NASA Conference Publication 2426

Space Station Human Factors Research Review

Volume III—Space Station Habitability and Function: Architectural Research

Proceedings of a workshop held at
NASA Ames Research Center
Moffett Field, California
December 3-6, 1985

NASA

NASA Conference Publication 2426

Space Station Human Factors Research Review

Volume III—Space Station Habitability and Function: Architectural Research

Edited by
Marc M. Cohen
Alice Eichold
and Susan Heers
Ames Research Center
Moffett Field, California

Proceedings of a workshop held at
NASA Ames Research Center
Moffett Field, California
December 3–6, 1985

National Aeronautics
and Space Administration

Scientific and Technical
Information Division

1987

Space Station Human Factors Research Review

PREFACE

This conference proceeding is a compilation of the papers presented at the Space Station Human Factors Research Review held at NASA Ames Research Center from December 3–6, 1985. These presentations represent the first year of research supported by the Space Station Advanced Development program as well as on-going related research supported by other NASA programs.

Each day of this research review was dedicated to a different focus or discipline. The foci represent the various areas of expertise in the Space Human Factors Office and the Aerospace Human Factors Research Division at Ames Research Center. In general, the structure of the conference was to proceed from the more general topics to the more specific issues during each day and throughout the week.

Vic Vykukal, a specialist in advanced space suit design, chaired the first day's session, *EVA Research and Development.* After Vykukal presented an introduction to EVA Research and Development at Ames, representatives of each of the three aerospace contractors participating in the EVA Systems Study presented their views on Implications for Man-System Design. The final presentation related experiences in the deep-sea diving industry that are relevant to EVA.

Yvonne Clearwater, an environmental psychologist who is pioneering the quantitative modeling of human spatial habitability, chaired the second day, *Space Station Habitability: Behavioral Research.* After Clearwater presented an introduction to the Space Station Habitability Research Program within the Space Human Factors Office, contractors and grantees made presentations on habitability, productivity, operational simulation and aesthetics for space station design guidelines. The session concluded with a panel discussion consisting of the principal speakers.

Marc Cohen, an architect in innovative Space Station design, chaired the third day, *Space Station Habitability and Function: Architectural Research.* After Cohen presented an introduction to Ames Research Center Space Station Architectural Research, each of the contractor or grantee architects presented reports on the progress of their work in architectural design research. The session concluded with a panel discussion consisting of the principal speakers.

Trieve Tanner, Acting Assistant Chief for the Research for the Aerospace Human Factors Research Division, chaired the fourth day, *Inhouse Advanced Development and Research.* After Tanner gave a brief introduction, the members of the division's basic research discipline groups presented papers in their respective areas of expertise: Cognition and Perception, Workload and Performance, and Human/Machine Integration.

Each of these four sessions is published as a separate volume of NASA CP-2426, with each day corresponding to the sequentially numbered volume.

TABLE OF CONTENTS

THURSDAY
December 5, 1985

SPACE STATION HABITABILITY AND FUNCTION: ARCHITECTURAL RESEARCH

Chair: Marc M. Cohen

8:30	Introduction: Ames Space Station Architectural Research Marc M. Cohen, Architect, NASA-Ames Space Human Factors Office
9:30	Space Station Architectural Elements Model Study Tom Taylor and Associates (TAI), with Ethan Clifton, Eyoub Khan and John Spencer
10:30	Break
10:40	Space Station Architectural Elements Model Study Michael Kalil Design Studio
11:40	General Discussion
12:00	Lunch
1:00	Space Station Group Activities Habitability Module Study David Nixon and Terry Glassman, Southern California Institute of Architecture
2:00	Full Scale Architectural Simulation Techniques for Space Station Colin Clipson, University of Michigan, Architectural Research Lab
3:00	Break
3:10	Social Factors in Interior Furnishings Galen Cranz and Alice Eichold, U.C. Berkeley, College of Environmental Design
4:10	Panel Discussion: Research Implications for Space Station Design Cohen, Nixon, Taylor, Kalil, Clipson, Cranz

INTRODUCTION:

AMES SPACE STATION ARCHITECTURAL RESEARCH*

Marc M. Cohen
Architect
Space Human Factors Office
NASA Ames Research Center

INTRODUCTION

Welcome to the third day of the Space Station Human Factors Research Review. Today, December 5, is devoted to Space Station Habitability and Function within the context of Architectural Research. To give you an overview of how we're proceeding, I will show a viewgraph of the make-up of the week (fig. 1). The first day I show in this column deals essentially with behavioral research and the second day, which is today, with architectural research. Each of the different speakers, grantees, or contractors are listed horizontally across the top. Also, on Friday, we have Richard Haines of Ames talking about windows. On the vertical axis we have behavioral factors and architectural subsystems and a break-out of these various topics. What we'll talk about today is architectural spaces. This is a key concept.

Most of the architecture we've seen from the contractors does not have a positive sense of architectural space. What we have seen as habitable space is purely residual volume: that which is left over when you finish packing it with equipment. We have a couple of studies that address this issue. We address the issue of secondary structure; the standoffs and the floors and major utilities distribution. Utilities are so important that they become a major form-giver. Circulation, which includes some mobility aids and restraints is next, then come furnishings, equipment packing, proportional systems, and configurations. Yvonne's day, behavioral research, has this elegant diagonal. For today, I have a kind of scatter-gun approach, but we've tried to cover every major topic with at least one major focus or concentration from a contractor or a grantee, and in some cases we have two presentations.

The other aspect of the organization of this conference is that we're moving from the specific to the general throughout this week. The most specific presentations were the EVA ones on the first day. The last day, tomorrow, Friday, is the basic research from our in-house discipline groups research. The two middle days roughly follow that sequence. We're starting with the people who have the most specific things to say and we're ending with most general. This progression illustrates one of the basic tensions that we have to face: the question of how applied

*Transcribed and edited by Alice Eichold. Photographs by Wade Sisler and Eric James, NASA Ames Imaging Technology Branch.

or how basic we should be. Obviously we need to support the lead program of the Agency, the Space Station program. But we are Ames Research Center and unless we do some basic research we are going to be out of business in a few years.

We're always caught in this tension of meeting research criteria; sometimes we sponsor some very application-oriented activities and sometimes we sponsor some fairly high risk basic research. Basic research can be "high risk" in that we don't know what we're going to find. We can say that the research has a specific application, and hope that it does, and then find out that it teaches us something completely different. There is a great deal of serendipity in the process. We hope to publish a great deal in the next year including the proceedings of this conference. We will be publishing the collected results of 3 years' work.

HUMAN FACTORS IN SPACE STATION ARCHITECTURE

About 3 years ago we started looking at Space Station architecture from a human factors point of view. At that time we were looking for alternatives to some of the contractor concepts which we felt had been conceived without any regard to mission requirements for habitability (figs. 2 and 3). We went through a set of functional analyses and other questions and developed various areas of concentration such as functional organization, geometry, various characteristics of function, configuration, and docking and berthing geometries.

These were a couple of the key concepts in 1982 when we had these rectangular geometries (fig. 4). We had these multiple-berthing adapter-type cans with numerous ports in them that ate up usable interior space (fig. 5). Concepts like this had no acceptable way of docking a Shuttle to it, with these very long docking tunnels that would give a terrible oscillation problem. At that time there were many questions to look at as well as the fact that these rectangular geometries were not self-rigidizing at all. The structural questions were eventually resolved with the large truss structures for payload attachment as well as supporting the solar array (fig. 6).

One of the major needs we found was for a study of Space Station architectural geometry. I undertook this study and came up with a concept of a triangular-tetrahedral geometry for which these are patent drawings. We've been allowed some of the claims (fig. 7). We continue to appeal the other claims. One of the claims is for this spherical docking hub which has now been incorporated into the Reference Configuration. We're very pleased by this step because it's a tangible indication that research can inform the engineering design process. Some of the other things we looked at were airlocks, both internal and external, and work stations for external proximity operations. We continue to concentrate on both of those topics in terms of habitability and functional operations. We looked at a variety of issues such as functional organization, territorial division, interchangeability of modules, and safety and found that the most critical architectural issue was volume. Volume becomes all the more important for the architectural design of the Space

Station to make a habitable, experiential, and perceptual volume; to make a good place to live. We have several people who will address this set of issues today (fig. 8). I undertook a number of diagram exercises to apply generic architectural programming techniques to develop a basic sense of what was involved (fig. 9). This particular exercise shows the evolution of the kitchen from process flows. In this case the function is preparing vegetables and washing the pots and pans. How the process flows evolve into a kitchen, viewed on this generic level, is analogous to the Space Station purely in terms of confluences and conflicts at the circulation nodes. From these types of generic studies (looking at Space Stations in a very crude way) I realized that the circulation node would be critical. This realization led to the triangular tetrahedral geometry. Very simply, what happens is that food moves around the counter from one "work station" to another (fig. 10). People in the kitchen run around independently of the counters. In a Space Station, you can't go out of the module; seeing this counter as a module on a metaphorical level, you cannot hop from one module to another; you must go along the primary structure. Therefore those circulation nodes become important.

Another issue that we looked at was the gross breakdown of habitability functions, whether you would combine everything homogeneously in one module type or have two specialized habitability modules. In this cartoon you see a wardroom, galley, and four sleep compartments (fig. 11). There are two modules, one for group activities and one for sleeping. This separation of functions was a recommendation that we made at the Concept Development Group (CDG) in Washington during 1983 (ref. 1). We're pleased that this recommendation made it into the Reference Configuration as hab modules one and two (ref. 2). That has been published in a NASA TM (ref. 1).

We also at that time undertook the Space Station Crew Safety Alternatives Study (ref. 3). Rockwell was the contractor. Lisa Rockoff was the project engineer. We developed a methodology that's applicable to a number of safety areas. We found that habitability is critical to safety. We developed this "Human Factors Interaction Model" of stressors and human performance (fig. 12). The method begins with a stressor. If the countermeasure against stress does not work, you may get degraded performance. From performance degradation you have countermeasures against errors. If that countermeasure fails you could have a safety hazard.

