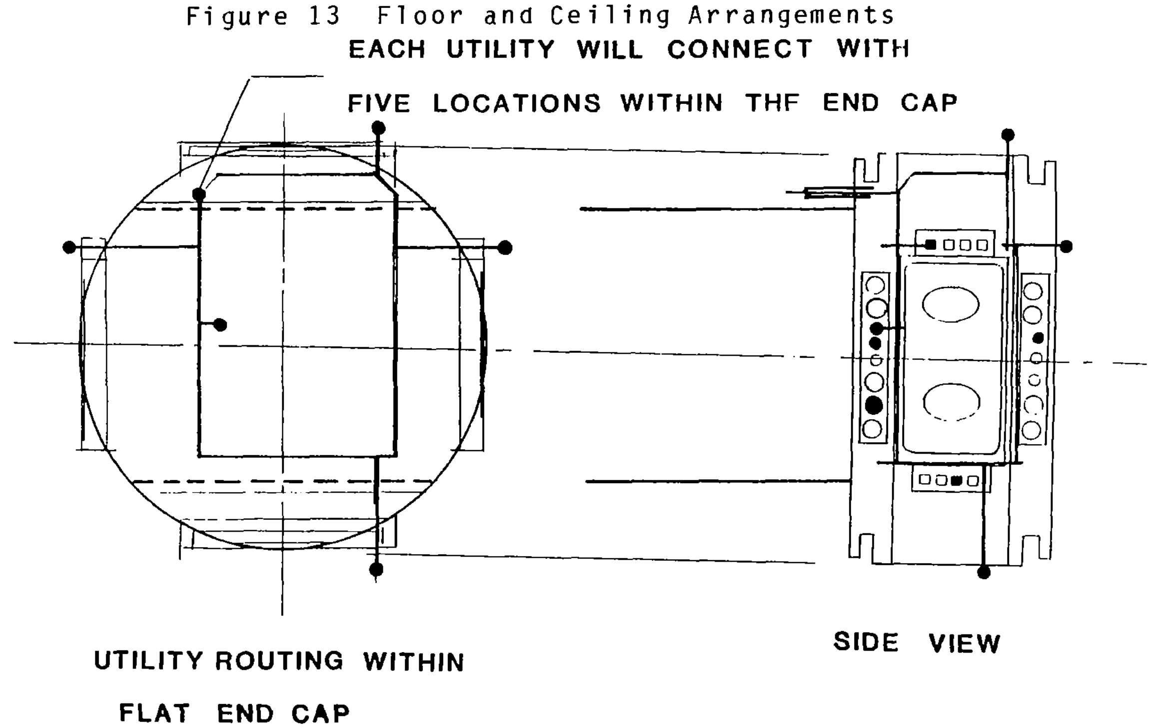


Figure 14 Utility Separation Arrangements

structural member with the division of the separate utility. Utility separation is important in most aspects of surface utility design and will likely dictate some of the thinking in orbital utility design locations.

ADVANTAGES/DISADVANTAGES - END SUPPORTED INTERIOR

The above concept requires no cylindrical wall attachments and begIns to address the multitude of utility and future utility growth problems by providing a system of maximum volume for the solution of these problems.

ALTERNATIVE CONCEPTUAL DESIGN - WORK SPHERE

The work sphere is a 48 inch diameter work sphere interior environment in which the user can control lighting, temperature, air flow, sound and privacy. The work sphere is not necessarily spherical in shape. Its shape will be a function of extensive research into the design parameters which drive the shape of the work sphere. It is depicted as a sphere until it is properly researched and defined as a shape. The sphere has sliding doors that when closed separates the user from other station activities allowing the user long term comfortable concentration.

The work sphere can function as a mini office in the station. It allows direct and effective access to the computers, records, communication; it enables the user to produce in an efficient manner.

The sphere concept lends itself to multiple functions.

a. Work space
b. Rest/nap/relax
c. Communication
d. Entertainment
e. Emergency sleep quarter
f. Experimental testing and monitoring

The work sphere can be positioned within the module in a variety of arrangements and can be moved from module to module through the 50 inch hatches.

The definition of a work sphere is a human interface volume dedicated to concentrated human productivity using high technology equipment. The user environment created is by client specified, mission specific equipment and general work sphere equipment.

The work sphere is a user defined volume designed to maximize the human productivity in a hardware unit that contains general modular equipment such as:

1. Electrical
2. Air Flow
3. Temperature Control
4. Data Flow Network

and user specified hardware such as:

1. Color Panels
2. Plug-in Units Mission Equipment
3. Discipline Specific Package

Some general equipment subsystems are standard in each work sphere, but the majority is user defined and relatively easy to reconfigure. See Figures 15 and 16 for one conceptual design.

Equipment layout can be modeled after automated office, aircraft, and spacecraft cockpit design to facilitate efficiency, comfort, and concentrated user effort. User view, reach, and lighting will be main design objectives.

Equipment will be of the plug in/out type to facilitate repair and replacement.

Support equipment will be stationed adjacent to the sphere to extend the sphere capabilities. Sphere can be linked to experiments for monitoring and testing.

The work sphere permits a small concentrated work environment to be located near the work location without a major commitment to volume. In a semi-permanent environment it can be integrated with other storage and equipment volumes.

SALIENT QUESTIONS - WORK SPHERE

1. How can this sphere be optimized anthropometrically?

2. What sphere user specific type equipment is required?

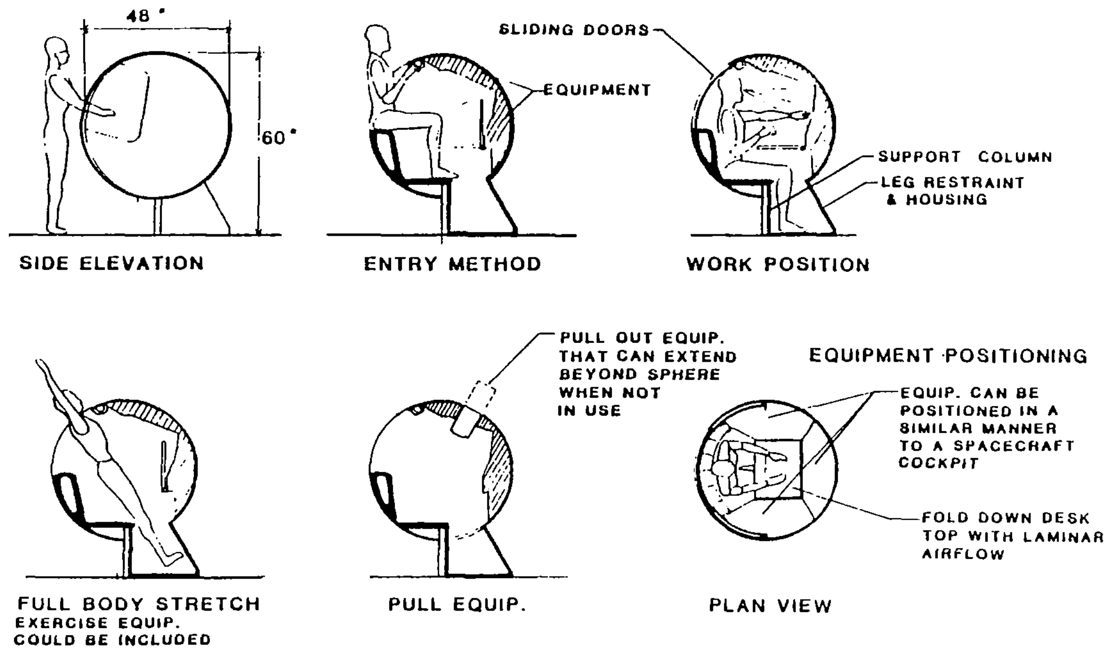
3. What type of "pull into position" equipment is possible?

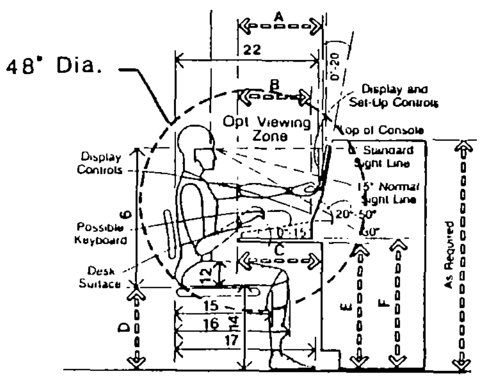
4. How expandable or telescopic can the work sphere get? Can it be expanded to sleep quarters?

5. What are the limits of hatch transfer of the sphere?

WORK SPHERE - ADVANTAGES

Sphere can be installed in station module prior to launch. Sphere can be brought to the station in the Shuttle mid-deck in a shirt sleeve environment. Sphere can be brought to station in Cargo Bay of Shuttle in a space safe canister which attaches to the airlock

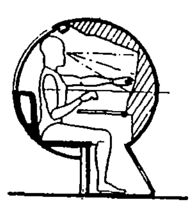




DESIGN GUIDELINES/
WORKSTATION DISPLAY CONSOLE

From Human Factors Engineering.
U S Air Force Systems Command Handbook DH 1-3 P DN2E5. 4

	in	cm
A	16–18	40.6–45 7
B	16 min.	40 6 min
C	18 min.	45.7 min
D	15–18 adjust	38.1–45 7
E	26.5 min	67 3 min
F	30	76 2



Work Position

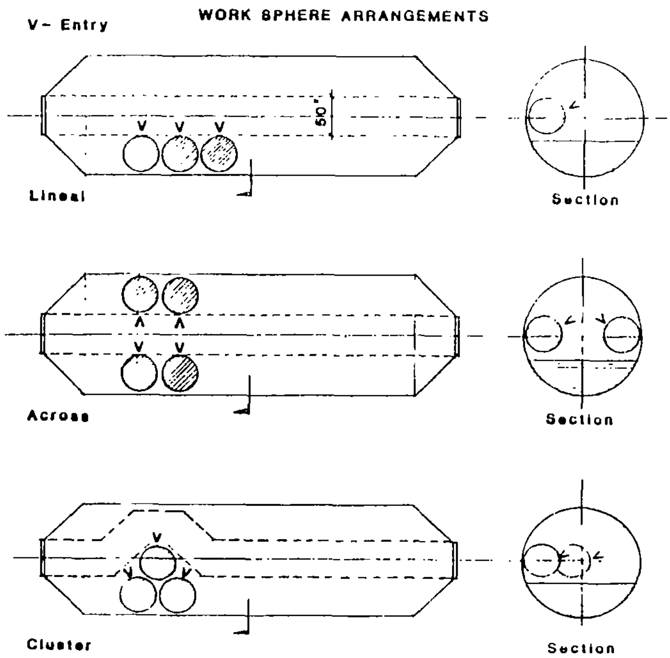


Figure 15 Conceptual Design Work Sphere

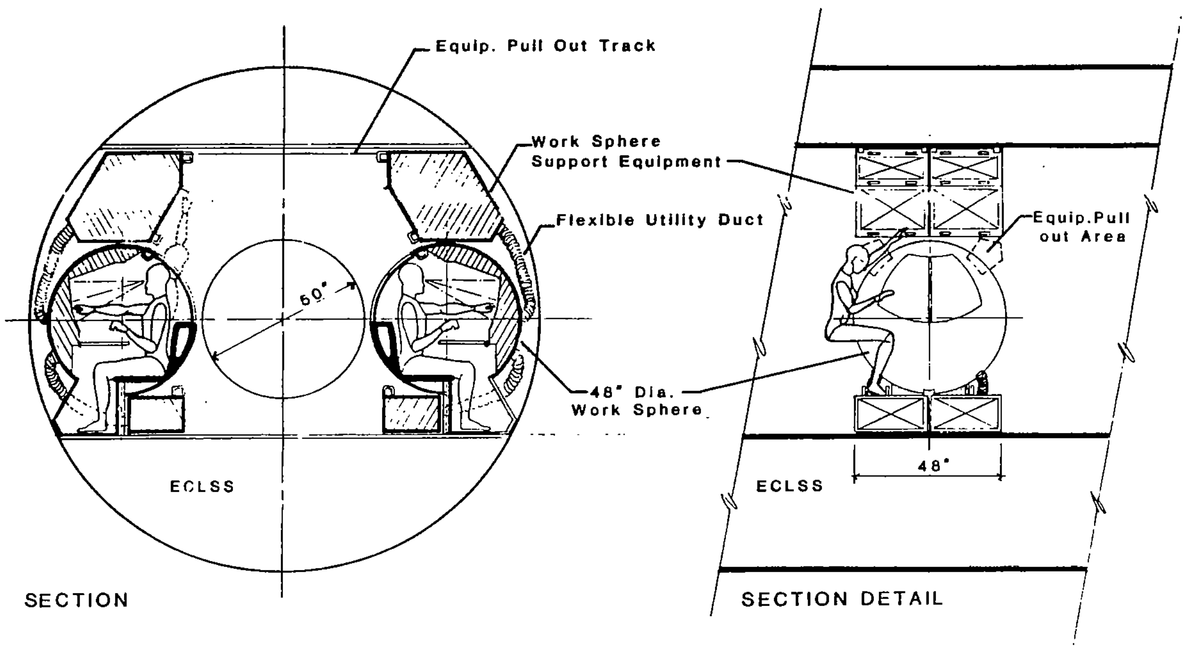


Figure 16 Conceptual Work Sphere Details

for sphere transfer and/or the sphere can be made space safe through design or packaging. Old spheres could be brought back to Earth in logistics module. Sphere 48" diameter allows movement throughout entire station assuming 50" diameter passage clearance. Useful in major interior arrangement re-organization. Sphere can be arranged inside the station in several different configurations. Sphere is similar to spacecraft cockpit which astronauts and technically oriented people appreciate. This appreciation and familiarity could enhance the sphere's acceptance and use. A Black Box Sphere can be brought to the station with a visiting scientist, plugged into general services, used and then returned to Earth with the scientist or only Black Box components and data banks are removed from the sphere. Security possibilities are excellent.

Work Sphere can contain closed environments that are monitored and manipulated by an adjacent or remote sphere.

Work Sphere allows long term work (days, weeks, months) to be conducted by one person without work area interrupted by accident. Correspondent sphere on Earth will allow direct Earth/Station link. Ground researcher can infuse data and information to station sphere while sphere user is doing other work or not in the sphere. Maintenance, testing and problem solving can be conducted on Earth with duplicate sphere.

WORK SPHERE - DISADVANTAGES

There is a potential for user psychological problems of confinement and isolation. Potential problem with packaging of support equipment, especially future upgraded equipment. Work sphere form does not match inner hull. Potential problem of industrial acceptance of new concept.

WORK SPHERE - ADVANTAGES

- EASE OF INSTALLATION
- TRANSPORTABILITY
- DESIGNED TO FIT THROUGH THE HATCHES
- PROVIDES PLEASANT ENVIRONMENT
- MAXIMIZES CONCENTRATION
- PROVIDE MAXIMUM CONCENTRATION LEADING TO MAXIMUM HUMAN PRODUCTION
- USER CONTROLLED TEMPERATURE, AIR FLOW, SOUND, ETC.
- USES PREFERENCE ON HUMAN FACTORS ISSUES SUCH AS TACTILE, SMELL, ENTERTAINMENT, BODY POSITION, PERSONAL TURF HUMAN FACTORS
- USER DEFINABLE MODULAR EQUIPMENT
- USER CONTROLLED ACCESS AND INTERRUPTIONS INCLUDING SECURITY
- USER MODIFICATION ON SHORT NOTICE, USER RECONFIGURABLE
- CUSTOMER COMMUNICATION VIA DUPLICATE SPHERE IN SPACE STATION AND CUSTOMER SURFACE FACILITY. (COULD BE MAJOR ENHANCEMENT TO SPACE STATION MARKETING SCENARIO).

WORK SPHERE - DISADVANTAGES

- DOESN'T FIT WELL INSIDE THE EQUIPMENT INDUSTRY STANDARDIZED ON SQUARE FORMS
- PSYCHOLOGICAL PROBLEMS WITH CONFINED SPACE
- ENCLOSED VOLUME - CLAUSTROPHOBIA
- USER ACCEPTANCE UNKNOWN

- CONSTANT FOCAL LENGTH
- BOREDOM
- HUMAN FACTORS AND ENCLOSED VOLUME LIMITS NEEDS RESEARCH AND MAY VARY WITH INDIVIDUAL

RESEARCH QUESTIONS - WORK SPHERE

1. What type of work will be done in the station and how does it relate to the work sphere?

   A. Near term (first three years of operation)
   B. Long term (beyond first three years)

2. What type of standard equipment and services will be necessary for any type of IVA administrative and research work?

3. How can this sphere be optimized anthropometrically?

4. What other functions could a privately controlled environment serve?

5. What types of sub-utility systems could be integrated into the sphere? Can a technology transfer scenario be set up for societal benefits from the Space Station?

SUGGEST WAYS RESEARCH CAN BE UNDERTAKEN FOR WORK SPHERE VIA NORMAL ROUTE WITHIN NASA

- RESEARCH WITH MODELS AND REFINE SHAPE
- CREATE FULL SIZE MOCK UP
- CHECK ERGONOMICS AND DETAILS
- RESEARCH EQUIPMENT
- SIMULATE EARLY HUMAN PRODUCTIVITY TESTS ON THE SURFACE
- REFINE CONCEPT
- SURVEY CURRENT COMPUTER/WORKSTATION INDUSTRY
- CREATE A NORMAL GRAVITY EQUIVALENT WORK SPHERE
- REFINE THE COMMUNICATIONS LINK FOR WORK SPHERE USE ON SPACE STATION
- FLIGHT TEST ON STS MID DECK PRIOR TO TESTBEDS

- UTILIZE ON TESTBED MISSIONS AND EVALUATE
- PRODUCE FOR NASA AND COMMERCIAL MARKET
- CONTINUED EVOLUTION IN MOCK UP FACILITY

ALTERNATIVE CONCEPTUAL DESIGN - CENTER SERVICE CORE

The Center Service Core is a result of the combination of the requirements for interior arrangements, utility routing and station circulation. The design goal is to create large concentrated work and/or living volumes.

The Center Service Core Concept concentrates the utilities and ECLSS plus the circulation volume in the center of the module volume within a 50 inch to 5' - 6" wide zone extending the full height and length of the module. The arrangement creates two separate volumes, one on either side of the service core. The volumes can be used for work or living and are 54 inches wide. The circulation zone is 72 inches high by 50 inches wide and permits easy access by the surface fabrication work force. See Figure 17.

The Center Service Core Concept is similar to modern office building planning which concentrates the mechanical, utilities and circulation in a service core located in the center of the building with large continuous office space surrounding the core. The utilities and circulation volume in surface buildings becomes smaller and more efficient as it radiates from the core and services fewer users. A larger more productive area is created by this concept.

The Service Core Concept promotes efficient servicing of the station in orbit and provides reasonable access to the utility volume while on the ground prior to launch. The large concentrated volumes created offer new interior arrangement opportunities for designing the volume by recognizing the neutral body position as a functional design requirement.

The utility runs such as air ducts, electrical, etc. occupy in an efficient manner the volume created by the curved interior wall joint with the straight floor and ceiling. The concept also creates enhanced adaptability and flexibility for equipment maintenance and repair.

SALIENT QUESTIONS - CENTER SERVICE CORE

1. How does the service core interface with the end cap and hatch?

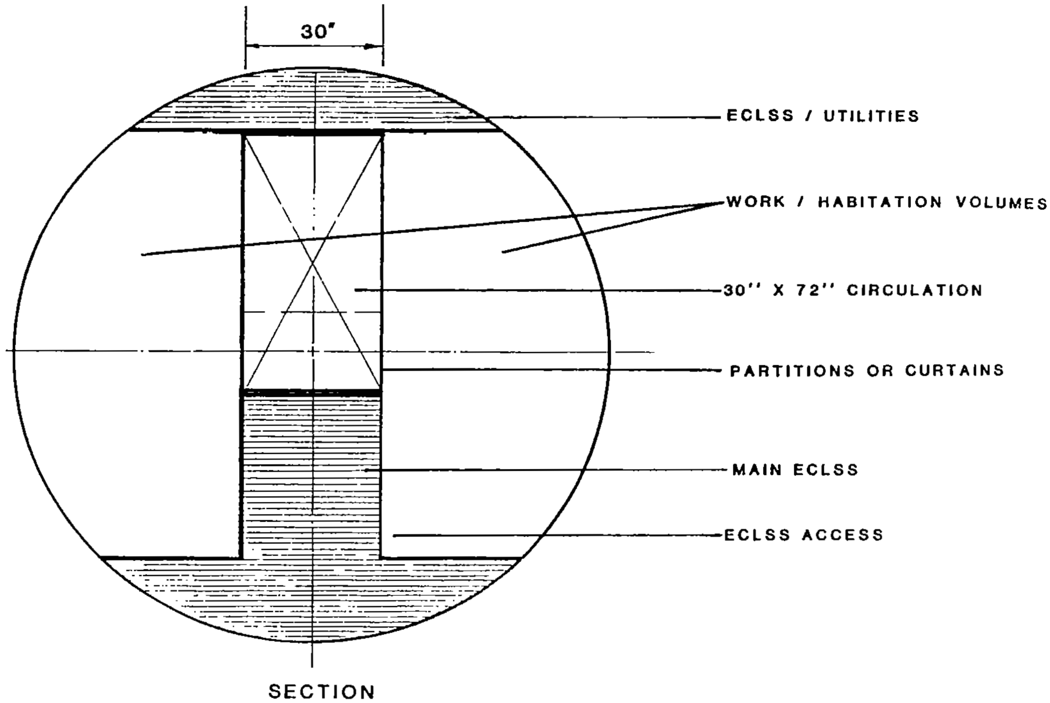


Figure 17 Conceptual Design Center Service Core

2. How can the utility system design permit efficient access to all parts of the system for inspection, servicing and maintenance, repair and update?

3. Is the service core to be extended for additional ECLSS upgrades, module additions and expansion?

4. What type of construction is required to maintain the structural integrity of the service core during construction on the ground and removed to go into orbit?

5. How is equipment to be placed near the service core to take maximum advantage of the concept?

ADVANTAGES - CENTER SERVICE CORE

The Center Service Core concentrates service functions to a small volume and permits the rest of the volume to be used for other purposes. The concept provides enhanced three sided access to the core of utilities and distribution system. This starts with two level workspaces. This provides efficient interface to curved surfaced by moving the previously side mounted equipment to the center of the module and placing the back of the crewmember against the curved surface and approximating the neutral body position.

The concept provides efficient utility runs and reduces circulation volume required while it creates enhanced volumes for productive work. It balances microgravity and surface fabrication requirements by providing a hard walkway down the middle which can be unbraced and lightened for orbital loads.

DISADVANTAGES - CENTER SERVICE CORE

The access to concentrated services below the utility runs may be limited. The concept creates more work volume by creating two separate work/habitation volumes where one existed and may have a crowding effect or feeling on occupants.

ADVANTAGES - CENTER SERVICE CORE

- CONCENTRATES SERVICE FUNCTIONS TO SMALL VOLUME
- PROVIDES ENHANCED THREE SIDED ACCESS
- PROVIDES EFFICIENT UTILITY RUNS
- REDUCES CIRCULATION VOLUME REQUIRED
- CREATES ENHANCED VOLUMES FOR PRODUCTIVE WORK

DISADVANTAGES - CENTER SERVICE CORE

- ACCESS TO CONCENTRATED SERVICES MAY BE LIMITED
- IT MAY COMPLICATE SURFACE INSTALLATION AND TESTING
- CREATING TWO SEPARATE WORK/HABITATION VOLUMES WHERE ONE EXISTED MAY HAVE SOME UNKNOWN EFFECT ON OCCUPANTS

IDENTIFY QUESTIONS THAT REQUIRE FURTHER RESEARCH ON THE TOPIC OF INTERIOR ARRANGEMENTS OF THE SECONDARY STRUCTURE

What is the minimum and maximum volumes anticipated for the ECLSS and utilities plus growth?

Can the sphere volume be utilized effectively in a basic cylindrical module?

What is required for general sphere type equipment?
What sphere user specific type equipment is required? What range?

What type of "pull into position" equipment is possible? What type of exterior mounted equipment?

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SUBSYSTEMS

Topic 3. UTILITY ROUTING

The scope is defined as the utility routing and distribution from the berthing ports to the use points.

The definition of the routing possibilities include any location within the module. Utilities are defined as anything that requires movement and distribution within the module.

Identify the basic architectural component of utility routing as the third topic.

Define the basic architectural component of utility routing as the method of routing and distributing the required service, functions and future needs of a utility nature. The topic covers the placement, positioning, access for maintenance on the surface and in orbit, replacement, on-orbit hookup, on-orbit testing, repair of on-orbit utility, replacement of on-orbit lines and provisions for growth.

SUBSYSTEMS - UTILITY ROUTING

Current research into the utility routing indicates most thinking to date focuses on the floor and ceiling concept of placing the utilities either under the floor or overhead in the ceiling. This reflects surface building design solutions, but may not be appropriate in a microgravity environment.

Researching the topic of utility routing in Skylab experience literature and other Space Station related literature indicates utilities are seldom mentioned as a group or addressed in a specific area with an integrated design approach.

Utilities as a combined component are normally addressed in buildings in a specific volume or service core. Some of the same logical criteria may be used in orbit. Some will need to be revised to reflect the new microgravity environment. Utilities in orbit can be broken down by the product within the utility.

1. Fluids
    a. Hydraulic
    b. Water
    c. Sewer
    d. Heat Rejection Coolant
    e. Process Fluids
    f. Other
    g. Growth

2. Gas
    a. Breathable Atmosphere
    b. Return Air
    c. Compressed Air
    d. Process Gas
    e. Fire Suppression

3. Solid
    a. Cargo movement
    b. Carry on experimental equipment
    c. Finished Product - Commercial and/or Experimental
    d. Data Tapes, Results, Etc.

4. Wire
    a. Electrical Power
    b. Monitoring and Sensing
    c. TV Video
    d. Communication and Data
    e. Computer Network
    f. Command and Control
    g. Other
    h. Future

5. Fiber Optics - Part of 4. above

Each division above has specific design constraints such as shut off valves, connections, spare and alternative routing, survivability, testing, repair considerations, replacement techniques, updating, contamination and others.

Several rules of thumb derived from surface utility operations include:

1. Keep water and electrical as far as possible from each other.
2. Keep sewer as far as possible from drinking water to minimize contamination, proper back flow valves, etc.
3. Use fluid shut off valves to minimize discharge in damage and repair situations.
4. Provide adequate clearance for maintenance and repair.
5. Don't make it more complicated than required.

ALTERNATIVE CONCEPTUAL DESIGN - UTILITY ISLAND CONCEPT

The utility island carries electrical, communication and equipment cooling systems. The utility island simplifies the placement and connection of standard equipment 19" racks by providing multiple connections on a high volume basis. Space Station is expected to use a 48 inch spacing.

The utility island can be placed in the center of the module or to one or both sides. The island can create a U-shaped utility environment that can have equipment on 3 sides with the fourth side off the 50" circulation zone. This configuration provides a commercial user with an individualized space, a private work space.

The equipment connected to the utility island can be configured in a variety of ways according to purpose and associated requirements. This system will enhance the user's ability to quickly and efficiently change his work area to respond to new task requirements or research opportunities. See Figure 18.

SALIENT QUESTIONS - UTILITY ISLAND

1. How will power be distributed throughout the station? What type of requirements and distribution methods are appropriate?

2. How can unknowns be planned for? Examples, unknown types of equipment, power needs, positioning, etc.

3. Is the utility island adaptable to the habitation module? In a much smaller form, could it be placed in the crew quarters?

4. Will the utility island increase or decrease the amount of equipment a user can place in a module?

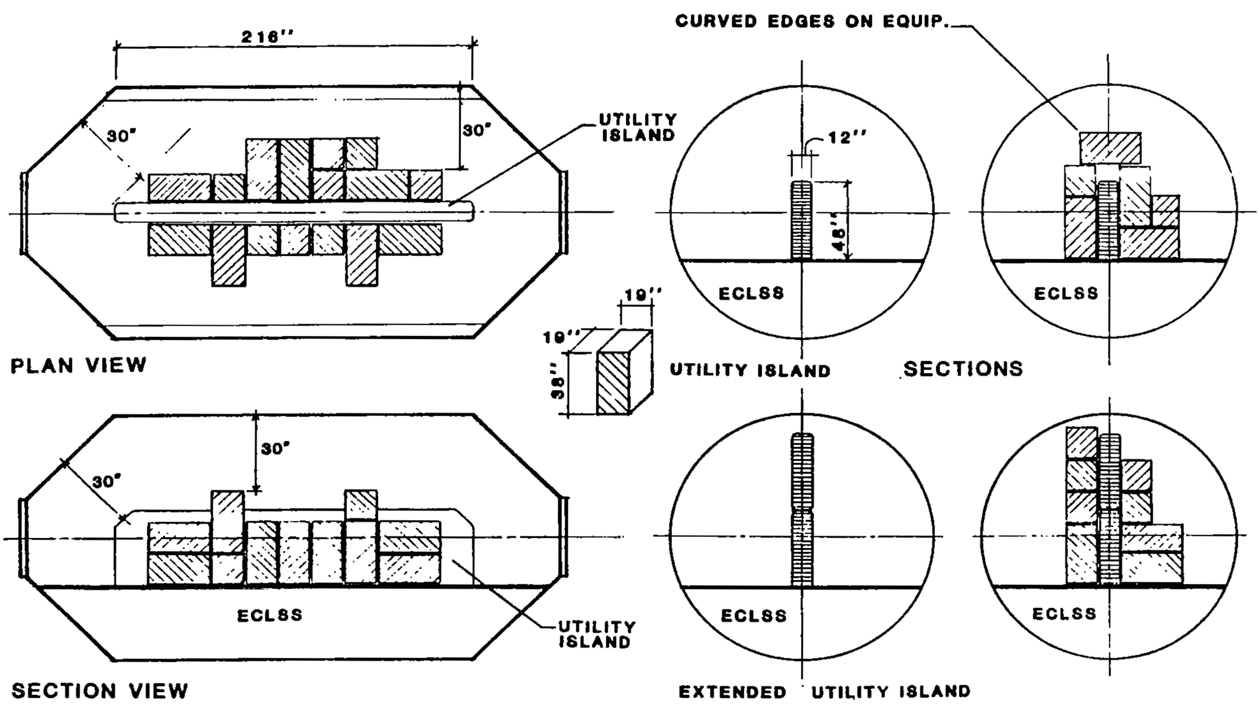

Figure 18 Conceptual Design Utility Island

UTILITY ISLAND - ADVANTAGES

The utility island is an example of a commercial user design approach. This approach is dedicated to providing the following commercial advantages:

A. Provide as much usable volume as possible to the greatest variety of users.

B. Provide as many utility services as possible.

C. Provide a utility connection system that stimulates flexible equipment configurations.

D. Provide a utility connection system that minimizes equipment down time for maintenance, repair, replacement and upgrading.

E. Provide an overall utility system that caters to both the large, long term commercial user as well as the small, single experiment, short term user.

F. Provide an overall utility system that allows a user to be secluded from other users for corporate security.

The utility island provides multiple connection points to a variety of different types and sizes of equipment. The utility island provides a widely distributed power, communication/computer link up system that is integrated with equipment cooling and heat exchange opportunities. The utility island minimizes equipment down time for maintenance, repair, replacement and upgrading. The utility island reduces contamination possibilities due to the fact that the whole equipment rack can be removed and the utility island and connection points of the rack/equipment can be inspected and cleaned. The utility island reduces equipment contact with the inner modular hull. The ventilation can be either negative or positive flow. It eases inspection, contamination control, hull repair, and provides a larger portion of inner hull view, giving an impression of a larger interior volume which may have a positive psychological effect on the crew. The changes in equipment position will add to the variety and changeability of the station. The utility island caters to both large, long term users and small, short term users. The utility island provides opportunities for secluding work volumes for corporate security.

UTILITY ISLAND - ADVANTAGES

- MORE USER VOLUME
- MAXIMIZES UTILITIES IN A SINGLE VOLUME

- ENHANCES AND PROMOTES FLEXIBILITY
- ADAPTABLE TO ALL SIZES OF USER
- PROVIDES LIGHT AND ACCESS FOR MAINTENANCE AND REPAIR

UTILITY ISLAND - DISADVANTAGES

- MAY ADD WEIGHT AND COMPLEXITY
- LIMITS TRANSPORTATION FLOW PATTERNS
- MORE CONNECTION POINTS
- ACCEPTANCE BY INDUSTRY

ALTERNATIVE CONCEPTUAL DESIGN - CENTER UTILITY CORE

The center utility core concept takes full advantage of the microgravity aspects of near Earth space. The triangular core that is 3'-0" on a side contains all the utility distribution of a module, the air, power, communications, equipment cooling, etc. The core is suspended in the center of the module by struts radiating from the triangle ends. The center core is primarily intended to serve the lab - work modules but can also be used in the habitation area. Equipment is attached to the core plugging into the services and locking on to the core structure. The center utility core is markedly different from current aerospace designs. This difference could stimulate dialog, questions and identify new utility research questions. The development of the center utility core could provide an opportunity to compare current and unique new systems in an attempt to isolate future research issues. See Figure 19. The Center Core Concept clearly must be compatible with the End Cap Design to be functional. A future application of the concept is depicted in Figure 20.