In the Triangular Tetrahedral Space Station Study (ref. 4), we began looking at the geometry starting from Buckminster Fuller's reordering of the Platonic Solids by numbers of vertices as opposed to Plato's method of the number of faces (fig. 13). We looked at the key properties and found that a tetrahedron is the only self-rigidizing and space filling solid with growth of equal angle geometry, within certain limitations. We focused on the tetrahedron. If I were to go through this exercise again I would take a long hard look at an octahedron because of the right angle in the internal planes. I examined the replication properties of these geometries and found that the tetrahedron also held an advantage in terms of the ratio of edges to vertices.

I started looking at the assembly processes (fig. 14), particularly the properties of agglomeration of these geometries. With a triangle you start out with three edges or modules and three nodes for a ratio of 1:1. Once you start to go three dimensional or to add edges in a plane the ratio of modules to hubs increases from a ratio of one to one to a ratio of 2.38:1 for an ensemble of 6 tetrahedra. This growth ratio improves as the geometry agglomerates (fig. 15). A major problem with the triangular geometry for the present space station program is using these spherical hubs, given the 50-in. hatch diameters to which we've grown. We fought very hard to enlarge the hatches from the 40-in. shuttle hatch. But I didn't realize I was shooting myself in the foot in terms of triangular geometry because there just isn't enough surface area on a hub that fits in the shuttle cargo bay to fit more than 4 ports around any one great circle. The Tri-Tet node requires six circumferential ports. So we may have to wait for the next generation space station to pull off this concept completely.

I went through a variety of these assembly sequences (figs. 16 and 17). Then I looked at packing modules in the shuttle and various functions; such as reach envelopes, remote manipulators and view angles (fig. 18). My next step involved a number of physical modelling studies, developing a variety of configurations that could grow using this basic geometry (fig. 19). This agglomeration uses 12 modules and 6 hubs and a perverse variation in which I try to integrate some of the ideas of large truss structures for payload support and construction platforms (fig. 20).

One critical issue is berthing the modules together. The precedent we've followed for berthing and docking is the Apollo/Soyuz method of Axial alignment; simultaneously smacking them together. For the triangular geometry, the Apollo/Soyuz method will not work because simultaneous axial alignment is not possible. In fact, most of the rectangular geometries will not allow axial alignment either. The distinction between docking and berthing is that docking occurs between the shuttle and the space station while berthing occurs between the module and the hub or between module and module. Here I've incorporated a sort of Power Tower approach for supporting the solar array (fig. 21). The connection to the solar arrays is where the major bending moment occurs, so the truss rather than the module berthing ports would carry those stresses.

I went through a variety of exercises to conceptualize dedicated berthing hubs (fig. 22). Out of these exercises came the idea that the hub, in order to be truly omni-directional must be basically passive (fig. 23), I concluded through these study models. I put all the active mechanisms on the module and all the passive mechanisms or receptors for those mechanisms on the hubs. Of course, that was our high budget period of model building.

Then, I took a look at the utilities and at the whole problem of automated versus manually connected utilities. This device (figs. 24-26) is a manually installed preassembled utility connection channel. After berthing the module to the hub you would install this channel in a shirt sleeve environment. I believe we can show that it's far more economical, efficient, and maintainable than many of the remotely actuated fantasies we've seen from some of the contractors and the other centers. To make a further point with the manual channel, installing it in the interstice between the module gives two leak points at the imbeds in the pressure wall (fig. 26). Installing the remote actuator system there gives five leak points; the two imbeds plus going into the actuator plus between halves of the actuator and coming out of it. So for a lot more money you can have a system that's two and a half times less reliable than the manual channel, and far less maintainable.

I looked at the geometry of these spherical shell structures ad nauseum (fig. 27) and found virtually every conceivable way of dividing the surface to support a geodesic solid. This exercise was enlightening, but I never did find a way to get more than four ports in a plane that would give us sufficient spacing for the triangular geometry (fig. 28). But from those shell studies came an idea that relates to Spacelab. This development is an example of a spin-off although I don't know if we'll ever see it implemented.

Late access to the shuttle (fig. 29), to the Spacelab, is currently obtained through the mid-deck tunnel down the airlock into the Spacelab, through two right angle bends and two bosun's chairs, a very complex process. This idea is to take half of a spherical hub, put it on the end to allow late access directly, at 60° rather than go through the mid-deck hatch (fig. 30). There's a protocol problem in that the cargo bay doors are closed seven days before launch, but I don't think that is an insoluble obstacle if we really want to make this improvement.

This concept led to an idea for a space station logistics module (fig. 31). Although this sketch is one of the least successful designs in this series, it illustrates that method of access. I looked at a variety of other applications in terms of a resources or utilities module (fig. 32), to make pressurized access to the main electrical, computer and thermal busses, electrolysers, and control moment gyros. I also looked at airlocks, adapting the spherical hub as an air lock in a variety of ways (fig. 33). October of 1983 was when I presented this exercise at Johnson Space Center to the Common Module Study Group and some people became interested at that time.

EVA ACCESS FACILITY STUDIES

From this initial investigation of airlocks, we have developed a series of studies of EVA space suit servicing systems. We call our airlock study an "EVA Access Facility." The key point is to address all aspects of EVA work: extra vehicular activity; space suit servicing, donning, checkout, and doffing; ingress and egress as one complete system (ref. 5). It's not just a problem of making the most efficient airlock "can" in isolation from everything else. It is one complete system. We also looked at the implications of the EVA access system for overall space station architecture and the reciprocal implications of space station architecture for EVA access. I'm at the point where I'm ready to reiterate the whole effort, and reconsider everything I've done. But we learned a lot in the process.

The type of space suit we're considering is an all hard space suit, the AX-5. This is Vic Vykukal in the AX-2 (fig. 34) which is one of the predecessors of the AX-5 (fig. 35). We hope the AX-5 will become the prototype suit for the Space Station. And this is the Soviet suit with a rear entry hatch (fig. 36). It's a soft suit but it shows that rear entry hatches have been in use elsewhere. One of the concepts that I came up with was the suitport concept where the rear entry hatch of the portable life support system (PLSS) would mate to an inner hatch within the airlock wall and the astronaut could get in, theoretically without having to pump down the airlock. Theoretically, the crew member could get in and out during nominal operations and would never have the penalty of pumping down the airlock. You would only need to pump down the little interstitial volume between the PLSS and the outer hatch. This concept is proving to be an awesome engineering design problem and we're still working on it.

The approach we took to the EVA Access facility was to identify four concepts of space suit servicing. We used the story board technique (fig. 37) that I learned from John Spencer of Tom Taylor and Associates. Also we were supported in developing the servicing procedures by Steven Bussolari on the MIT grant. The four types of airlocks we examined were: the shuttle type airlock expanded for space stations, the transit airlock which is the same technology (but with the suit serving taken out of the airlock), the suitport which I just described, and Crewlock which is a concept by William Haynes of the Aerospace Corporation (fig. 38). Crewlock is a very small one-person airlock. Bill suggests putting conformal void fillers in the Crewlock as well.

Here are a couple of panels from the story board, this one shows ingress and egress for the relative procedures compared on a step by step basis (fig. 38). This is the mid EVA rest period which is a really critical item for a successful EVA (fig. 39). If we're planning to have people working six, eight, ten hours a day EVA, outside of the station, and we want human productivity at the same time, I don't think we're talking about, for example, urination and defecation as normal procedures within the suit. What we would need is the ability to reenter the station quickly, for a lunch break or a rest or to do something else and then to go back out, without enormous time penalties.

I don't see us achieving real productivity with the very long time penalties that are anticipated either for pump down or for servicing. Those improvements are what the Suitport and the Crewlock aim at in particular. One of the main keys is reducing the pump down volume. We studied how to systematize this issue, and developed a matrix where we (fig. 41) have those four concepts and then four potential locations and configurations. It works out to sixteen possibilities, all of which are analyzed. We were supported in this study by Gilda Jacobs of Foothill College and Wade Schauer of the University of the Pacific. Also, at this time, we're studying the pumping in great detail, supported by Bernadette Squire of Informatics General Corporation. These are sketches of some interiors by Gilda and Wade (figs. 42 and 43). We developed these envelopes as anthropometric and ergonomic volumes which are not intended to represent pressure vessels in this configuration.

We studied these airlock envelopes in scale models which were built by two of our high school students, Mike Fishbein and Tom Lavelle, now both at UCLA (figs. 44 and 45). Also we used this vacuum formed model technology we've been developing here supported by Jim Hogan, Larry Perez, Bob Lockyer, Sue Praskins, Fred Lude, and Mark Washington in the model shop. You can see some of these models on display. We provided a number of our grantees and contractors with these model shells to build interiors and to demonstrate their concepts. You will see them in the following presentations. We also provided a shell to Level B at JSC which now resides in Manned System Division. We are discussing the possibilities of some commercial spin-off of this technology so that somebody on the outside could either use our molds or build their own molds and sell them to the public (since we're not in the business of selling plastic).

We went through a number of analyses of the volumetrics and we have numbers coming out of our ears. We found seven data points for different combinations of these data. We found that there are basically two options for each of the three concepts A, C, and D and one for B, the transit airlock. These data points are shown here in terms of a volumetric efficiency ratio (fig. 46), and plotted on this graph (fig. 47).

On the horizontal axis is the Office of Air and Space Technology (OAST) "Technology Readiness Scale" in which the number one means it's just a gleam in someone's eye and an eight means it's flight-ready operational hardware. The vertical axis is a logarithmic scale for volumetric efficiency. You can see that the state of the art we have ready now has a low VER, but there are some significant things we could do to improve this figure. For example, with the Crewlock and no void fillers we could cut the volumetric problem by half. Then there is the Transit Airlock; by just taking the suits out of the airlock we could be twice as efficient as the STS Type airlock. So there's room to grow, not by changing the technology, but by designing it more appropriately.