SALIENT QUESTIONS - CENTER UTILITY CORE

Can the perception and functions of the volume be changed by utility arrangement?

How does the end cap contribute to the problem?

How does one evaluate and test the performance?

How can the problems of long term contamination be minimized in utility spaces?

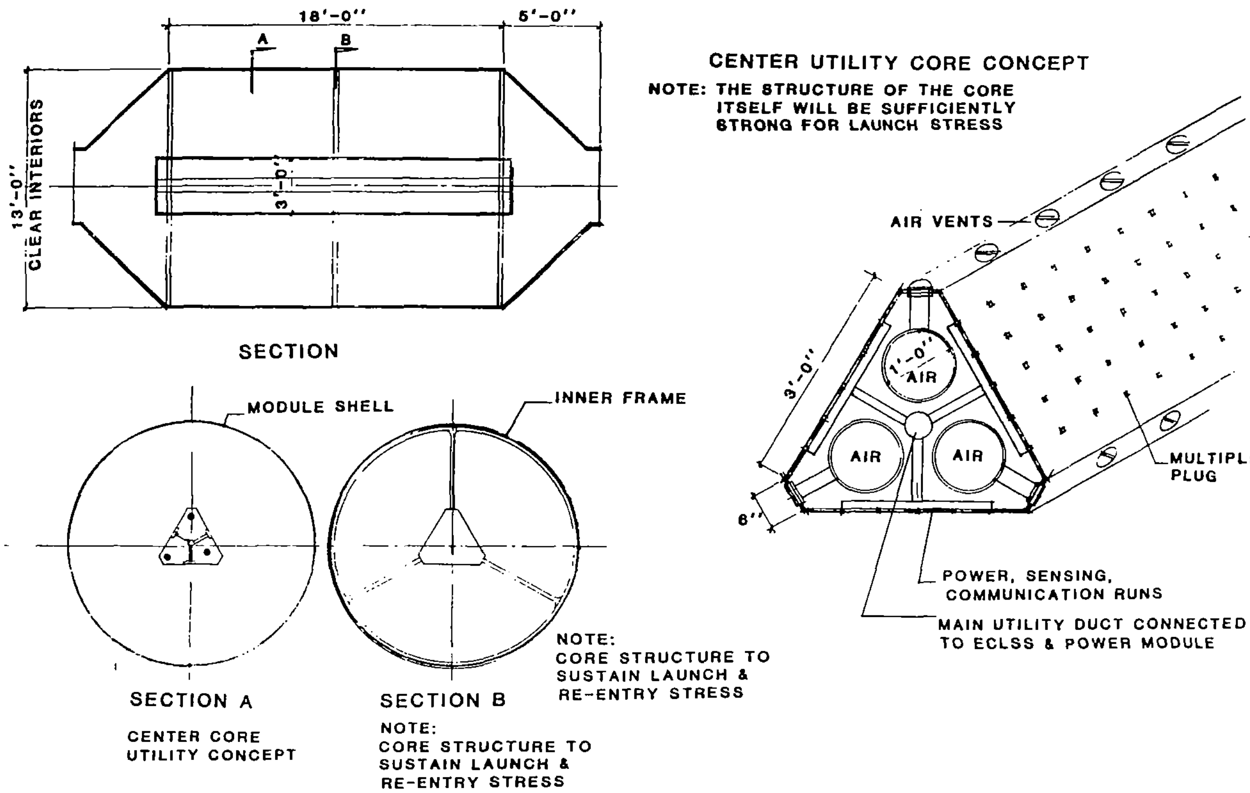

Figure 19 Conceptual Design Center Utility Core

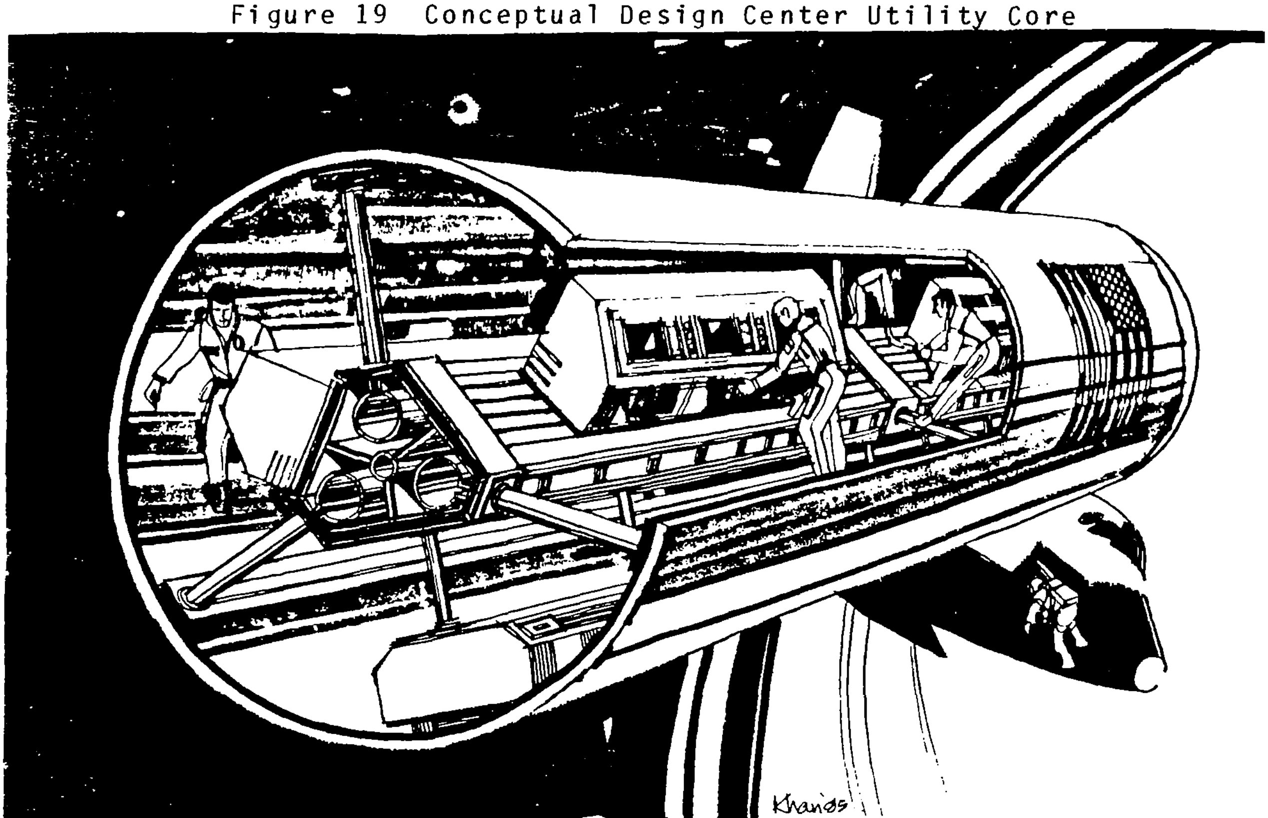

Figure 20 Future Application of Center Core Concept

2. How can the length and weight of power and utility runs be minimized?

3. Should overall air flow and equipment cooling be combined?

4. How can the interior volume of the station appear larger and therefore reduce the feelings of confinement?

5. How can the utilities be integrated so as to reduce the problems of end cap utility ports?

CENTER UTILITY CORE - ADVANTAGES

- QUICK ACCESS FOR REPAIR
- ENHANCED VERSATILITY IN PLUGGING INTO SYSTEM
- SHORTER UTILITY RUNS

CENTER UTILITY CORE - DISADVANTAGES

- LOCAL VERTICAL IS DIFFERENT THAN SURFACE BASED REFERENCE
- OBSTRUCTED CROSS TRANSPORTATION PATH IN MODULE
- LAUNCH LOADS DIFFERENT
- LAUNCH PAD SERVICING DIFFICULT
- INDUSTRY ACCEPTANCE

ALTERNATIVE CONCEPTUAL DESIGN - DUCT RUNS

The use of the prefabricated duct run can have advantages in the initial module fabrication and in the reconfiguration of the module in orbit. See Figure 21.

The duct is based on the division of the utilities into four separate and distinct groups which are compatible with each other. These utilities are then fabricated into two types of integrated duct runs. The first is as long as the common module segment length or some multiple of the length. The second is the end cap segment which turns and goes through the utility openings above and below the hatch.

The duct runs have easy to connect joints with simple snap together, individual connections. The O.R.U. (orbital replacement unit) is shipped in a compressed condition until expansion in

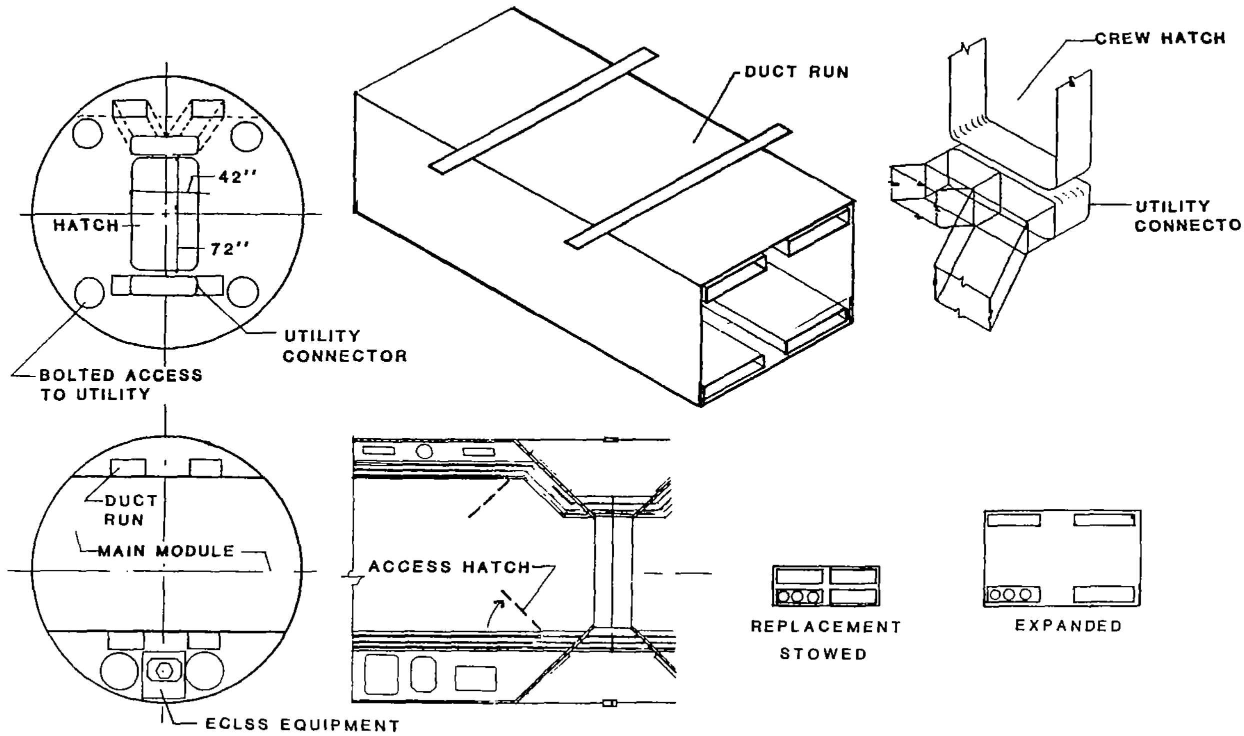

Figure 21 Conceptual Design Duct Runs

orbit. The duct run can be opened in orbit for work or replacement of individual components.

The duct run is designed to become part of the floor system and transport a variety of different utility runs. Each of the four duct runs is different. Several critical utilities are duplicated in separate duct runs. Some of the utilities have return lines in different duct runs. The duct runs have sensors and are prewired for the monitoring of the critical utilities. This includes limited closing and rerouting of ECLSS services in normal operations, repair, maintenance and emergencies.

The duct run shown in Figure 22 is designed for a standard hatch of 50 inches.

The duct runs become simpler with a 72 inch door or hatch height. See Figure 23.

The attachment of a module requires some cross over ducts to be installed. See Figure 24.

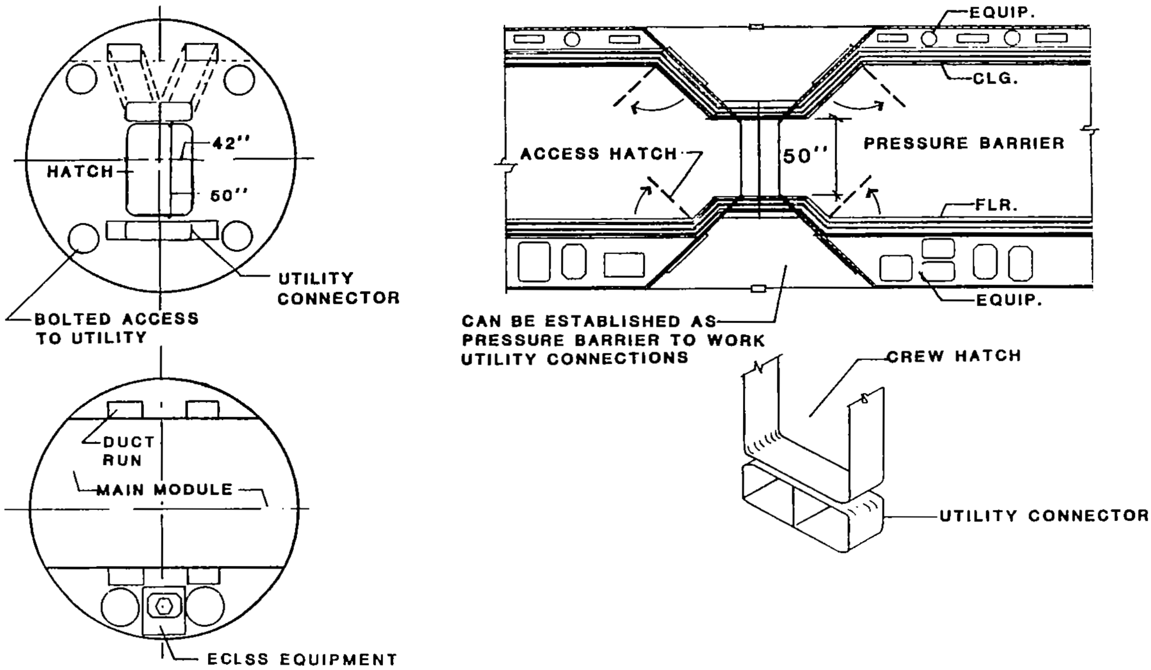

Figure 22 Interface Details Duct Runs

ADVANTAGES - DUCT RUNS

The duct run concept creates a modular system of utility routing which should limit the on orbit spares required. It lays out a system of utility routing and distribution on which suppliers can depend and is defined early in the design process. The duct runs are replaceable units with only two basic types. The unit designed to be transported into orbit is compressed for easy transport.

Each unit has an integrated monitoring and control system built into the unit and installed with the replacement unit. A standard set of tools is created to maintain and repair the units. A similar trend to the ducts run concept can be seen in the surface building industry.

The duct nature of the concept may contain some of a damaged utility problem. The problem sensing unit of one utility may be helpful to another.

DISADVANTAGES - DUCT RUNS

The replacement units are bulky and probably nine feet long by two foot square. A fluid line break in a duct run would be contained in the duct run, but may damage other utilities.