With the two conformal airlock options, the Suitport with PLSS seal and Crewlock with void-fillers, we are considering order of magnitude improvements. I understand that "order of magnitude improvement" is the buzzword of the year in certain places. I'm not at this point persuaded that either the Crewlock or the Suitport is the absolute solution. But these two data points indicate to me that a solution can be found that will give us the great reduction in power and time penalties which we need.

These penalties are evident in the STS type and Transit Airlocks. We're talking about pumping down an airlock and recompressing the gas to store it in a half hour to an hour, depending on how much power is available, in the 6 kW to 20 kW range. Here are some more configuration specific drawings by Susan Majors of Foothill College. This is the Transit Airlock (figs. 48 and 49). It's a two-chamber relocatable airlock. We concluded that an autonomous airlock must be a two-chamber relocatable unit. This is the Crewlock installed on one of the external unit configurations (figs. 50 and 51).

One of the other ideas we're working with here is that you need to step out into some sort of front porch. I was surprised to see Fred Abeles of Grumman point to a guy wire that you would hook onto when you step out of an airlock port. Would anybody step out of their own front door and hook onto a guy wire? Perhaps if you lived in a bivouac on the face of El Capitan you might, but other than that I don't see it. This slide wraps up the EVA studies as far as we've proceeded. We're continuing to work on it, and hope to build a full-scale suitport mock-up in the next year.

PROXIMITY OPERATIONS WINDOW ARCHITECTURE

We've given a great deal of attention to window architecture and Dick Haines of our division has given us tremendous support in this area. Basically we're trying to develop a single, consolidated window geometry that serves all viewing tasks. We still don't know if this is achievable. But, in the course of trying, we've learned some very interesting and I hope useful things.

First of all, the environment around the space station is going to be very busy during the post IOC period (fig. 52)--after the initial station is assembled--in terms of proximity operations; with a variety of spacecraft moving in and out. This is a graphic from Goddard Space Flight Center showing satellite servicing based in an external tank. I don't know if we'll have an external tank up there, but this rendering shows some of the operations. This is a 3-D computer graphic from Steve Ellis and Mike McGreevy in our division showing an orbital traffic control simulation which is based on some aviation traffic control situations that have been developed in our division (fig. 53). This display shows the type of representation we may need to correlate what our instruments say with what you can see out the windows.

We also need to put the windows in the right places, in the right shapes and sizes. To do this simulation study we're using a computer graphics simulator in Dick Haines's lab with this three-screen computer graphic display that gives us peripheral vision and infinite depth perspective effect (fig. 54). Hopefully, Dick will have the time to explain more of this to you tomorrow. We're about to cannibalize this system to put it into a space station demonstrator, as we're calling our mock-up facility. Here is a sequence of views from this simulation (figs. 55-57). You see a wire model object against the starry sky in these three fields. The operator at the prox-ops station is controlling the movement of this object which represents an unmanned platform.

In looking at the window problem, the first step was to survey all of the concepts I could find for windows that were out among the contractors and in the Agency. Virtually all of the operational window concepts were on the ends of the modules, in the end caps. So endcap geometry became very important. The upper row (fig. 58) shows the Boeing concept by Brand Griffen, the Lockheed concept by Stan Musil, and the JSC/Spacelab concept and the lower row shows two that derive from the Tri-Tet study (ref. 6). We also had to consider the configuration: where the modules point, the shuttle approach path, earth and anti-earth observation and inspection/monitoring of the space station itself (figs. 59 and 60). As you all know, the configuration has changed. It's actually changed several times since the Concept Development Group and probably will continue to change for some time. What we at Ames have learned from this uncertainty is that we need to pull back more toward basic research, because we can't change everything we're doing everytime there's a change at some Control Board. We need to work on a more universal and generic basis but we're learning to cope with changes in the process. At first we were trying to be more configuration specific and now we're being more general. Here's the original reference configuration (fig. 61). We looked at different locations and view angles, end cap geometries and surfaces, window shapes (in order of structural preference shape) and also size and evaluated them. We started studying some of these in detail. We looked at the frusto-conical end cap and the oblate ellipsoidal series from a 90° hemisphere down to a 10° ellipsoidal shell.

All of the models we saw before had these frusto-conical end caps but we found that none of them (fig. 62) were appropriate for proximity operations viewing tasks for two major reasons. First, the view angles are not good for looking out over a wide range because from a shallow end cap here your view is obscured by the bezel thickness of the wall. Second, if you have a port in the middle, it prohibits you from having any sort of decent work station, least of all if you have two people working at the same time. This series was drawn by Andrew McMills of De Anza College (fig. 63). We analyzed the ellipsoidal end cap series and found that this middle range, of about 30° to 45°, presented a variable curvature which gave us the opportunity for a range of wide angle viewing. The 35° shell approximates the Cassini Dome, the natural ellipsoidal end of a cylindrical pressure vessel.

We then asked how this approach would fit into the common module as it existed then with the radial port segments. We looked at some of the window configurations applied to both the frusto-conical (fig. 64) and the ellipsoidal (fig. 65) end caps. This view shows the paradigm of some of Dick Haines's three screen computer graphics simulator placed on the surface. We were already looking at how we would simulate out-the-window viewing. This image is not to be taken literally as a design but rather as a wish that we could find enough computer graphics monitors to create this level of fidelity. In this sense, these window layouts are design paradigms for wide-angle viewing. The upper window is intended for viewing objects moving up or down the r-bar. Our approach to the common module is that the prox-ops work station situated in the end dome should not infringe on the usable interior of the common module. As the distal end cap beyond the radial ports was generally considered unusable for any purpose except hatch stowage, it appeared ideal for the Prox-Ops work station.

Then we did another iteration on the end cap geometry. This one is drawn by Justin Carrico of Foothill College. What Justin did here is to project painstakingly the view angles onto these variable ellipsoidal shells from different eye-points. We could work wonders if we had access to a top-of-the-line computer graphics system. But right now we're constructing these by hand which has been very time consuming. We finished this iteration and it's been very interesting. This set, K1 and K2, shows an eyepoint back five feet from the wall in ranges from 10° to 45° (fig. 64) and from 50° to 90° (fig. 65), respectively. This exercise diagrams peripheral vision and binocular vision. The dark zones you see are outside the range of vision. Binocular vision, where both eyes see together, is the middle zone and peripheral vision, just one eye, is the middle zone. Based on the location of the eye point and the shell geometry, there is an interation of abilities to see the instruments and the target object at the same time. We're still evaluating what this means.

Here are some of the end cap geometries as shown in our vacuum-formed scale models (figs. 68-71). We represented both the frusto-conical end cap with port on center, and the frusto-conical end cap with port off-center (note this little flat point at center). This second one is a real loser structurally. We can't put an off-center port on a conical end cap, because the important meridian hoop stresses are lost. Here's the ellipsoidal end cap which allows you to maintain the meridian hoop stresses around three quarters of the shell and also obtain these variable curvatures that enhance wide angle viewing. The other off-center port option is the flat end cap that is advocated by Chas Willets at Rockwell-Downey. We find severe deficiencies in the flat end cap for achieving the wide angle viewing which Dick Haines has found to be essential for proximity operations.

SPATIAL ORIENTATION AND CIRCULATION

Another issue we had to deal with is spatial orientation. The precedent we have is Skylab (fig. 72) where we had a so-called zero-g environment in the multiple docking adaptor and a so-called one-g environment (fig. 73) in the crew quarters. Some very conflicting data has been reduced to one gospel which is that you need a clear up-down reference and that is generally interpreted as a floor and a ceiling of some kind (fig. 74).

I had dinner a couple of weeks ago with Dr. Joseph Kerwin and Robert Overmeyer and I asked both of them about this question of local vertical. Joe said that although he felt he needed an up-down orientation on Skylab he couldn't really say whether it was the floor and ceiling that gave it or whether some other cues might do equally well. Overmeyer said from his Spacelab experience that he was mostly concerned that people did not step on each others' heads. A floor and ceiling meant a partition system to him. Those were both very astute points. Up-down orientation has proven to be a thorny issue. It means defining the basic cognitive and perceptual responses and needs of people in zero gravity. We have no real experimental evidence of this at all. All our evidence is purely anecdotal and has been hashed over many times and subjected to varying interpretations.

For example, here are four different ways of defining "up," each of them equally consistent within a generic space station (fig. 75). Sketch 1 shows "up" the short axis, Sketch 2 shows "up" the long axis, Sketch 3 shows "up" with all floors coplanar and the vertical coming up out of the screen, and Sketch 4 shows "up" as away from the center with a race track around the middle. One of the other things we learned from Skylab is that through circulation was found to be very disruptive in the multiple docking adaptor (fig. 76). That's one thing we hope to avoid in a prox-op work station. The last thing we need is someone conducting a delicate operation maneuvering two vehicles together and having somebody else go barreling through there and bang the operator in the legs, which would be inevitable if we had a prox-ops work station in a conical end cap.

These are some models of interior geometries and circulation cores built by Paul Piksukanjana who is now at U.C. Santa Cruz. One describes the problems with orientation being intermixed with circulation (fig. 77). We've isolated some of the variables with mixed success (figs. 78 and 79). Here's another view of circulation, both on center and off center, with different relations to end domes.

Here you see an interpretation of the Reference Configuration based on Sketch 4 of the earlier "generic space station" (fig. 80), with ellipsoidal end domes. One feature of this prototype is that all the operational windows occur on the outside corners, giving maximum wide angle viewing. The two prox-op station locations occur on both the plus and minus velocity vectors. The earth observation station can also occur on the plus velocity vector so that you can see what is ahead and then make observations orthagonally on the nadir. But as I said we can no longer do this work on the basis of being configuration specific because chances are that the configuration will change half a dozen more times.