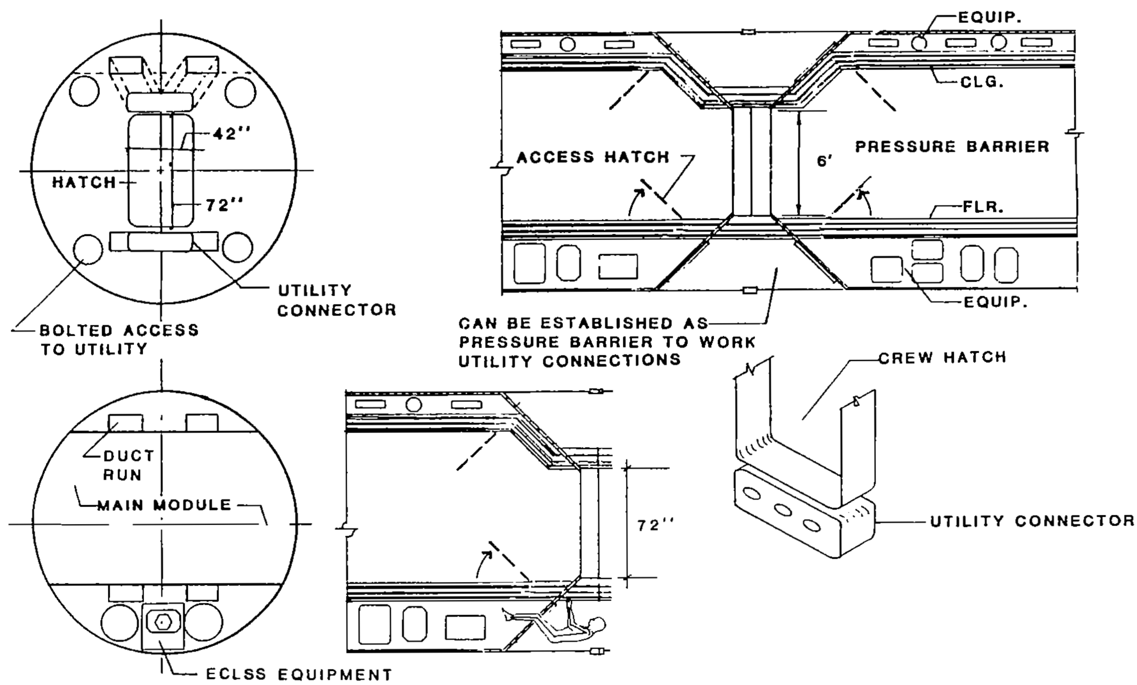

Figure 23 Conceptual Design Duct Runs - Detail

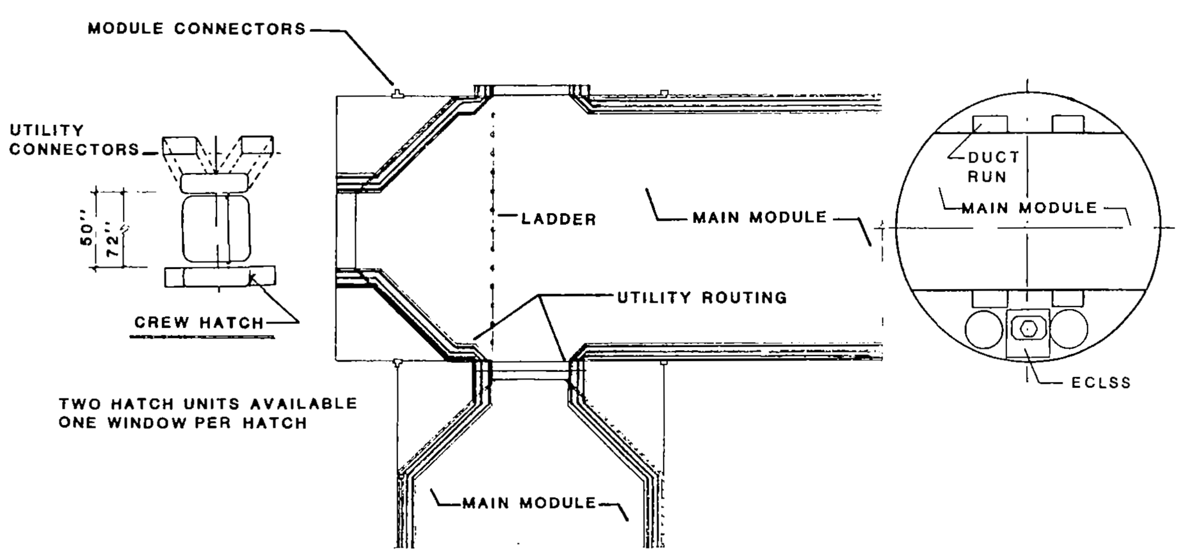

Figure 24 Interconnect Design Duct Runs

IDENTIFY QUESTIONS WHICH REQUIRE FURTHER RESEARCH - UTILITY ROUTING

1. How will power be physically distributed throughout the station?

2. Is the utility island adaptable to the habitation module? In a much smaller form, could it be placed in the crew quarters?

3. Will the utility island increase or decrease the amount of equipment a user can place in a module?

4. How can the length and weight of power and utility runs be minimized?

5. Should overall air flow and equipment cooling be combined?

6. How can the utilities be integrated so as to reduce the problems of end cap utility ports?

7. Can the modular duct run provide a predictable attachment point for all equipment in the Space Station?

SUGGEST RESEARCH AVENUES - UTILITY ROUTING

A detailed mock-up addressing the utility placement, routing, distribution, maintenance repair and future replacement is suggested. It could be combined with a mock up addressing other issues. See Figure 25.

Several utility routing and distribution systems could be assembled and put through a Mock-up test in a lab. The end cap utility connection could also be included to insure full coverage of the topic.

IDENTIFY RESEARCH ISSUES ON UTILITY ROUTING

Can the duct run provide a template for interface?

How much monitoring and control of the utilities will be automatic?

What are the standard tools and support equipment required?

What else in surface construction techniques may be helpful?

How often will something utility related fail and need repair?

- ON-ORBIT LABOR MINIMIZED
- MODULAR APPROACH TO CONNECTIONS AND UTILITY HANGARS, ETC.

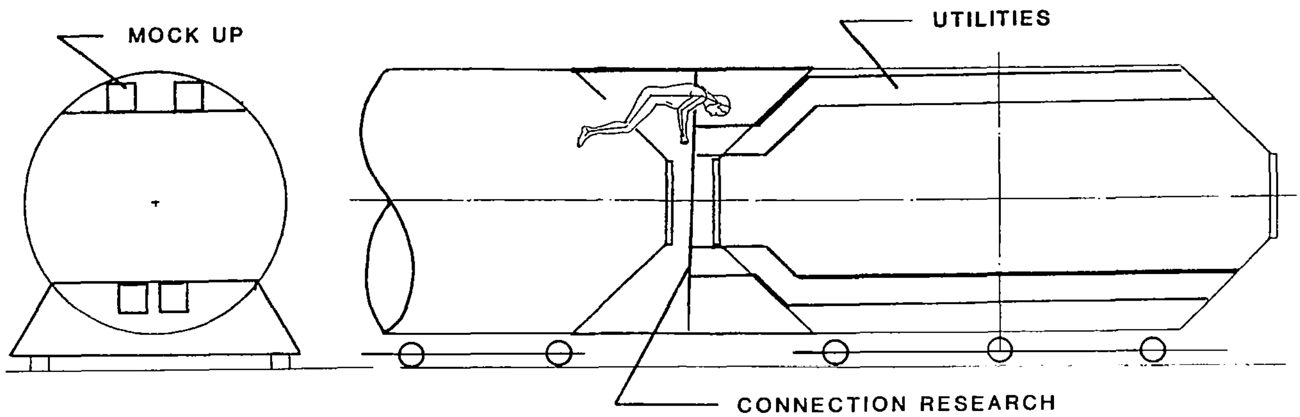

Figure 25 Utility Routing

- MONITORING AND CONTROL OF THE UTILITIES
- STANDARD TOOLS AND SUPPORT EQUIPMENT
- PROBABILITY OF UTILITY RELATED FAILURE
- LONG TERM CONTAMINATION ISSUE
- MINIMIZING UTILITY RUN
- DUCT RUN AS TEMPLATE INTERFACE

Topic 4. SLEEP/PERSONAL QUARTERS

The sleep/personal volume is identified as the volume on the Space Station used for the double functions of sleep and personal habitation. It is the single volume the crewmember can call his or her own without intrusion by others. It may be the location in which the crewmember will spend more time than any other single location on the Space Station.

The complexity of this function has in the past varied greatly. The scope in this study varies from the hammock or sleeping bag approach to the fully integrated personal volume.

The sleep/personal quarters are personal volumes used for sleeping, private space and other functions which may include personal tasks or recreation.

ALTERNATIVE CONCEPTUAL DESIGN - INTEGRATED SLEEP/PERSONAL QUARTERS

The first alternative conceptual design for the sleep and personal quarters is expected to fulfill the following requirements:

The neutral body sleep position with provisions for other sleep positions appears like a good start for personal quarters. The privacy is obtained by an inside locked sliding door. The volume has personally variable temperature control and a personally regulated air flow.

The human factors psychological atmosphere is created by a flexible basic interior design which leaves the final touches and decisions to the occupant. This includes color panels of choice, personally selected interior equipment for work and entertainment, sleep clothing, textures, lighting for reading and mood and some decisions in the final arrangement of the volume.

The equipment of choice is selected from an array of communications and entertainment equipment designed to fit into the racks designed to be a part of the interior space. Those who do not desire any equipment can so chose. The stowage locations can be modular and positioned as desired by the occupant.

The interior volume is large enough to provide a freedom of movement sufficient to turn and reconfigure the volume with a modular framework design. The personalization of volume is the key to making this space the personal quarters or turf of the individual.

ALTERNATIVE CONCEPTUAL DESIGN - INTEGRATED PERSONAL VOLUME

The integrated sleep and personal quarters volume is a combination of standard items and user specified items which together form an appealing private volume for each separate crewmember. See Figure 26. The unit conforms to the neutral body shape, but is reconfigurable to other shapes and sleep positions. The equipment is as little work related as the occupant desires. The entertainment equipment is also occupant specified. The author observed habitation behavior on the North Slope of Alaska; sleep and personal quarters evolution indicate women are more adept at defining a volume for personal habitation and personalizing it in an attempt to maximize the positive impact of the surroundings. In orbit the personal touch is chosen by the occupant through the lighting, color, textured wall surfaces, music, air flow, perfume, personal items, etc. The total cubic volume shown is small compared to the standard used in the industry and suggested by the Space Station Concept Development Group, which was 150 cubic feet.

The concept of integrated personal volumes provides a sleep volume, personal equipment and the personal privacy needed for the long duration habitation at the Space Station.

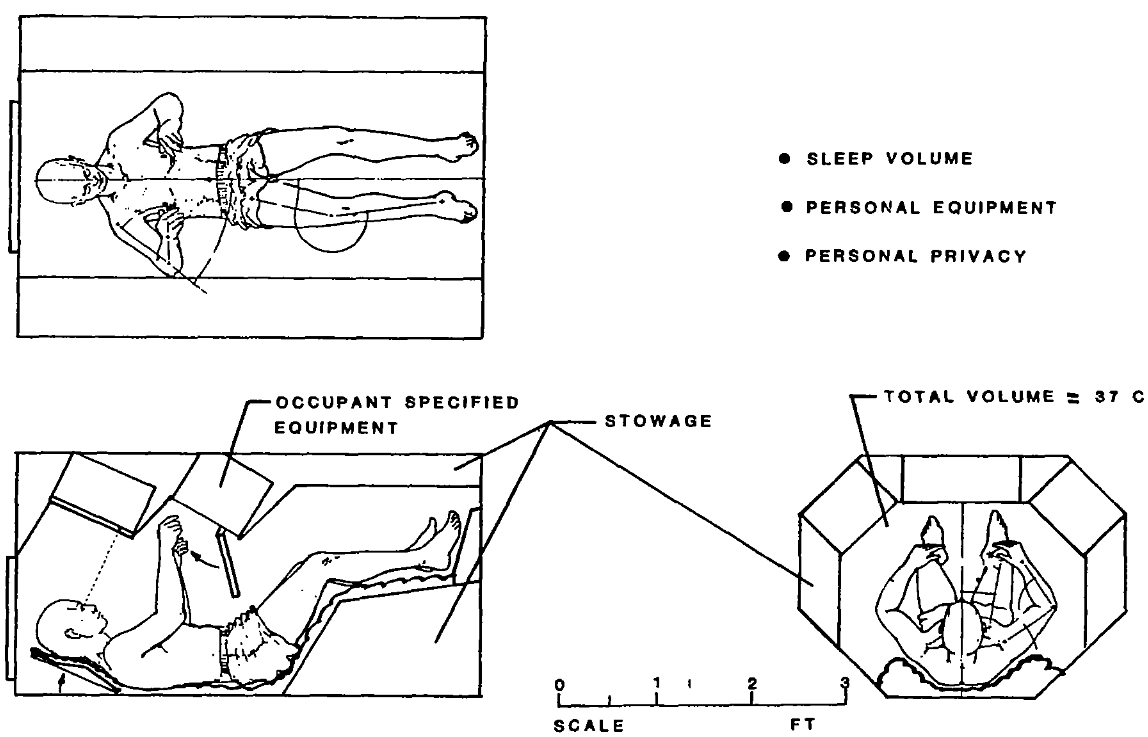

Figure 26 Conceptual Design Integrated Personal Volume

SALIENT QUESTIONS - INTEGRATED PERSONAL VOLUME

How is the personalization of the living volume accomplished? This may be a key human factors and human productivity design question in the station. The individual is likely to spend more time inside the volume than any other single location. Is the personalization effective if nobody else sees it. What culture related personalization is to be designed into the system for foreign crew? This issue should be a future research issue.

What social considerations are important? Alaska construction camps had both locked doors and unlocked doors, and the "No Locks" system worked best, but it was a social end result and not a hardware question. Is a key lockable door required?

1. HOW IS THE PERSONALIZATION OF THE VOLUME ACCOMPLISHED?
2. WHO CLEANS IT AND HOW IS IT DONE?
3. IS A "KEY" LOCKABLE DOOR REQUIRED?

ADVANTAGES - INTEGRATED PERSONAL VOLUME

- NEUTRAL BODY POSITION SLEEP
- PRIVACY
- OCCUPANT TEMPERATURE CONTROL
- PERSONALIZED ENVIRONMENT
- OCCUPANT SELECTED EQUIPMENT
- OCCUPANT SELECTED ENTERTAINMENT
- OCCUPANT CONTROLLED AIR FLOW
- COMMUNICATIONS

DISADVANTAGES - INTEGRATED PERSONAL VOLUME

- COST MAY NOT BE JUSTIFIED AND BENEFITS DIFFICULT TO MEASURE
- "INTEGRATION" MAY CAUSE LOSS OF FLEXIBILITY

SALIENT QUESTIONS - INTEGRATED SLEEP/PERSONAL QUARTERS

Can the sleep volume be made small enough to fit through a 50 inch hatch? It is about 4 feet by 6 feet by 1.5 feet. See Figure 27. The exact dimensions are future research issues, but are likely to be a result of Space Station Orbital Testbed research to factor in the neutral body position as defined by the Brand Griffen studies.

ALTERNATIVE CONCEPTUAL DESIGN - INFLATABLE SLEEP/PERSONAL QUARTERS

Several inflatable solutions are possible. Shown in Figure 28 is a fabric capable of inflation controlled by the user and configured for comfort. The degree of complexity can be varied in research to determine the optimum configuration.

ALTERNATIVE CONCEPTUAL DESIGN - LONG AXIS SLEEP/PERSONAL QUARTERS

The sleep volume and personal quarters can be oriented parallel to the long axis of the module. A pull out unit shown in Figure 29, above the passage way, limits headroom during use.