Using the model shells, Andrew, Wade, and I set up an "orientation simulator" (fig. 81). We tried to separate out the variables of module to module connection and rotation. In this exercise we have the ensemble rotated to eliminate the question of a global up and down. We found three possible floor orientations.

In the first of the three orientations you see the ensemble with the floor around the outside (fig. 82). If we were to have artificial gravity in a rotating torus, up would be toward the center and down would be away from the center through the floor. The interesting aspect is that the torus, long the darling of Science Fiction space stations, proves to be the most counter-intuitive of all of them. From a perceptual and cognitive point of view, why would you want to look down at your feet to see out?

In the second orientation we rotate the modules 90° around their central axes to make all the floors coplanar. This arrangement works the best from the point of view of consistency for the floor but you get all the eyes on one side of the head like a flounder fish (fig. 83).

In the third orientation, we rotate the floors another 90° to put all floors in the middle and the prox-ops station on the outside (fig. 84) as in Sketch 4 which I showed earlier. This exercise was successful in isolation from a global vertical, but when we tried to incorporate a global vertical, with variations in circulation, the variables became very complex. We still don't have all of those variables sorted out. At this point I suspect the way to do this is either to get away from being configuration specific, or do a great many configuration permutations and see what we learn.

"FIGURE-EIGHT" REFERENCE CONFIGURATIONS

One of the studies that we did most recently with the new "Figure-8" Reference Configuration, which incorporates the spherical docking hubs (ref. 4), was to look at the view angles when you have a work station right at the end. Here we see the abysmal frusto-conical end cap, with the hatch that swings through where the feet are and also the very much occluded vision along the velocity vector and the narrow view angle (fig. 85). Here we have the flat end cap (fig. 86). We get somewhat better vision forward on the velocity vector but we're forced to have this fairly large blind spot between the flat plane and the curved cylindrical side, as well as a sharp right angle break in the planes. But at least the flat end cap allows the off-center work station and port. Going on to the ellipsoidal end cap, we have the wider view angle, the widest really, with the least amount of body movement (fig. 87). We did some studies of body movement which I won't go into because they were not conclusive. I drew this illustration to show that the normal is running through a muntin which emphasizes the problem that if we have a series of smaller windows, the placement of the window frames is quite important. Dick Haines will talk about how seeing the outside horizontal edges is important for judging distance. Equally important and less well understood is the effect of vertical mullion and horizontal muntin spacing.

When I first learned about this configuration change to the "Figure-8" module connection pattern, I heard about it over the phone. What leapt to mind immediately was this configuration as a way to combining spherical nodes and ellipsoidal end caps, to retain the advantages of keeping the prox-ops windows on the outside corners. Usually, I begin a presentation with the status quo and show my solution last, but in truth I thought of this design before I knew what the real configuration was with tunnels, and so I show you this concept first. I thought that if we put the pair of hub-module-hub units back-to-back we would replicate the advantages of the prox-ops station on the outside corners. This is just two modules; we're still hoping for four, but this drawing shows the basic subassembly, simple and elegant (fig. 88). We could have about six feet of clearance between modules which would be reasonable for an astronaut to inspect. When I finally saw a drawing of the new Reference Configuration I was surprised to see the tunnels. The Control Board decision was to keep the conical end caps and add these tunnels which, as far as I can tell, are totally unnecessary extra hardware (fig. 89). And you get the flounder fish effect, if you are lucky enough to see out at all. The same flounder fish effect happens with the flat end cap although your vision is not as obscured (fig. 90). The ellipsoidal end cap in that same position doesn't really give you any advantage in terms of seeing down to the docking port and seeing out the wide angles (fig. 91). But if we turn these back-to-back we start to recover a complete range of wide angle viewing (fig. 92). I like to think of this clear end cap as a "virtual wall." I prefer to start out with it all clear and to opaque the areas that aren't needed for windows rather than to start out with a predesigned structural shell and fight to punch a few holes in it. This is the procedure that we followed in these designs.

This sketch shows the new module connection pattern (fig. 93). The truss structure is not an accurate representation of the dual keel, but you see that full "Figure 8" module connection pattern as it now exists in the new reference configuration (fig. 94). I suggest that we alter it to use the back-to-back geometry (fig. 95). One of the other possible advantages that this arrangement offers us is that with a shuttle docking on axis we don't have an imbalance in the center of mass. We'll have the shuttle dock axially to the center of mass of the station rather than doing it off center. The current reference configuration pushes the shuttle out of line from the center of mass of the station which may not be a major perturbation, but if we want materials processing in high quality isolation from vibration, such an asymmetry won't help.

APPLICATION OF STUDY RESULTS

Several results came out of the Triangular Tetrahedral Space Station study and following studies that were quite useful (fig. 96). First of all, the docking hubs have been incorporated into the program at present. We're also looking at easy module changeout in the race track as a criteria, which was not part of the earlier configurations. We're also looking at windows and airlocks in creative ways, I hope. We're going to look at using these hubs as a proximity operations workstation option as well as a smaller add-on dome or cupola at a hatch for specific tasks (fig. 96).

SPACE STATION MOCKUPS

Recently, we began building some full-scale space station mockups. This drawing is an early concept for putting an ellipsoidal end dome for a prox-ops work station on the end of our two-segment shell mockup which I'll show you (fig. 97). This sketch is an idea for a more advanced concept to adapt a spherical hub or hemispherical end dome, where we would have a number of monitors mounted on the outside surfaces (fig. 98). The human operator would move on a horizontal air cushion cart in two degrees of freedom in response to the visual stimuli. This approach is at least a couple of years in the future. But we are building a proximity operations demonstrator/mockup which we hope to have ready by February.

To develop our ideas for this demonstrator/mockup we went through a number of model construction efforts, including several iterations on the computer systems to study their physical and electronic properties and performance characteristics. This basic concept was developed by Wade Schauer of the University of the Pacific. The interior work station and the exterior computer systems would sit on separate pallets, separated by an ellipsoidal shell. The pallets sit on the two horizontal beams, the ellipsoidal ribs run from the ring to a central connecting plate. This model was built by Phillipe Kennedy of Gunn High School (figs. 99 and 100).

Theoretically, we could change these pallets out to install different end cap designs but since we could scavenge only three computer monitors there was no need to build a palletized system.

We started out with a palletized concept also for the main body of the mockup; this is our two-segment mockup shell (fig. 101). The fiberglass cylinders were sent to us by Johnson Space Center. We designed and built the cradle here. The cradle was designed by our engineering division with some detailing by me. The floor and cradle were built in our Metal Fab shop under Al Perkins with the intention that we would have multiple floor pallets. Thus far we have had use for only two. Note the ceiling concept that we're developing with multiple lighting modes.

We've been working with tubular structural steel and at first we thought we'd continue with that method, for the prox-ops end dome as you say in the first two end cap models. We went through several cycles of design development. These are Justin Carrico's drawings of the palletized system using some light gauge steel framing as a partial alternative to the heavier tubular steel.

Finally, I ended up designing a big dumb box (for acronym buffs, that's a "BDB") in plywood to support the ellipsoidal end dome. We may put up to five thousand pounds of computer equipment on here, mostly on the lower level. These drawings show the final design. Here you see our first ellipsoidal half dome that we built a couple of months ago (fig. 102). The ellipsoidal ribs were made in the model shop; the steel ring was rolled for us through the Model Technology (Planning) Office, the front connecting plate was made by the carpentry shop and the little steel gussets were made in the Metal Fab shop. It was a broad-based cooperative effort. We developed a variety of window configurations made by both our students and our industrial designer from Informatics General, Phil Culbertson Jr. Here's Phil looking at some of the geometry and moving the ribs around (fig. 103). He's been cutting up the ribs with great liberty. We had to order eighteen more just to be sure we have enough for two shells. We're going to put one of these half rings on top that box this afternoon, if the paint dries in time. The table in front of the dome will support three columnating lenses used with the computer graphics monitors. And we're going through a design cycle on the problem of how we adapt the windows. You see here the natural geometry of the trapezoidal window and the ellipsoidal shell where the trapezoids get wider as the ribs go out from the center (fig. 103). However, due to the fact that we have a keystone effect with the lenses very much like the effect we have with this viewgraph projector, we must make the windows expand the other way (fig. 104). Already, in making an application here, we're being counter-intuitive and making life harder for ourselves, but there you have it. Research meets reality.

Here is a view of the control console built by Phil who has been doing an outstanding job in pulling this together for us (fig. 105). Here's a view of the big dumb box which I engineered to make sure we would be protected from any deflections and racking that might jiggle our computer graphics and knock the lenses out of adjustment everytime someone jumped on it (fig. 106). We're going to put one of these rings on top of the platform and mate it to the end of the cylinder using a set of threaded steel rods that were delivered to me yesterday here at the auditorium. You can see that building this mockup is a real learning exercise. We are developing human factors mockups that we hope will contribute to the basis for our new Human Performance Research Laboratory.

Do we have any questions before I go on to introduce the other speakers?

Are you planning to build a 12-ft diameter spherical hub?

We are contemplating that. Our only obstacle besides time and money is finding another high bay we can engage to build it in. In fact, I discussed with Frances Mount yesterday what would be involved in taking our existing stock of rings, we have eight of them, and to make spheres of a smaller diameter. We can do that by extending the length of the gussets.

Can you solve the air expansion problem, the time problem, by having air expand into a large volume such as a plastic bag?

One of the options is to just blow the air into the adjacent habitable module. The problem is that if it's a truly autonomous airlock it's got to have the capability of containing all its gas resources. If it did have an external bag you would have the question of what if it were punctured, what if it became embrittled and all of those kinds of things. So that is really not an option.

Have you taken a position on horizontal vs vertical floor orientation/configuration?

We haven't reiterated on that yet and I think that basically we're probably going to take another look at that in January. Right now Goddard wants the baloney slice and everyone else wants horizontal. We're going to stay out of that for at least a month.

REFERENCES

1. Habitability Module and Human Factors. Space Station Concept Development Study Workshop, Part 2, Task 1. (Compiled by Marc M. Cohen). NASA TM-85891, July 1983.

2. Systems Engineering and Integration Space Station Program Office Report. Space Station Reference Configuration Description. NASA JSC 19989, 1984.

3. Rockoff, L. A.; Raasch, R. F.; Peercy, R. L., Jr.: Space Station Crew, Safety Alternatives Study, Final Report. Vol. 3: Safety Impact of Human Factors. NASA CR-3856, June 1985.

4. Cohen, Marc M.: NASA case no. ARC-11505-1, Space Station Architecture, Module, Berthing Hub, Shell Assembly, Berthing Mechanism and Utility Connection Channel, Filed March 1984.

5. Cohen, Marc M.; and Bussolari, Steven: Human Factors in Space Architecture 2: EVA Access Facility: A Comparative Analysis of Four Concepts for On-Orbit Space Suit Servicing. NASA TM-86856, Sept. 1985.

6. Cohen, Marc M.: Ames Mock-up Ideas for Space Human Factors Research. Proceedings of the Seminar on Space Station Human Productivity, NASA TM-86673, March 1985, p. 5-2.

SPACE STATION HUMAN FACTORS RESEARCH REVIEW

DECEMBER 3-6, 1985

BEHAVIORAL AND ARCHITECTURAL RESEARCH IN HABITABILITY AND FUNCTION RESEARCHERS

STUDY TOPICS	CLEARWATER (SHFO)	LOCKHEED	McDONNEL DOUGLAS	INFORMATICS	U. OF WASHINGTON	U.C. DAVIS	S.F. ACADEMY OF ART	U.C. IRVINE	COHEN (SHFO)	TAYLOR & ASSOCIATES	KALIL DESIGN STUDIO	SCI:ARC	U. OF MICHIGAN	U.C. BERKELEY	HAINES (ASHFRD)
BEHAVIORAL FACTORS															
HUMAN PERFORMANCE AND PRODUCTION	○	●													
FUNCTIONAL RELATIONSHIPS	●		●									●			
OPERATIONAL SIMULATION	●			●									●		
SPATIAL HABITABILITY	●	○			●										
PRIVACY/INTERPERSONAL DISTANCING	●	○				●						●			
COLOR	●	○					●					○			
HUMAN ADAPTATION	●	○	○					●							
CULTURAL/CROSS CULTURAL		○					○							○	
GROUP SOCIAL ACTIVITIES		○				○						●		○	
ARCHITECTURAL SUBSYSTEMS															
ARCHITECTURAL SPACES					●				●	○	●			●	
SECONDARY STRUCTURE									○	●	○				
MAJOR UTILITIES DISTRIBUTION									●	●			○		
CIRCULATION		○	○						●	○		○	○	○	
EQUIPMENT PACKAGING		○							●	○				○	
WINDOWS									●			○			●
PROPORTIONS									○		●				
CONFIGURATION									●	○					

● MAJOR FOCUS ○ MINOR FOCUS

Figure 1.- Table of Space Human Factors Behavioral and Architectural Research Concentrations.

SPACE STATION ARCHITECTURE

OBJECTIVE:

- EXPLORE ALTERNATIVE CONCEPTS TO CURRENT SPACE STATION DESIGNS

REVIEW OF CURRENT CONCEPTS:

- HAVE SEVERE PROGRAM CONSTRAINTS INHIBITED THE EXPLORATION OF NEW POSSIBILITIES?

FUNDAMENTAL QUESTIONS RAISED:

- WHY ASSUME CARTESIAN X-Y-Z COORDINATES IN ZERO-G ?
- DO APOLLO TYPE DOCKING JOINTS (PLUG-IN) DETERMINE THE ENTIRE STRUCTURE ?
- CAN FUNCTION DICTATE GEOMETRY ?
- HOW CAN WE USE GEOMETRY TO PLAN FOR UNPREDICTABLE GROWTH ?

Figure 2.- Key points for Space Station architecture.

SPACE STATION ARCHITECTURE
ISSUES ADDRESSED

1. FUNCTIONAL ORGANIZATION
   - CONNECTING ELEMENTS AS CRITICAL STRUCTURAL DETERMINANTS
   - FUNCTION CAN DICTATE GEOMETRY
2. APPROPRIATE GEOMETRY
   - STRUCTURAL RIGIDITY, "SPACE-FILLING" AND REPLICATION PROPERTIES
   - TRIANGULAR/TETRAHEDRAL CONCEPT ("TRI-TET")
3. FUNCTIONAL CHRACTERISTICS
   - SPACE SHUTTLE APPROACH CONE
   - GROWTH W/ C.G. CONTROL AND SYMMETRY
   - ATTITUDE CONTROL AND STABILIZATION
   - SYSTEMS: UTILITY LOOPS
4. DOCKING HUB/JOINT DESIGN
   - PASSIVE, OMNIDIRECTIONAL BERTHING HUBS
   - SEPARATION OF BERTHING FUNCTIONS BY VECTOR
   - SEQUENTIAL BERTHING ALIGNMENTS
   - MODULE REPLACEABILITY
5. HUMAN FACTORS AND HABITABILITY

Figure 3.- Key issues addressed by Space Station architectural studies.

SCIENCE AND APPLICATIONS MANNED SPACE PLATFORM

MARSHALL SPACE FLIGHT CENTER 1982 WITH TUNNEL CONNECTOR UNITS

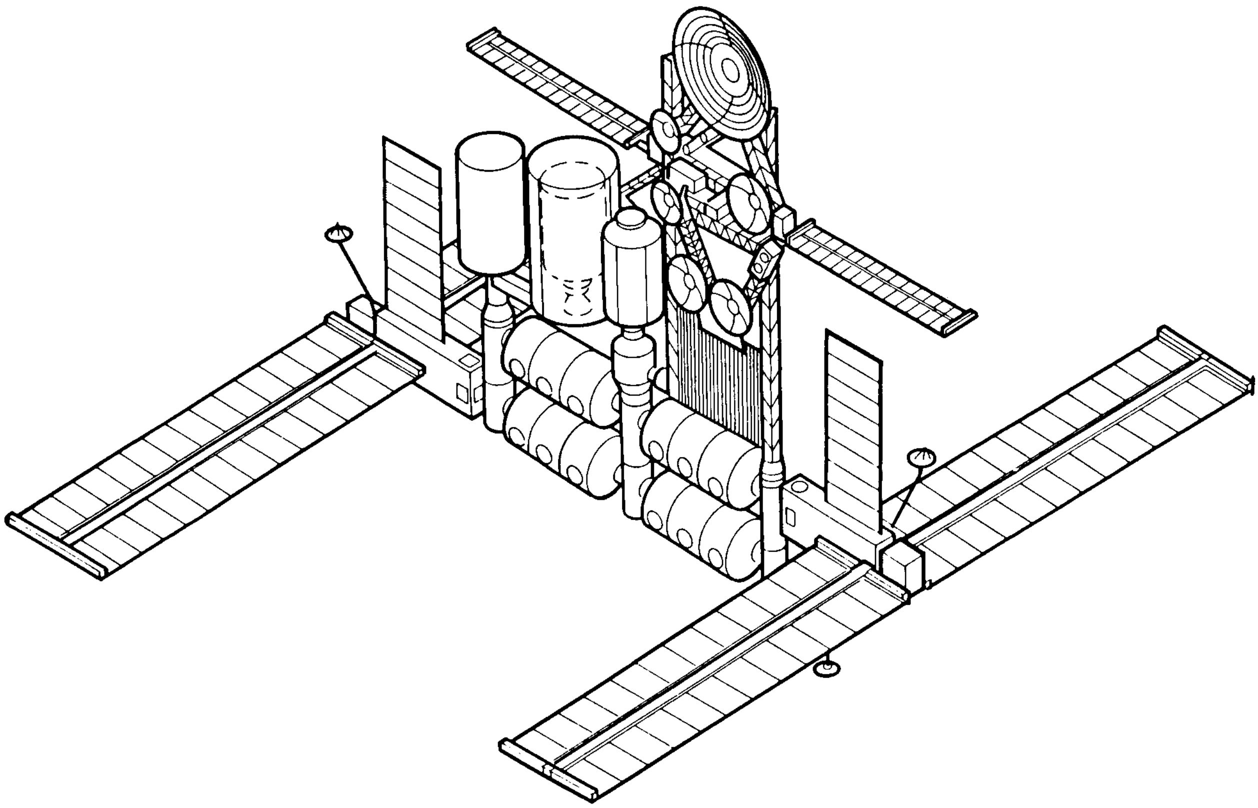


Figure 4.- Rectangular Space Station.

SPACE OPERATIONS CENTER CONCEPT (SOC) AFTER 7 LAUNCHES.