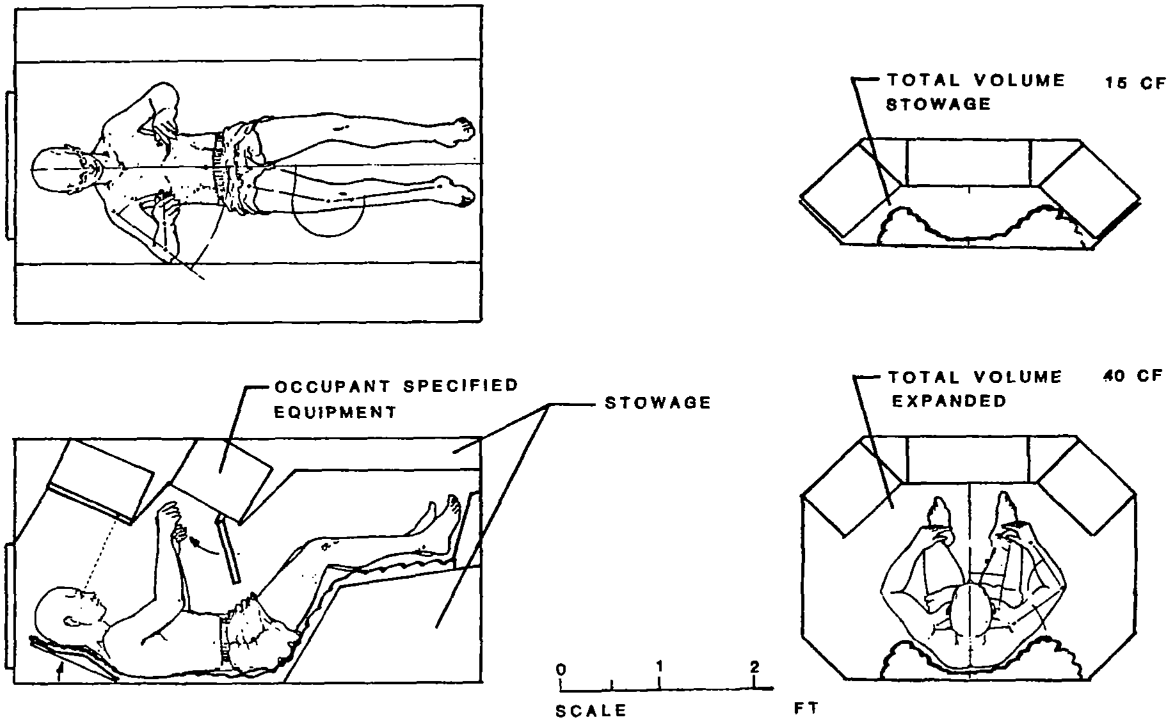

Figure 27 Conceptual Design Expandable Quarters

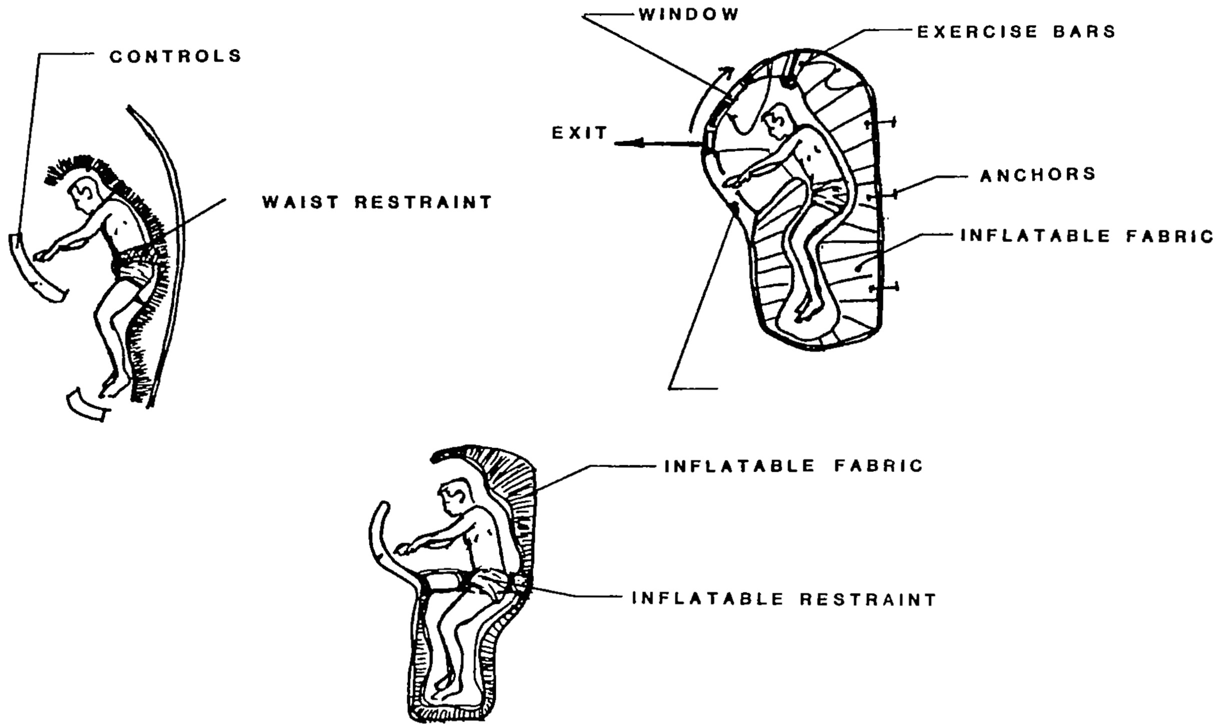

Figure 28 Conceptual Design Inflatable Quarters

ALTERNATIVE CONCEPTUAL DESIGN - CURVED BACK SLEEP/PERSONAL QUARTERS

The neutral body position nearly duplicates the curvature of the module in orbit. This can be used to position the back to the outside module curvature to some advantage. See Figure 30.

SALIENT QUESTIONS - INTEGRATED SLEEP/PERSONAL QUARTERS

The inflatable sleep/personal quarters offers a better sleep location in the same volume as previous designs and also may offer alternatives to temporary habitation of the Shuttle crew and short term occupants.

Does the inflatable concept offer better sleep? There can probably be a cocoon effect created with the inflatable concept. A feeling more closely related to the weight of the blankets and sheets on Earth. The effect on Earth can be seen in the difference between a thin electric blanket and a thick down comforter. The comforter seems to provide weight and security, possibly psychological to the sleep process. This "ideal sleep condition" is reversed in orbit by the microgravity. Inflatables could restore some yet to be researched human emotion.

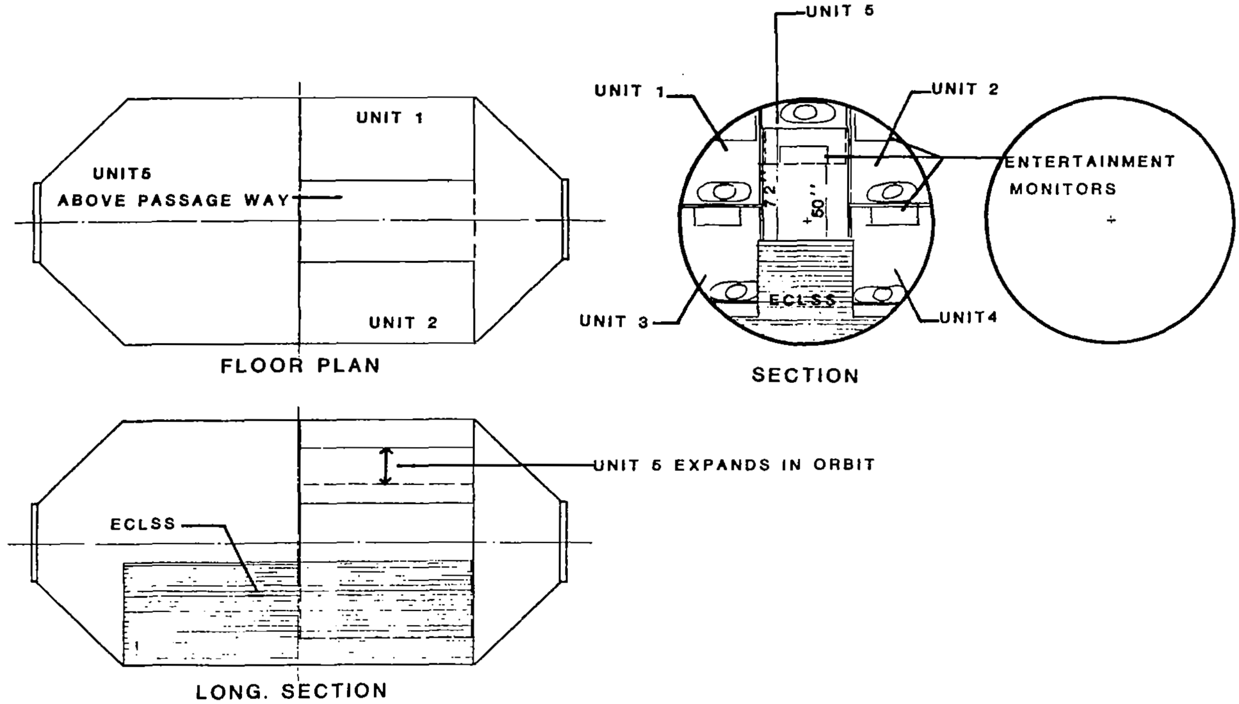

Figure 29 Conceptual Design Long Axis Quarters

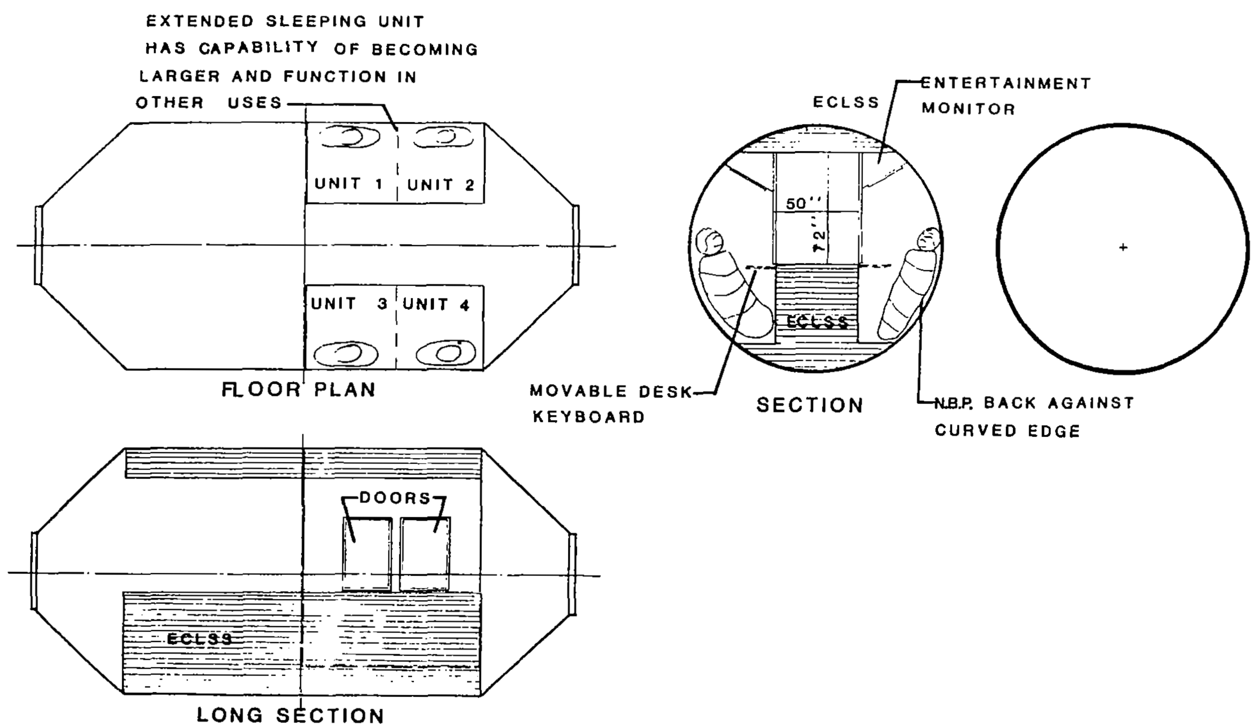

Figure 30 Conceptual Design Curved Back Quarters

Astronauts quickly learn to sleep in any position. Noise and a sense of security are important parameters.

SALIENT QUESTIONS - INTEGRATED SLEEP/PERSONAL QUARTERS

Does the inflatable concept offer better sleep?

Can the inflatable system create a secure sleep volume that enhances sleep?

Is the positioning of the sleep device in relation to local vertical an issue?

ADVANTAGES/DISADVANTAGES - OF THE FOLLOWING SLEEP/PERSONAL QUARTERS

INFLATABLE SLEEP/PERSONAL QUARTERS

LONG AXIS SLEEP/PERSONAL QUARTERS

CURVED BACK SLEEP/PERSONAL QUARTERS

ADVANTAGES

Each provides more effective use of the interior volume and could be the subject of a research task.

The long axis concept provides horizontal sleep position and a system researchable on the surface without microgravity.

The concepts provide sufficient volume for personal quarters equipment and equipment of choice by the occupant.

DISADVANTAGES

The limited volume makes it difficult to turn around inside the sleep volume.

The rooms are probably single task rooms.

The limited stowage for personal items needs definition and research.

The guest visit has many implications and these volumes are not designed for guests.

IDENTIFY QUESTIONS WHICH REQUIRE FURTHER RESEARCH ON THE TOPIC OF SLEEP/PERSONAL QUARTERS

How much volume is required for sleep and for other purposes?

How is the personalization of the volume accomplished?

Is a key lockable door required?

Is the cost and complexity of the expansion concept worth the effort?

Can the inflatable system create a secure sleep volume that enhances sleep?

SUGGEST RESEARCH AVENUES - INTEGRATED SLEEP/PERSONAL QUARTERS

Research this volume in the NASA-Ames Human Productivity Mock Up Facility. Rework Mock Up based on results of the field testing. Create a mid deck flight model for testing in the Space Station Testbed Program. It must fit within the constraints of the Shuttle mid deck or a Space Station Interior Testbed (Spacelab) if there is to be one.

Shuttle flight test in mid deck or other Space Station Testbed alternative to test the microgravity effects of the concept. Combine the data collected to date and create a design which is recommended for the Space Station design.

SUGGEST WAYS RESEARCH ON SLEEP/PERSONAL QUARTERS TOPIC CAN BE UNDERTAK

- RESEARCH CURRENT NASA SHUTTLE EXPERIENCE
- CREATE SCALE MODEL
- CREATE FULL SIZE FOAM CORE MOCK UP
- REFINE ERGONOMICS
- DEFINE EQUIPMENT
- RESEARCH WORKING MOCK UP DESIGN
- BUILD MOCK UP
- MOCK UP FACILITY RESEARCH
- RECOMMEND SPACE STATION DESIGN

IDENTIFY RESEARCH ISSUES - SLEEP/PERSONAL QUARTERS

The volume required is a researchable issue and it appears less volume may be required if the interior is well designed and a secure feeling type of retreat from the work place. The local vertical orientation may require less adaptation by the crew and ultimately more effectiveness, but must be confirmed by research. The quality of the sleep in a controlled environment is a researchable issue with far reaching implications in orbit and on the surface. These issues would be of interest to air flight crews, all 24 hour operations which include shift work and of course the effectiveness of the orbital crew. The quality of the sleep vs. the effectiveness of the human with regular sleep requires research. The research could address the effect of quality sleep on human productivity in varied situations.

The value of inflatable quarters is not backed with research indicating it would be valuable. The value of the created ability to get away from work aspect is however well documented. The inflatable aspect is suggested as a research topic and research into its value in remote locations are suggested for inclusion in the research effort. The hatch transferable unit would be helpful in the flight testing phase, but the human productivity value of all related aspects of all components need further research. The personalization of volume is a human factors issue which may yield significant measurable gain through research. The psychological issue of confined volume has much previous data which may change if the interior is well designed. The equipment interface with station and the close viewing of the television monitor equipment should be researched. The warning and safety equipment required should be researched.

The social aspects of each crewmember retreating from the rest of the crew in off duty periods should be researched against a community type approach to determine first the optimum, second the differences in cultures on this point and third the differences between individual personality types.

IDENTIFY RESEARCH ISSUES ON TOPIC - SLEEP/PERSONAL QUARTERS

- VOLUME REQUIRED
- LOCAL VERTICAL ORIENTATION
- QUALITY OF THE SLEEP
- ABILITY TO GET AWAY FROM WORK ASPECT
- PERSONALIZATION OF VOLUME
- EQUIPMENT INTERFACE WITH STATION
- SOCIAL ASPECTS OF RETREAT FROM CREW

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Topic 5. COMMERCIAL WORK VOLUME

The definition of the commercial work volume is a location within the Space Station capable of performing work of a development nature. This work is expected to be difficult to predict precisely at the time of module design and fabrication, but is expected to parallel surface based development lab activities. The work volume is expected to be driven by technical, scientific, and commercial development requirements. It is called "commercial" because it is this utilization that is expected to be the most demanding.

THE PREDICTABLE REQUIREMENTS FOR THE COMMERCIAL WORK VOLUME INCLUDE:

- SIZE OF THE PRIMARY EXPERIMENT PACKAGE - USER FURNISHED
- SIZE OF EXPERIMENT SUPPORT PACKAGES - AVAILABLE FROM VARIETY OF SOURCES
- HABITATION AND SUPPORT FOR HUMAN EXPERIMENTER
- BASIC SCIENCE AREA, TECHNOLOGY FIELD OR EXPERIMENT AREA
- A REQUIREMENT FOR PROPRIETARY PRIVACY
- SERVICES AND CONSUMABLES

IDENTIFY/DEFINE - 8 FOOT WORK POD

The work pod is an 8 ft. diameter pressurized work volume, capable of attending to the needs and requirements of the client's initial concept development to the final work performed in orbit. It is designed to focus on user involvement early in the client cycle to stimulate the marketing of Space Station services.