JOHNSON SPACE CENTER 1982 WITH TUNNEL TYPE MULTIPLE DOCKING ADAPTERS

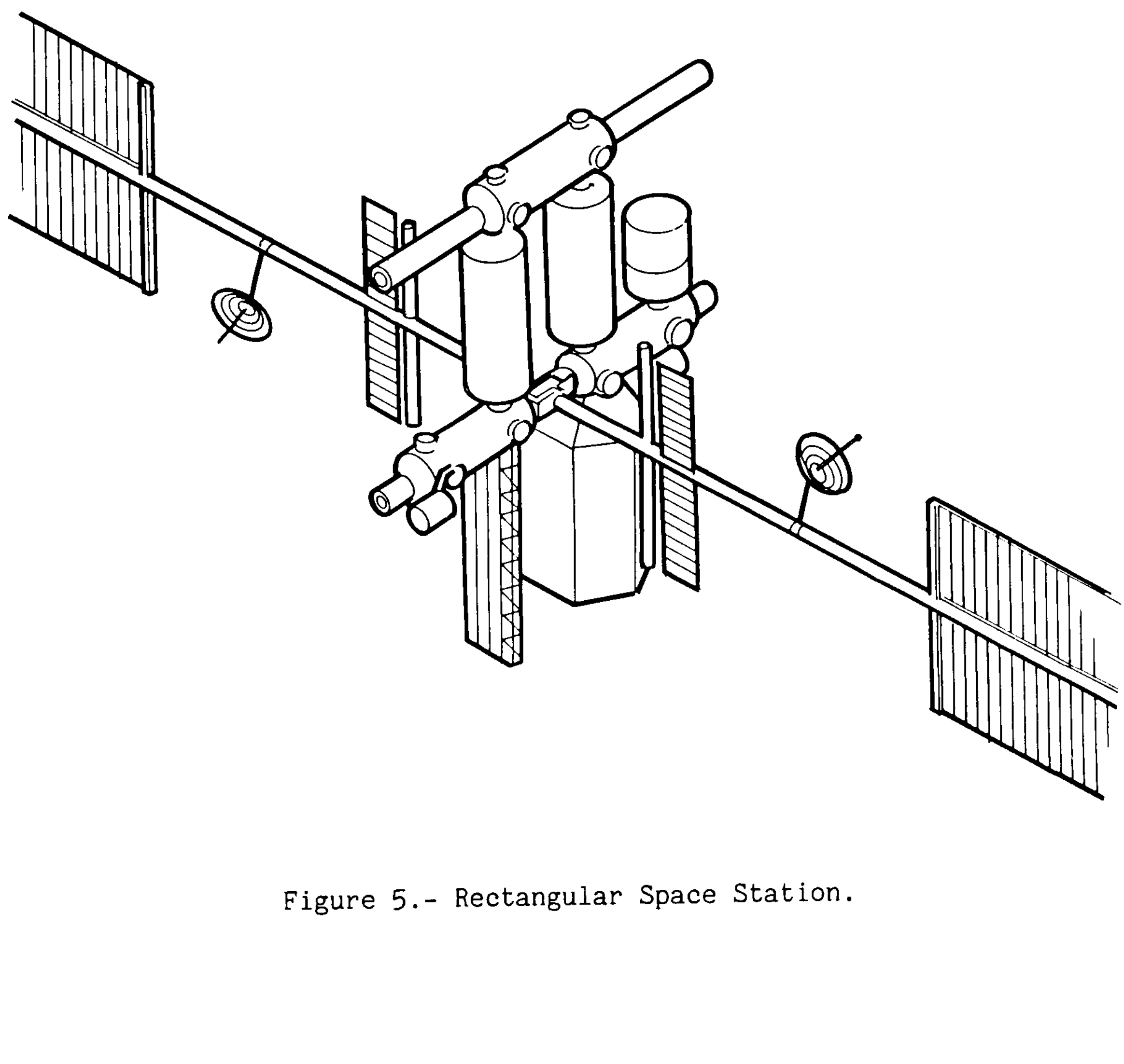


Figure 5.- Rectangular Space Station.

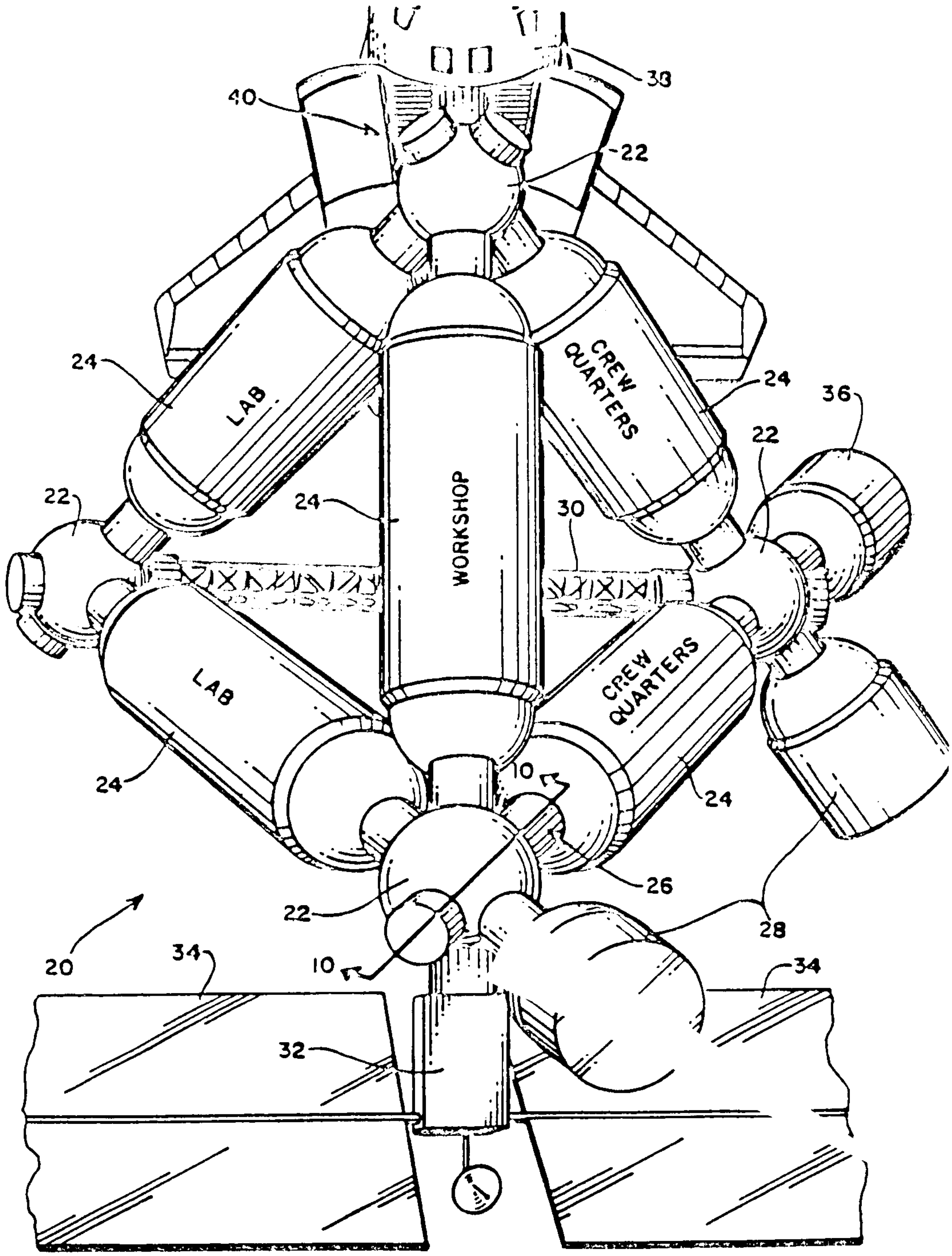


Figure 6.- Triangular-Tetrahedral Space Station patent drawing.

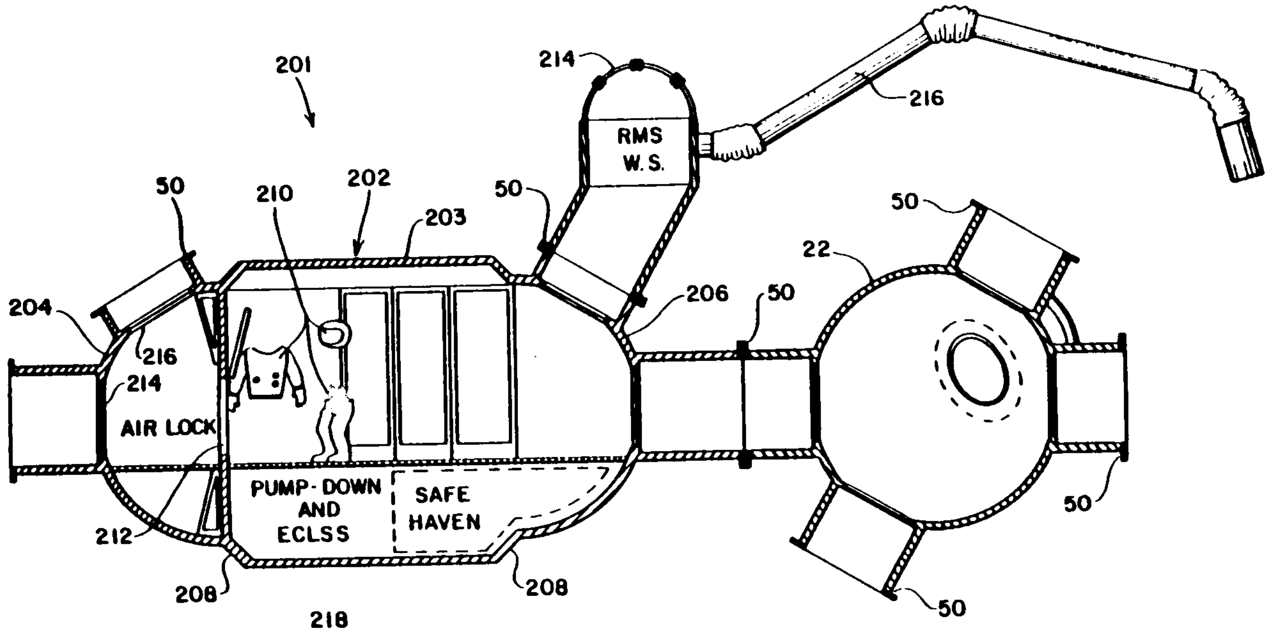


Figure 7.- Detail of patent drawing for Space Station module and spherical node showing cupola, airlock and space suite servicing options

SPACE STATION HUMAN FACTORS CRITICAL ISSUE:
VOLUME

EFFORTS TO REDUCE COSTS BY MINIMIZING VOLUME APPEAR TO PRESENT A FALSE ECONOMY

". . . . a classic case of tripping over a pound to save a penny."

MODULE SHELL SIZES DO NOT PRESENT SIGNIFICANT COST DIFFERENTIALS FOR 2, 3, 4, 5 SEGMENT MODULES COMPARED TO THE COST EFFECTS OF INADEQUATE VOLUME

MINIMIZING VOLUME WILL:

- FORCE MINIATURIZATION OF MANY ITEMS
- PRECLUDE MUCH "OFF-THE-SHELF" HARDWARE
- IMPAIR OR PREVENT ON-ORBIT MAINTAINABILITY
- DRIVE UP DESIGN, ENGINEERING, FABRICATION AND INSTALLATION COSTS FAR BEYOND THE INITIAL SMALL SAVINGS
- DIMINISH CREW PERFORMANCE AND COMFORT

Figure 8.- Volume limitations, a critical human factors issue.

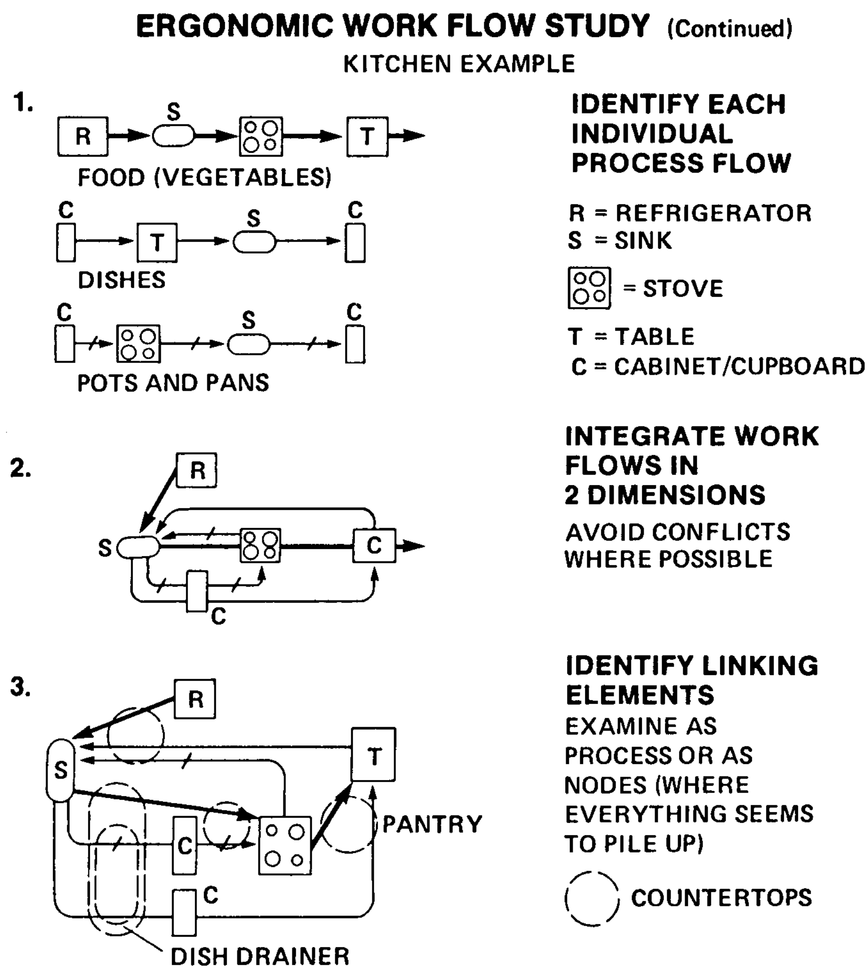
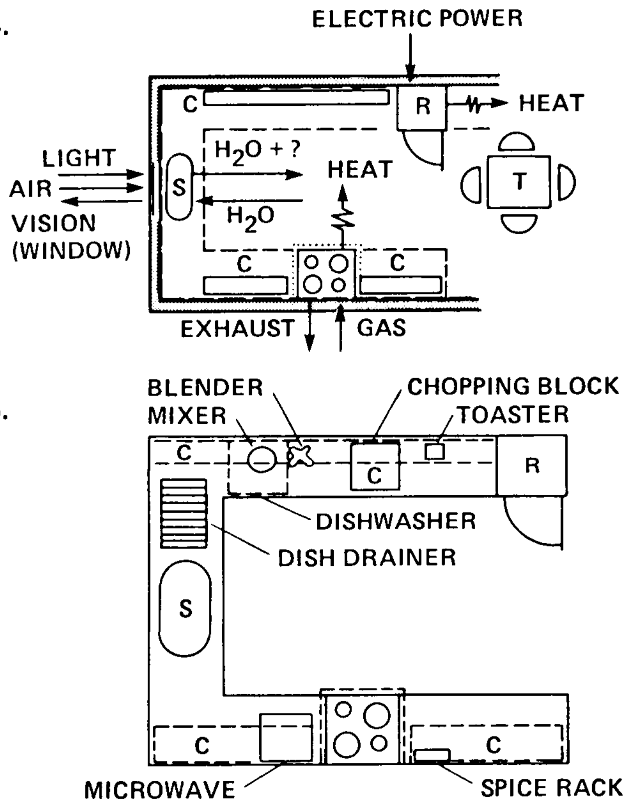


Figure 9.- Ergonomic work flow case study showing the functional development of a generic kitchen.

4.

5.



CONNECTING ELEMENTS
BECOME
ORGANIZATIONAL
DETERMINANTS

IDENTIFY UTILITY
INTERFACES

WORK FLOW DIAGRAM
COALESCES TO 3-D
FORM – CONNECTING
ELEMENTS ASSUME
MAJOR PROPORTIONS
IN "REAL SPACE"

**CONNECTING ELEMENTS
INTEGRATE
MAJOR FUNCTIONS
AND INFLUENCE USER
ACTIVITY PATTERNS**

COUNTERS ALSO
BECOME STRUCTURAL
SUPPORT SYSTEM FOR
SECONDARY FUNCTIONS:
TOASTER, BLENDER,
MICROWAVE OVEN, ETC.

Figure 10.- Ergonomic work flow study of a kitchen, completed.

SEPARATE SLEEP AND WARDROOM/EXERCISE MODULES

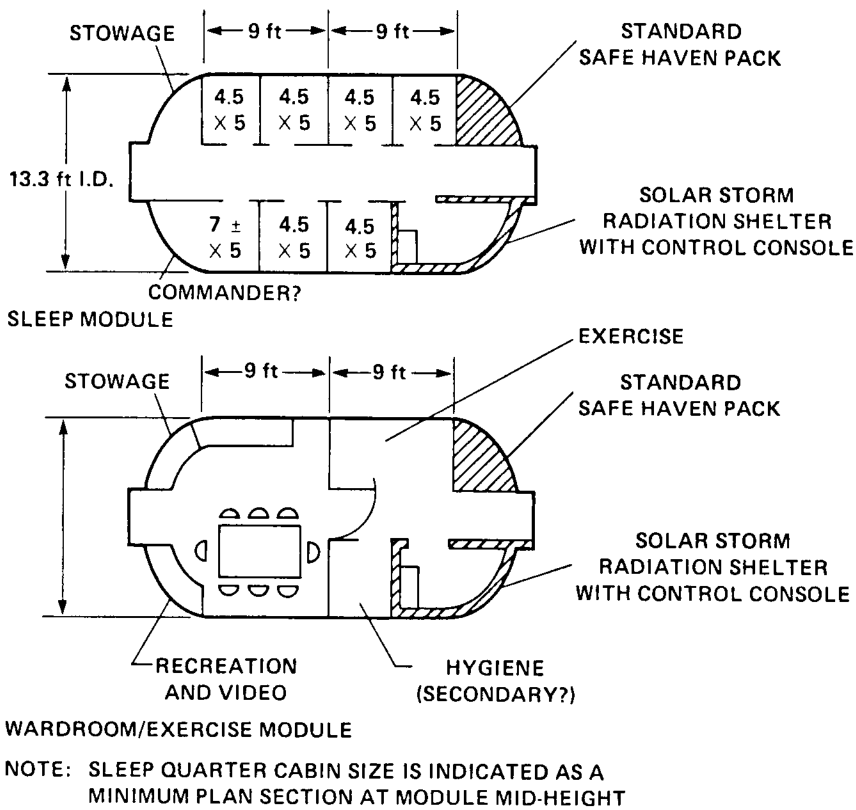


Figure 11.- Diagram of concept for separate noise/group activities module and quiet/sleep module.

SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL

2. CRITICAL HABITABILITY I

STRESSORS	COUNTER-MEASURES AGAINST STRESS	DEGRADED PERFORMANCE	COUNTER-MEASURES AGAINST ERRORS	SAFETY HAZARD
VOLUME LIMITATIONS	ARCHITECTURE: DESIGN PRIVACY, WINDOWS	FEELINGS OF CLAUSTROPHOBIA LACK OF PRIVACY	PRIVACY OR EVACUATION	IRRITABILITY PARANOIA
NOISE	VIBRATION, ISOLATION AND CONTROL	SLEEP DISTURB-ANCES POOR COMMUNICA-TION	EARMUFFS, HEAD-SETS, DRUGS COMMUNICATION DEVICES	FAILURE TO RESPOND FAILURE TO COMMUNICATE OR COORDINATE
HOUSEKEEPING	ROUTINES AND TRAINING	ENVIRONMENT QUALITY DETERIORATION	ASSIGNMENT OF RESPONSIBILITIES	BREAKDOWN IN LIFE SUPPORT
HYGIENE CLEANLINESS	PERSONAL PRACTICES	DISCOMFORT TO OTHERS ILLNESS DISEASE	GROUP PRACTICES	PERSONAL ILLNESS OR IMPAIRMENT INABILITY TO PERFORM TASKS

Figure 12.- Table of Space Station crew safety human factors interaction model, showing stressors, countermeasures and potential safety hazards.