This concept is designed to fill the market gap between the clients that share a spacelab type space station module and the ones that can transfer their equipment and experiments thru a 50 in. diameter space station hatch. The work pod is 8 feet in diameter for transporting in a highway van at common carrier rates.

DEFINE

The work pod is a sphere, cylinder or other shape that can attach itself to the common space station module and link up with the main module utility services.

This provides a private proprietary work volume which can be user configured, user controlled and user modified.

The pod can remain in orbit in an active or inactive mode. It also has the capabilities to return to Earth and be used again.

The pod is designed to minimize the cost to the user, enhance the commercial customer involvement, and expand the space station commercial market.

- USER CONTROLLED VOLUME
- USER CONFIGURED AT USER FACILITY
- USER RECONFIGURED VOLUME
- WORK POD CONNECTS TO THE EXISTING ECLSS
- DESIGNED TO FILL A MARKET GAP (COST & SIZE)
- DESIGNED TO TRAVEL IN STANDARD HIGHWAY TRAILER

ALTERNATIVE CONCEPTUAL DESIGN - 8 FOOT WORK POD

Graph chart indicating major expense to customer at minimal cost. See Figure 31.

Finding market gap for clients not able to afford a complete main module, but who require more than just standard equipment. 8 ft. dia. pod able to satisfy this specific clientele.

8 ft. diameter work pods connecting to main Space Station module. One module capable of adapting up to 3 work pods. See Figure 32.

The EVA crewmember assists in the final hookup of the work pod. The structural attachment is an area of further research.

Possible front end user involvement marketing system. The unit is delivered to the user's facility in a highway van (8 ft. limitation). The user configures the van sphere with equipment and NASA leased equipment. The access is obtained by spliting pod in two halves and inserting a modular equipment frame inside the sphere sections. See Figure 33. A complete Space Station User Marketing Scenario could be built around the concept, but this type of effort is beyond the scope of the contract.

NASA technical assistance is available at the user's site on an as required basis.

After the module is configured, checked, test run, and all the communications checks are complete, then the module is transported to the launch site integration facility near the launch

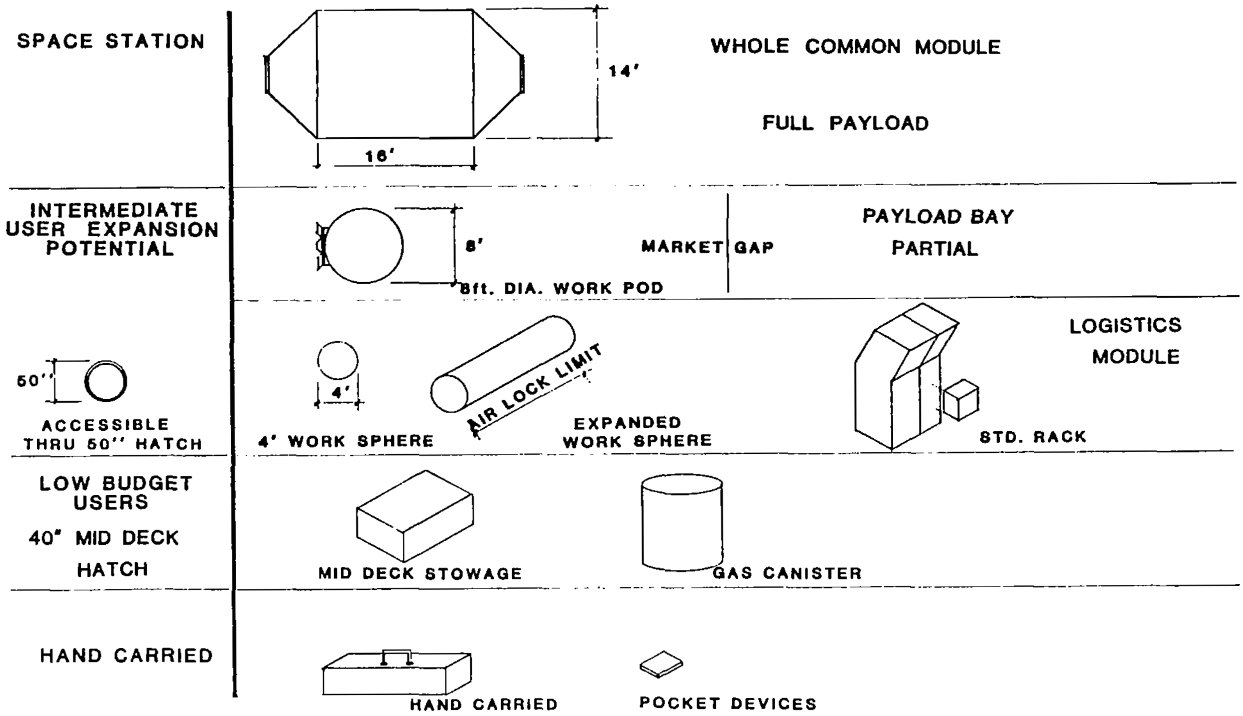


Figure 31 Graph Chart Commercial Work Volume

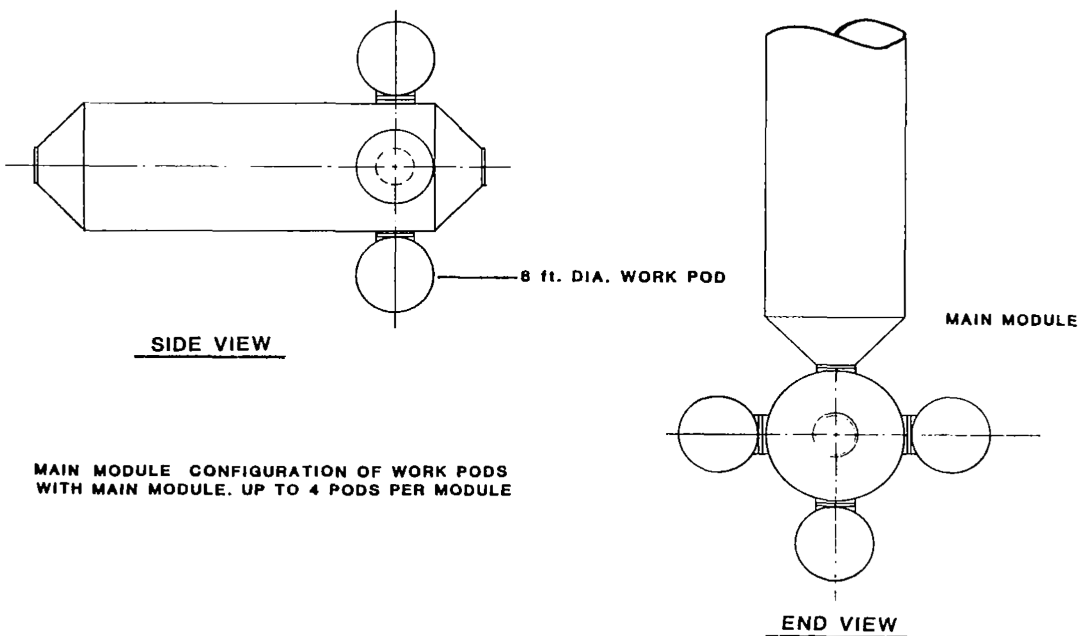


Figure 32 Conceptual Design Commercial Work Volume

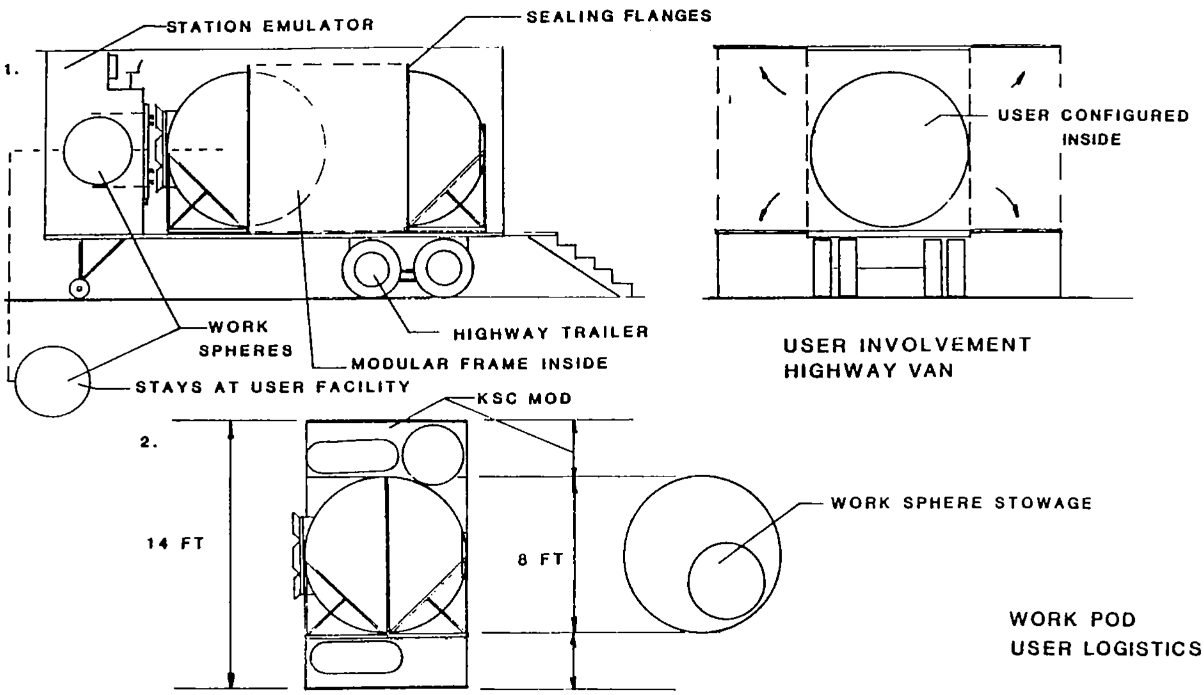


Figure 33 User Outfitting Details - Commercial Work Volume

pad and the support rack is added. The support rack is designed to contain tankage, equipment and other items that are cold-plated. The package fits transversely in the STS cargo bay.

The module is launched, utilized in orbit and probably remains in orbit, available for reuse, lease or sale by the original user or by NASA.

Connecting frame from main module to work pod. See Figure 34.

Frame on main module will be placed in orbit. Frame on work pod will be part of transport pallet, male/female frame connectors.

Section showing 14 ft. dia. and 8 ft. dia. work pod, indicating utility hookup, docking approach, and configuration of interiors with extension of exterior facilities. See Figures 35 and 36.

Plan view of work pod indicating possible configuration, and anthropometric movement in volume.

ALTERNATIVE CONCEPTUAL DESIGN - EQUIPMENT PLACEMENT ANALYSIS

The placement of equipment against the curved wall has certain disadvantages as are shown in Figure 37.

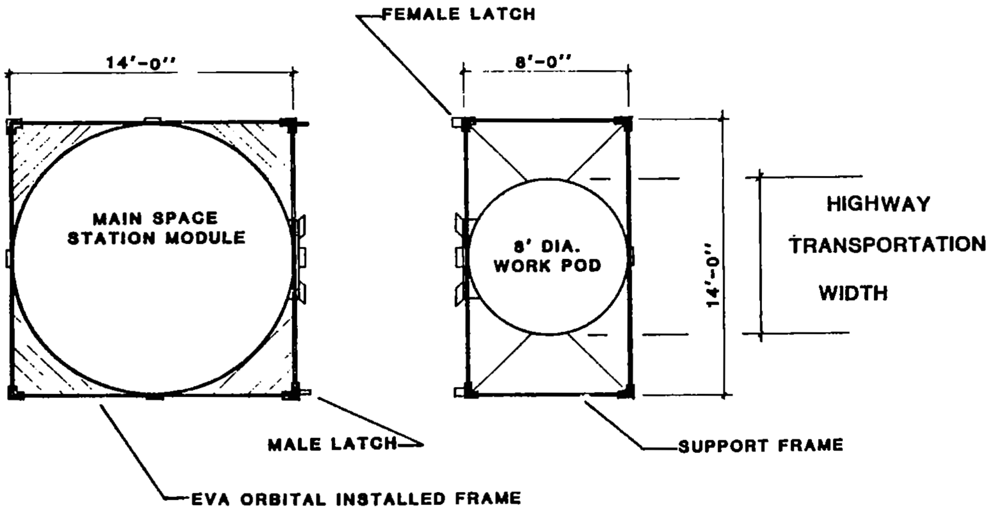


Figure 34 Space Station Interface - Commercial Work Volume

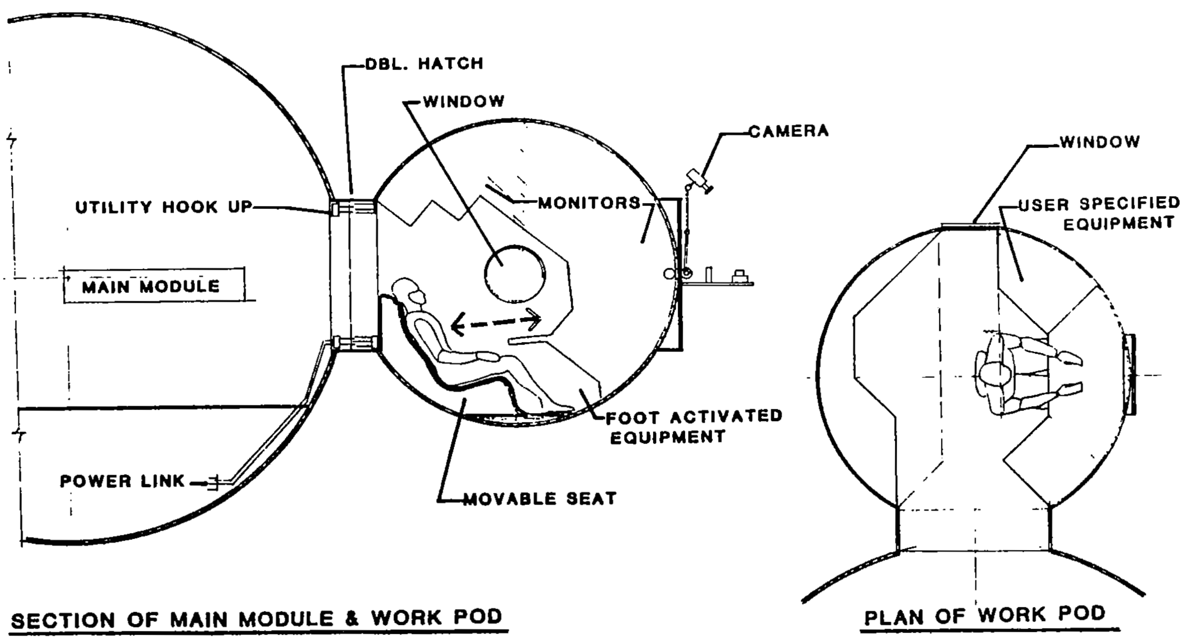


Figure 35 Space Station Utilization - Commercial Work Volume

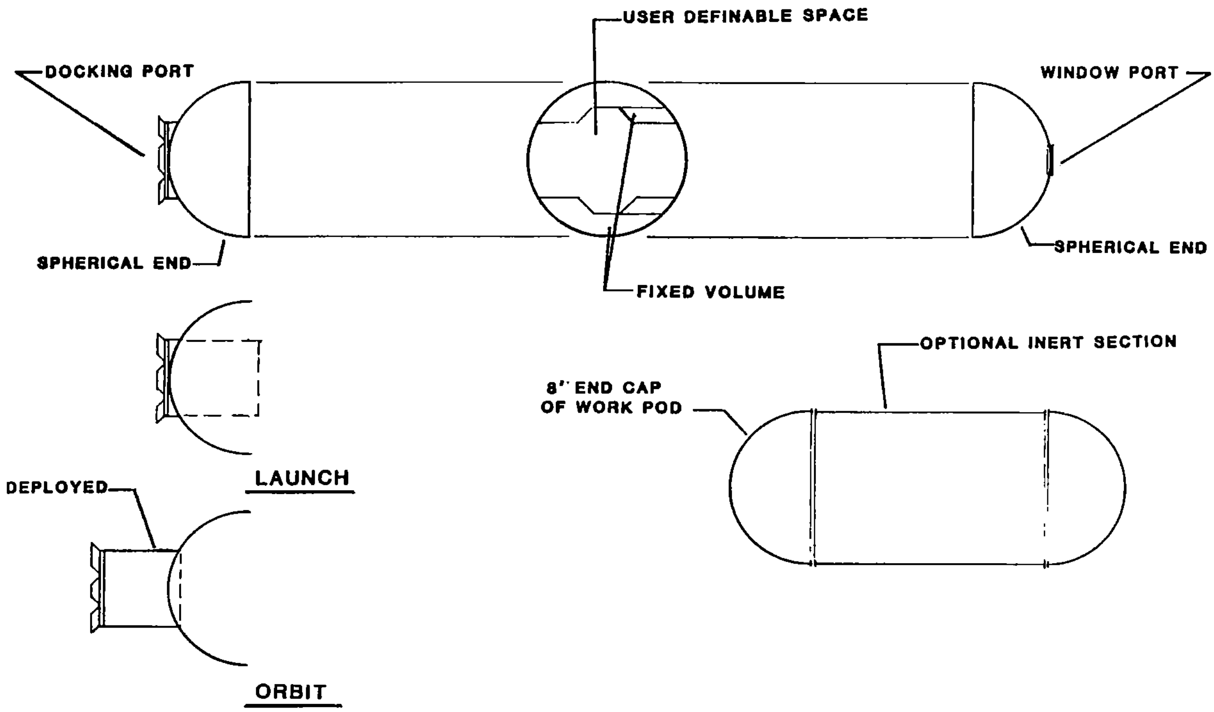


Figure 36 Expanded Design - 8 Foot Work Pod

The 79 inch radius provides a complementary fitup with the curved wall. See Figure 38.

The same is true of the flat equipment. See Figure 39.

ALTERNATIVE CONCEPTUAL DESIGN - FREE STANDING WORK VOLUME

The free standing work station offers a method of utilizing the interior free standing equipment. See Figures 40 and 41.

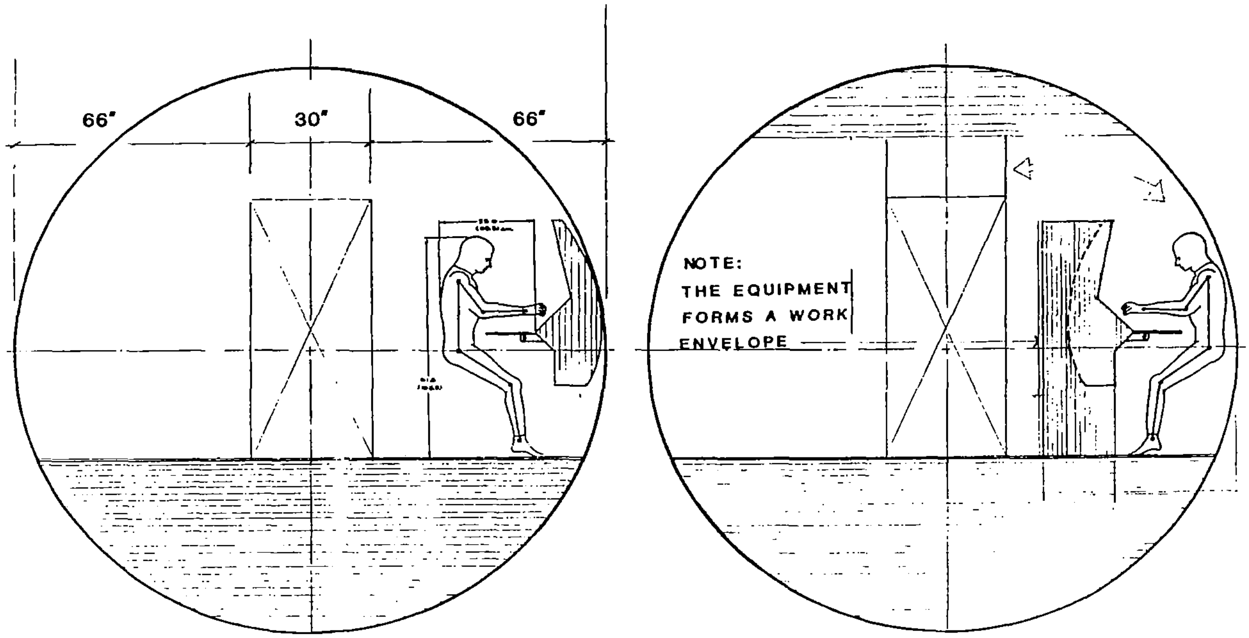
SALIENT QUESTIONS - 8 FOOT WORK POD

What is the market gap between a full dedicated module and the 50 inch opening experiment package?

What diameter work pod is required for 2 persons operating in a larger sphere than a 4 ft. diameter?

What options are open to the customer who requires a proprietary volume smaller than a dedicated module?

How much ECLSS can be taken from the space station module system?



SECTION

TYPICAL WORK STATION AGAINST HULL

SECTION

EXPANDED EQUIPMENT FREESTANDING MODULE
WITH CREW MEMBER AGAINST HULL

Figure 37 Conceptual Volume Equipment Placement

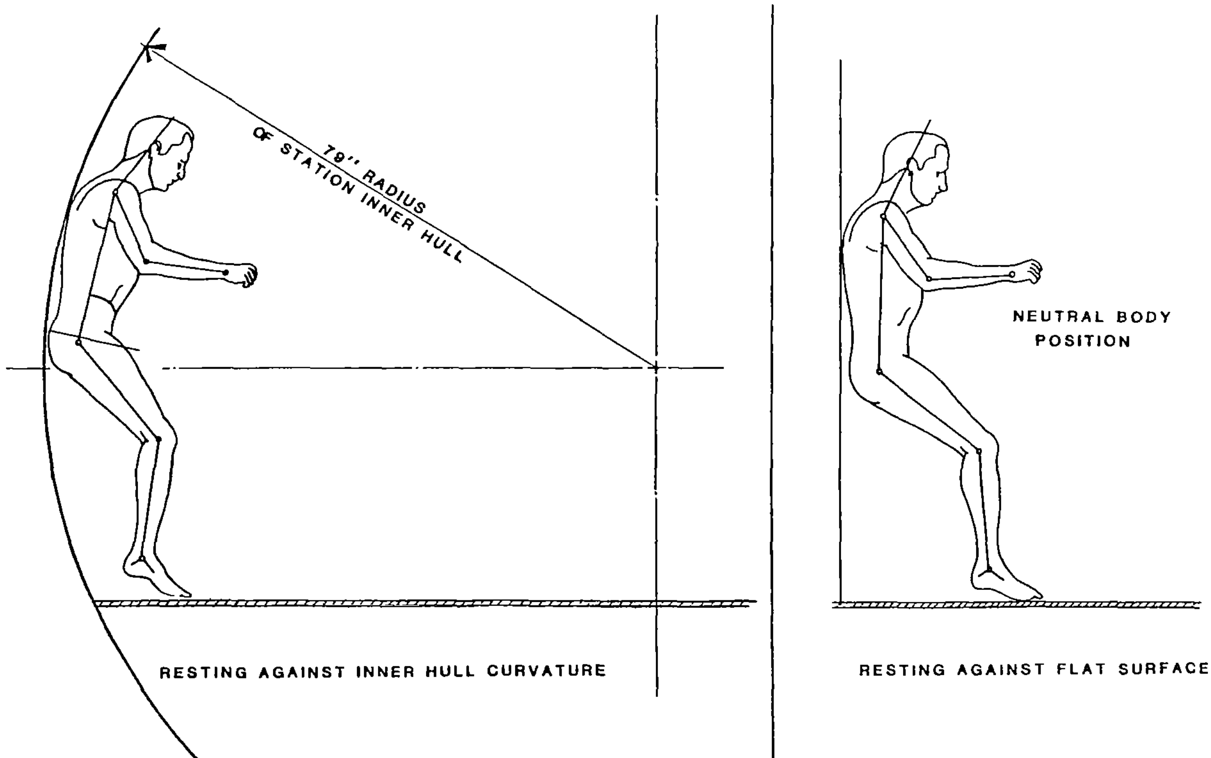


Figure 38 Man vs. Curved Surface

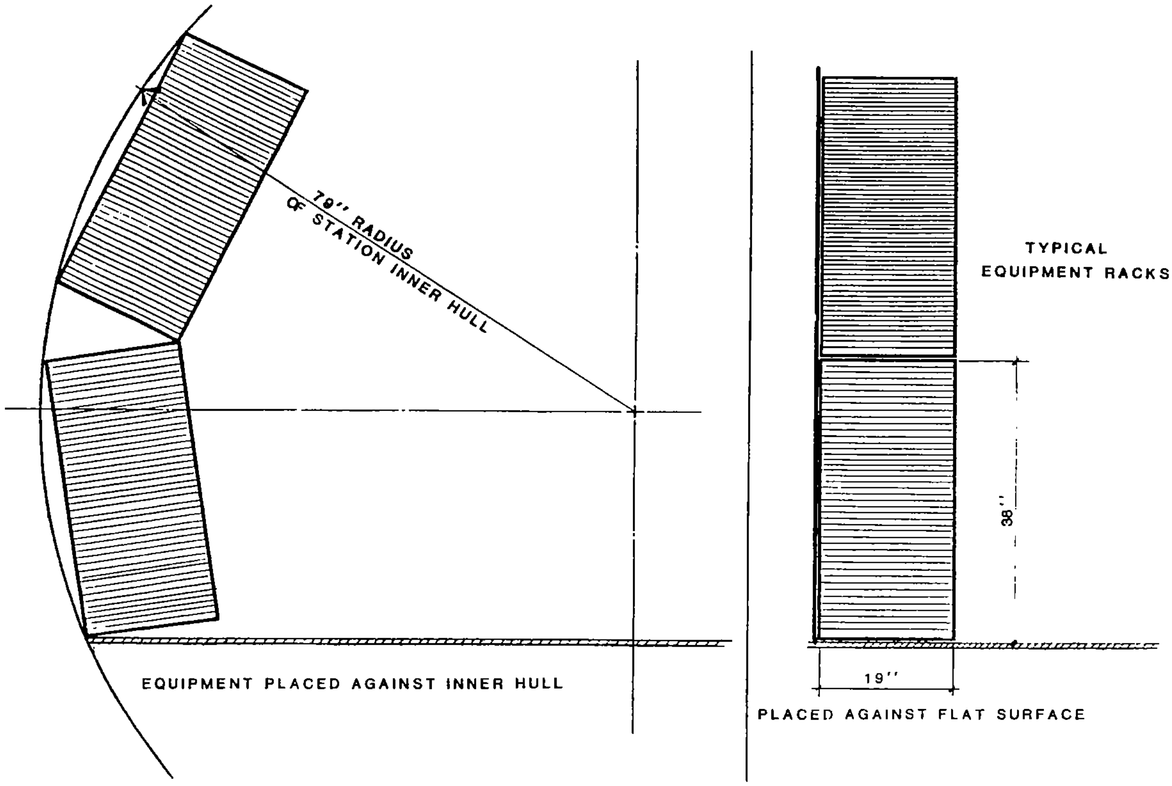


Figure 39 Conceptual Design Equipment Placement

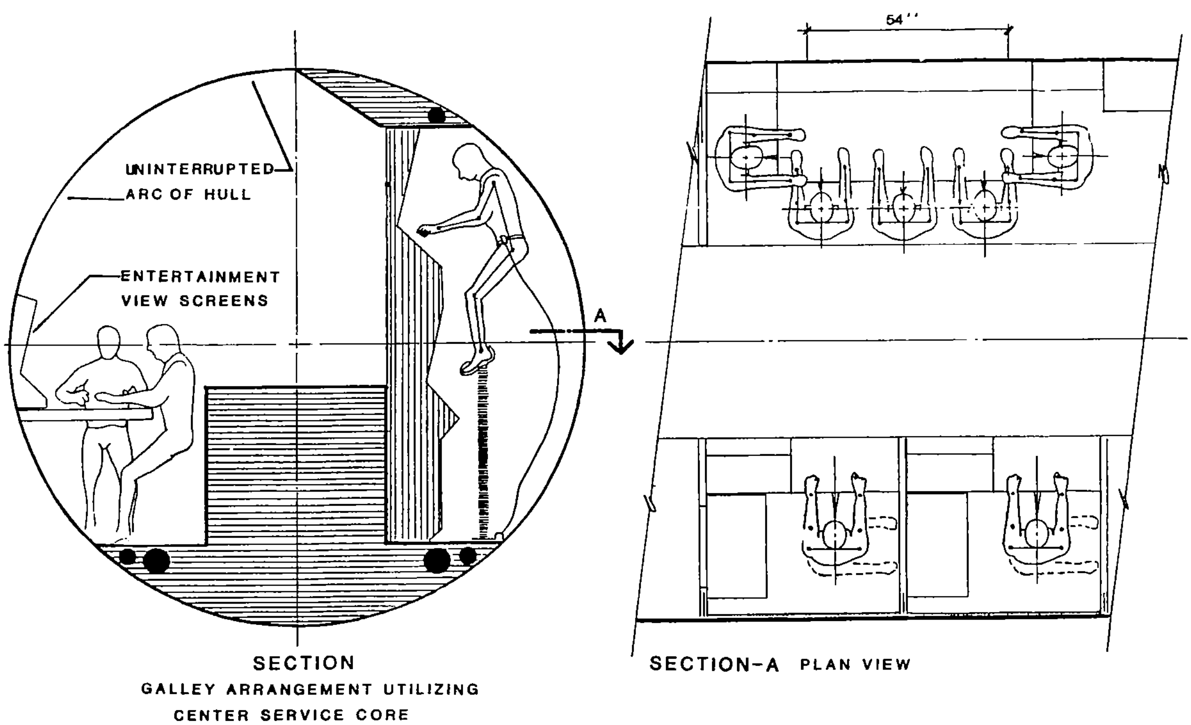


Figure 40 Conceptual Design Free Standing Work Volume

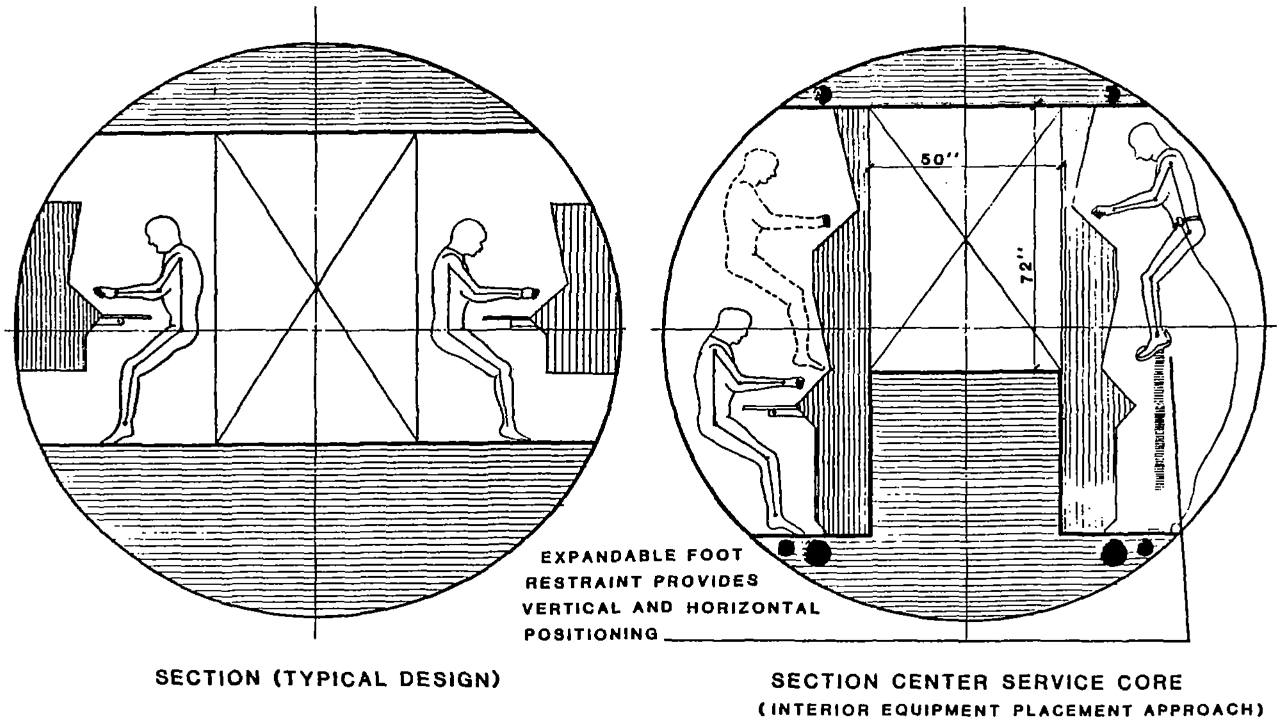


Figure 41 Conceptual Design Extended Work Volume

How does the 8 ft. dia. pod maximize the support for the 14 ft. dia. main module?

ADVANTAGES/DISADVANTAGES - 8 FOOT WORK POD

ADVANTAGES - SUMMARY

- LARGER VOLUME THAN 4 FOOT DIAMETER SPHERE
- SMALLER THAN FULL 14 FOOT DIAMETER MODULE
- PRIVATE PROPRIETARY VOLUME
- USER DEFINED INTERIOR EQUIPMENT
- TRANSPORTABLE ON THE ROAD
- SPECIFIC FRONT END USERS INVOLVEMENT
- CAPABLE OF INACTIVE STATUS IN ORBIT
- HAZARDOUS EXPERIMENTS ARE KEPT OUT OF THE MAIN MODULE

- PERMITS SAFETY FUSE, CONTROL AND METERING OF UTILITIES
- LEADS "PRESSURE BREAK" RECONFIGURE IN ORBIT, EITHER INSIDE LARGER PRESSURE ENVELOPE OR IN VACUUM
- PRIVACY - PROPRIETARY, SECURITY

DISADVANTAGES

- REQUIRES NEW MODULE
- IMPOSES UNKNOWN LOADS ON SPACE STATION

IDENTIFY QUESTIONS FOR FURTHER RESEARCH

- Anthropometrics
- Ergonomics
- Resale value on Earth vs. in orbit
- Modularity
- Standard equipment vs. user supplied equipment
- Customer acceptance evaluation

How can the concept be market tested so a complete customer acceptance evaluation can be complete prior to the Space Station deployment?

What research is required to develop dimensions for a specific middle market size payload requirement?

Does it have its own ECLSS or does it plug into ECLSS in a common module?

Does it have its own short term safe haven pack - 3 or 5 days for on-orbit rescue access?

WAYS RESEARCH CAN BE UNDERTAKEN

SUMMARY

- Models
- Mock ups
- Industry surveys

- Customer focus studies
- Flight mock up
- Work simulations of orbital operations
- In plant customer cycle include highway trailer transport
- Simulate Space Station hook up/unhook up procedure

RESEARCH ISSUES - COMMERCIAL WORK VOLUME

SUMMARY

- CAREFUL DIMENSIONAL STUDY
- USER - CUSTOMER SPECIFIED EQUIPMENT
- MARKETING TECHNIQUES - Customer involvement activities
- USER CONFIGURATION - Interior organization
- USER PROFILE - Market analysis and costs
- USER OPERATIONS - Microgravity, etc.
- USER TRAILER - Space Station emulator, etc.
- TRANSPORT ON TRAILER TRUCK

Concentrate the commercial work in a secure economical volume capable of closure.

Keep it transportable by normal highway vehicles.

Research:

Volume required

Security required

Cost parameters

GAS canister expanded program for the Space Station

Isolated environment requirements

IDENTIFY RESEARCH ISSUES - 8 FOOT WORK POD

Size - 2 at 7 ft. dia. fit side by side in cargo bay.

Equipment.

Customer involvement activities.

Interior organization.

Market analysis and costs.

Microgravity.

Space station emulator.

1. How can commercial space work environments best be defined from a user's point of view?

2. How can commercial space work environments be enhanced so as to be highly productive and profitable for the commercial user?

3. How can concentration on work tasks be enhanced to produce a higher quality work product? Does maximizing concentration maximize the productivity?

4. How can work environments be packaged for launch and transferred to space station and eventually be upgraded effectively?

5. Should the station have totally dedicated work areas separate from habitation or should there be a combination?

RESEARCH QUESTIONS - 8 FOOT WORK POD

1. What type of work will be done in the station and how does it relate to the work pod?

   A. Near term (first three years of operation)
   B. Long term (beyond first three years)

2. What type of unique equipment and services could be required by the users?

3. What other functions could a privately controlled environment serve?

4. What type of contained environments can a pod hold?

5. What type of pod structure and packaging will allow it to be brought to the station in the Shuttle Cargo Bay and will shield all non space safe equipment?

SUGGEST WAYS RESEARCH CAN BE UNDERTAKEN - WORK POD

- RESEARCH WITH MODEL
- CREATE FULL SIZE MOCK UP
- CHECK ERGONOMICS AND DETAILS
- RESEARCH EQUIPMENT
- SIMULATE EARLY HUMAN PRODUCTIVITY TESTS ON THE SURFACE
- REFINE CONCEPT
- SURVEY CURRENT COMPUTER/WORKSTATION INDUSTRY FOR INPUT
- CREATE A NORMAL GRAVITY EQUIVALENT WORK POD
- REFINE THE COMMUNICATIONS LINK FOR WORK POD USE ON SPACE STATION
- UTILIZE ON TESTBED MISSIONS AND EVALUATE
- PRODUCE FOR NASA AND COMMERCIAL MARKET
- CONTINUED EVOLUTION IN MOCK UP FACILITY

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SECOND AND THIRD PRIORITY TOPICS

The second priority topics include:

1. Module and End Cap Geometry - The Flat End Cap offers significant opportunities in both the commercial near term applications and future far term Space Station modules where cost and volume on orbit become decision parameters.

Module and End Cap Geometry question is a an integral part of the Flat End Cap Concept discussed previously in the study. This Flat End Cap can evolve from commercially financed sources and existing technology to produce an alternative to the "Common Module" which enhances and expands the options for the module use in orbit. The Flat End Cap Concept actually could become a pivotal link between near term commercialization concepts and far term "Beyond Space Station" concepts with more study and research. The Flat End Cap appears useful in the Space Station context, because the End Cap Geometry allows the functions of the module cylindrical wall to be transferred to the end cap.

2. Bulkheads, Floors, Partitions - The first research question maybe "Are they needed at all?" Bulkheads, Floors, Partitions required in orbit can provide several functions in orbit. One function is the division of the various volumes. It is thought by the authors that these partitions should be as flexible in their utilization as possible and permit the crewmembers as much innovation in their use as possible.

3. Packaging of Equipment - Figure 42 depicts a packaging of equipment concept which permits an interface panel to allow off the shelf carry on scientific equipment to be used in the Space Station. Power and cooling enhancement are among the added services available to the surface designed user supplied equipment.

Packaging of Equipment is a function of the level of "Off the Shelf" carry on equipment permitted. Shown in Figure 42 is a scenario which permits the launch and use in orbit of equipment which is off the shelf and adapted to the conditions of the Station through an anchor pad interface panel capable of providing those services required in orbit and not available in the "Off the Shelf" equipment.

4. Maintenance Provisions - Figure 43 relates a general maintenance provision which suggests the design philosophy of movable equipment. Maintenance Provisions for the interior module wall probably dictates periodic cleaning and inspection. Most interior systems use the exterior wall as the back of the equipment. The Tilt Rack Concept permits the tilting of the racks by providing a swivel electrical connection at the floor. See Figure 45 for one method of Tilt Rack maintenance.

5. Laboratories - Biological contamination appears to be an important design parameter. The Laboratories eventually required

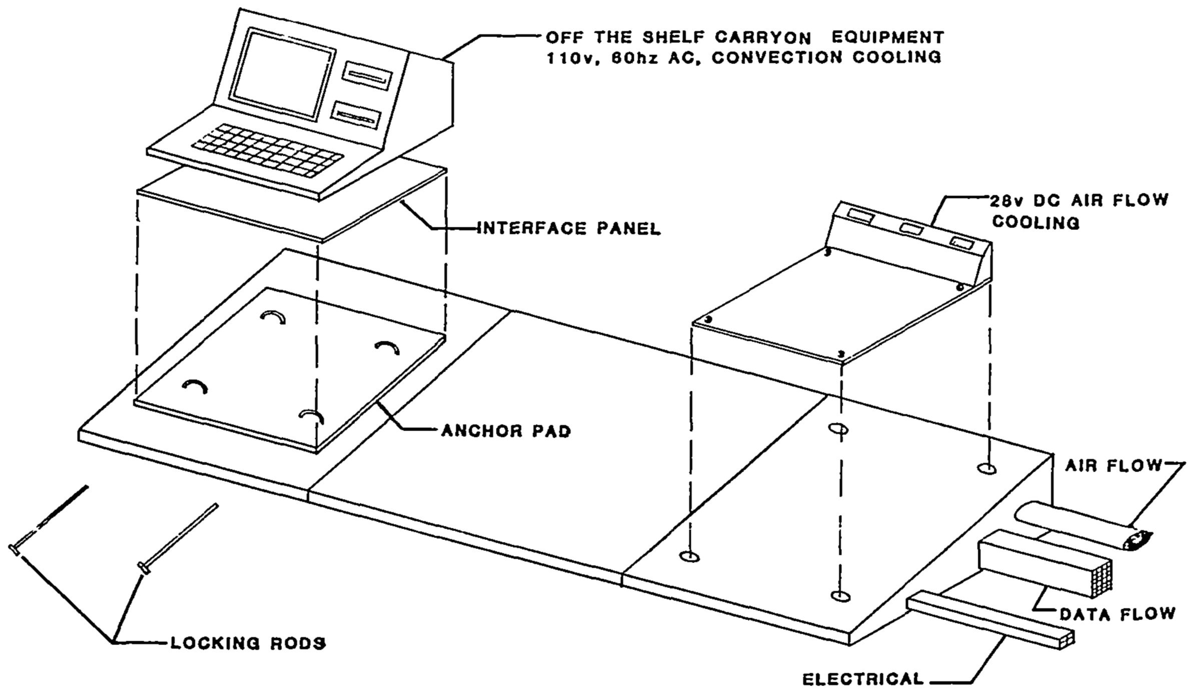

Figure 42 Conceptual Design - Packaging

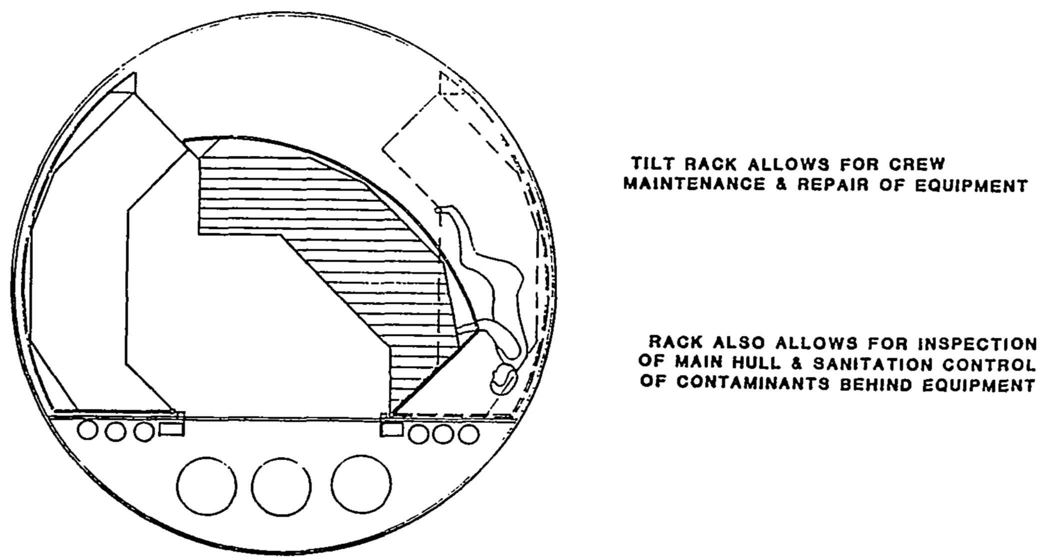

Figure 43 Conceptual Design - Maintenance

in orbit are a function of the user requirements and the major players in this market probably have not emerged as yet. The logical design approach for these labs is to keep the ability to produce the interiors for these labs as flexible as possible. The normal and traditional scenario will be to find a user, press for requirements, base the entire system on a single beginning user and end up with an inflexible hardwired interior which is expensive to reconfigure in orbit or on the surface.

6. EVA Suit Maintenance and Storage - It appears innovation and reapplication of deep ocean work techniques may offer significant human productivity gains in Space Station EVA activities.

The third priority items below are identified as areas for further research or study.

1. Window Types and Locations - Round windows appear to offer some design and human factors advantages. Window Types and Locations are constrained by the shell wall material and the degree of difficulty in providing the windows at the required locations. A good avenue of further exploration is the development of windows able to "look" parallel to the module long axis.

2. Provisions for Interior Modifications and Update - An important point. It is not known if the weight of the module will grow in orbit with the addition of equipment to a point where it will exceed the landing limits when a surface refurbishment is required. Provisions for Interior Modifications and Update is an easily ignored item. It is of even more value if these module designs eventually become saleable to commercial organizations.

3. Safe Haven Pack Form and Location - A future research topic.

4. Lighting, Acoustics, Ventilation, Color, Texture - A topic to be addressed in the mock-up phase of development. Lighting, Acoustics, Ventilation, Color, Texture should become early goals in the construction planning and researchable topics in the anticipated mock up. The adequate lighting of all work locations is probably as impossible in orbit as it is on the surface. Equipment repairmen always carry flashlights, etc. The solution in orbit is Direct Task Lighting which combines several functions to create a head gear able to perform several functions including lighting as required.

5. Galley - Requires extensive microgravity testing in mid-deck testbed or specifically designed Space Station Emulator Testbed alternative to the orbiter mid-deck.

6. Wardroom, Exercise, Workshop, Health Unit and communications are future research topics. The workshop volume offers a change from surface, one gravity workshops. The absence of gravity provides an ease of movement in several directions which could be exploited by a variety of means.

CONCLUSIONS

The study resulted in the following list of research questions and recommendations.

LIST OF RESEARCH QUESTIONS - FUTURE STUDY AREAS

The research questions suggested by this report are varied and numerous. The five general categories of future research include:

1. How can the Flat End Cap impact the IOC Common Module and commercial development?

2. What interior arrangements could enhance the interior of the IOC module and retain the layout flexibility required for the long term considerations?

3. Utilities with the Flat End Cap require a completely different approach to the problem and the solution. What kind of mock-up could best research these questions?

4. One sleep arrangement is probably as inappropriate in orbit as it is on the surface. What can be learned from Shuttle experience and how can it be applied to Space Station?

5. How can the Worksphere and Work Pod evolve into a workable Space Station Workvolume with commercial implications?

MODEL AND MOCK-UP RECOMMENDATIONS

The following model and mock-up recommendations are offered:

1. Flat End Cap model in 1" equals 12" scale including several of the four variations to assess the value of the concept and the impact the IOC Common Module. These are suggested for assembly at our southern California location in conjunction with circular shell furnished by NASA.

Utilities with the Flat End Cap model are recommended to completely layout the various utilities, valves, maintenance, etc. to approach the development of the problem and later the solution. What kind of a mock-up could best research these questions prior to a full scale mock-up? A 1/4 scale model is suggested using foam core materials and built in southern California and transported to NASA-Ames.

Later a full scale mock-up at NASA-Ames of the Flat End Cap and utility impacts is suggested.

2. Small scale interior arrangements of the IOC modules using NASA furnished shells is recommended. An attempt to retain the layout flexibility required for the long term considerations should also be done.

3. Utilities with the Flat End Cap require a completely different and larger scale approach to the problem and the solution. See above recommendation. The suggested size is a scale reasonable for transport to NASA-Ames after foam core research and construction at a southern California location. The suggested scale is 1/4 and of sufficient size to detail individual duct and utility runs, valves, clean out provisions, congestion problems, etc. This leads to the full size mock-up at NASA-Ames to fully research these questions.

4. One sleep arrangement is probably as inappropriate in orbit as it is on the surface. Shuttle experience seems to indicate many individual preferences. What can be learned from Shuttle experience and how can it be applied to Space Station? A foam core mock-up of an individual steep location which later evolves to a Space Station Testbed trial prior to IOC deployment is suggested.

5. The worksphere modified to an egg shape appears to have commercial as well as Space Station potential. It could evolve into a NASA/society interface type hardware item which benefits the program in some unknown way. NASA-Ames is in the ideal Silicon Valley location to capitalize on both the Space Station and commercial aspects of the concept research. A full size foam core mock-up of a modified worksphere which makes it more egg shaped and explores the commercial potential is suggested in Phase II. The worksphere can evolve into a workable Space Station work volume with commercial implications.

The next phase of effort should contain some conceptual study effort, but should concentrate on models in several different scales.

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15. Supplementary Notes

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16. Abstract

A study was conducted to define the architectural elements and issues of the Space Station. The objective of the study was to identify those questions which require further research and suggest ways in which the research can be undertaken. The study examined five primary topics, asked salient questions and described the merits of alternative solutions.

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