PLATONIC SOLIDS SERIES
ORDERED BY NUMBER OF FACES

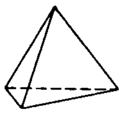
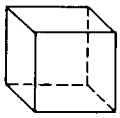
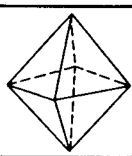
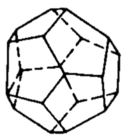
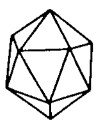
NAME	FIGURE	FACES	EDGES	VERTICES
TETRAHEDRON		4 (TRIANGLES)	6	4
CUBE		6 (SQUARES)	12	8
OCTAHEDRON		8 (TRIANGLES)	12	6
DODECAHEDRON		12 (PENTAGONS)	30	20
ICOSAHEDRON		20 (TRIANGLES)	30	12

Figure 13.- Table of platonic solids.

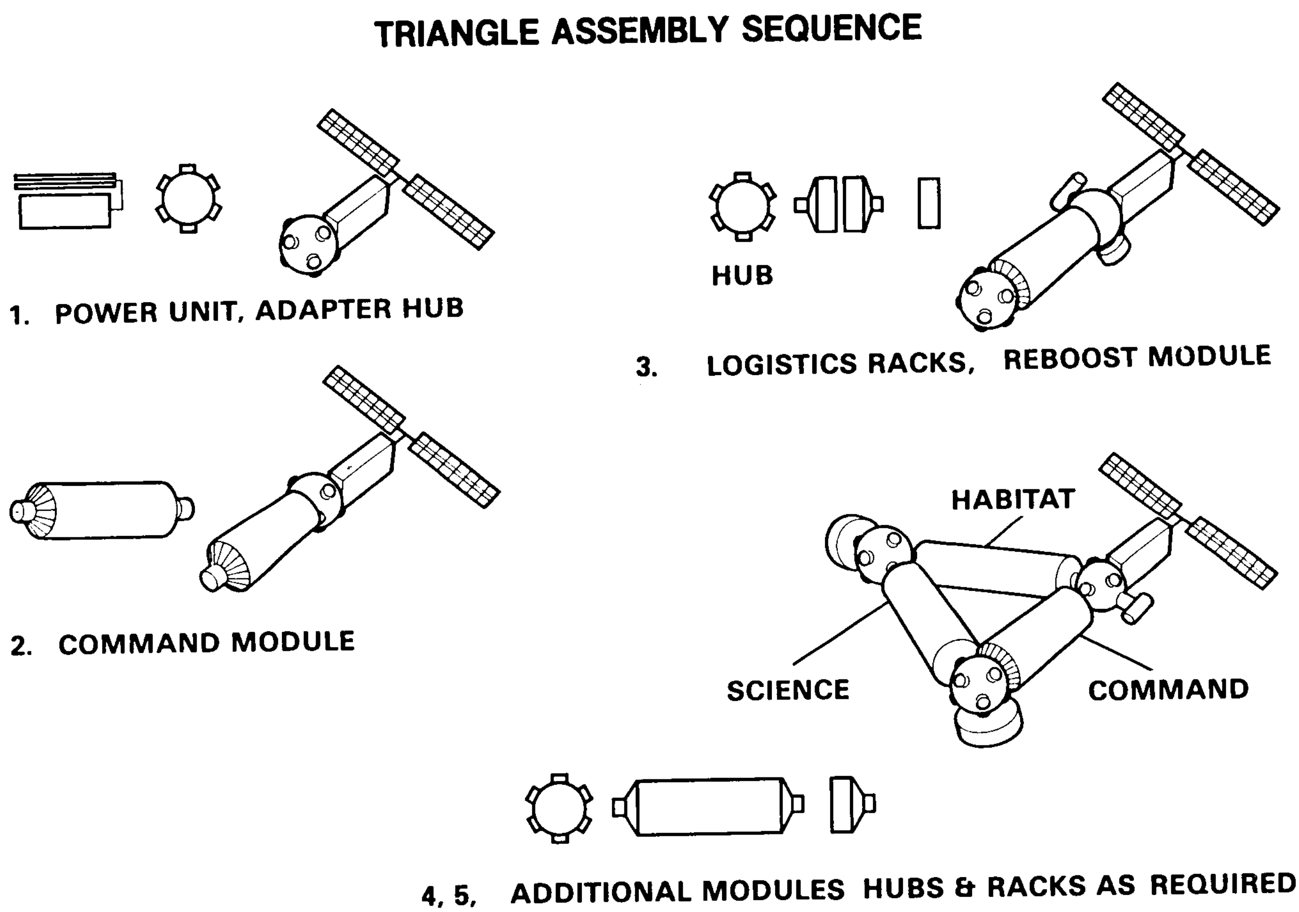
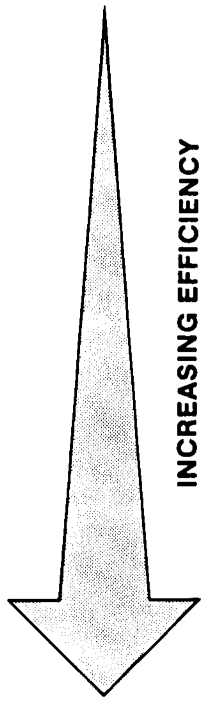


Figure 14.- Triangular Space Station assembly sequence.

SPACE STATION GROWTH TABLE

GROWTH RULE: ADDITIONAL HUB MUST PRECEDE ANY ADDITIONAL MODULE.

GROWTH UNITS	MODULES	HUBS	RATIO M/H
TRIANGLE			
0.33	1	1	1.0
	1	2	0.5
0.66	2	2	1.0
	2	3	0.66
1.0	3	3	1.0 *
TETRAHEDRA			
0.5	3	3	1.0 *
0.66	4	4	1.0
0.83	5	4	1.25
1.0	6	4	1.50
1.33	7	5	1.40
1.66	8	5	1.60
2.0	9	5	1.80
3.0	12	6	2.0
4.0	15	7	2.14
5.0	18	8	2.25
6.0 **	19	8	2.38



** TRIANGULAR DODECAHEDRON W/CENTER "AXLE"

* 1.0 TRIANGLE = .5 TETRAHEDRA

Figure 15.- Table of triangular Space Station growth. (Hubs are the same as nodes.)

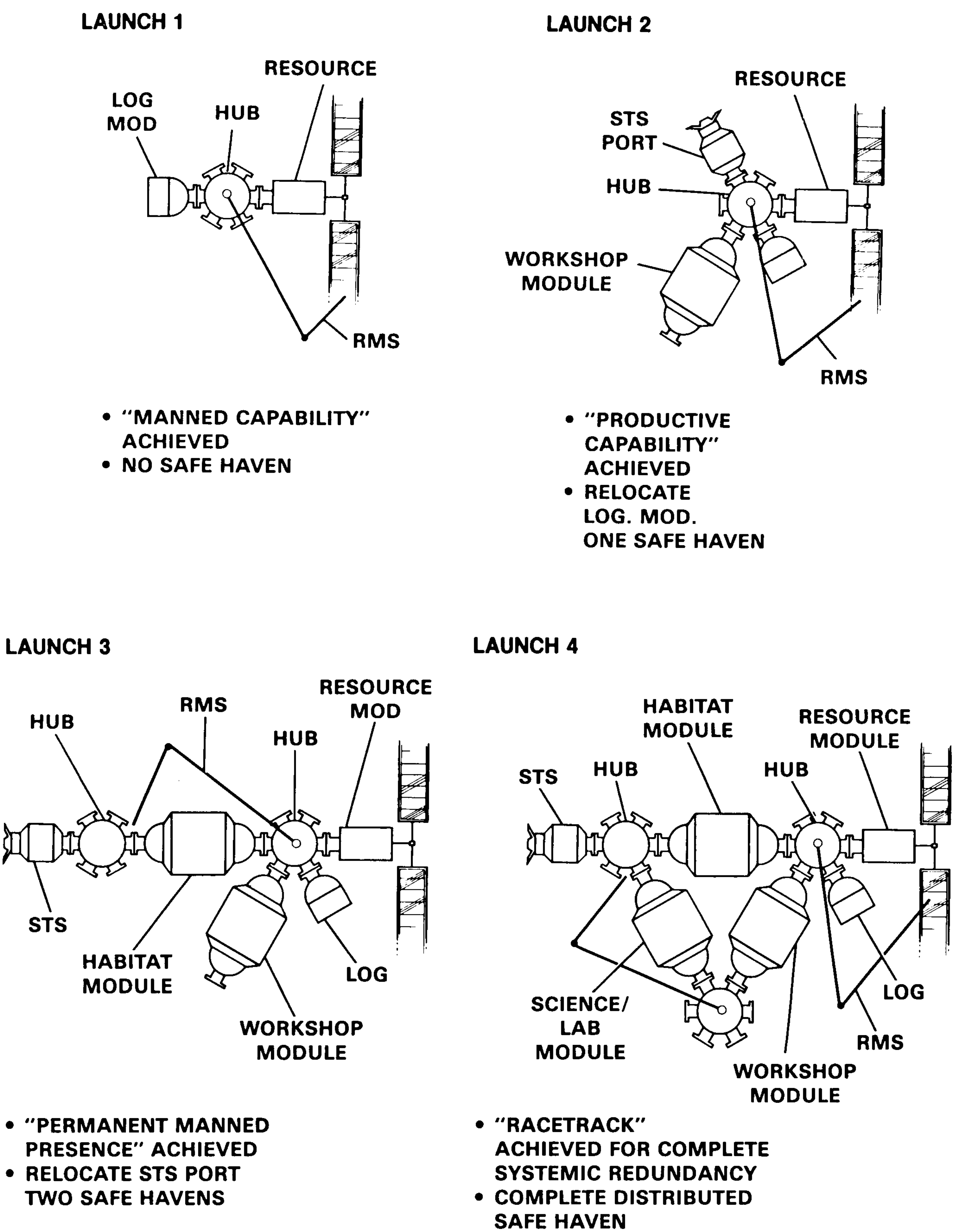


Figure 16.- More detailed triangular Space Station launch sequence. "STS" refers to an orbiter docking tunnel.

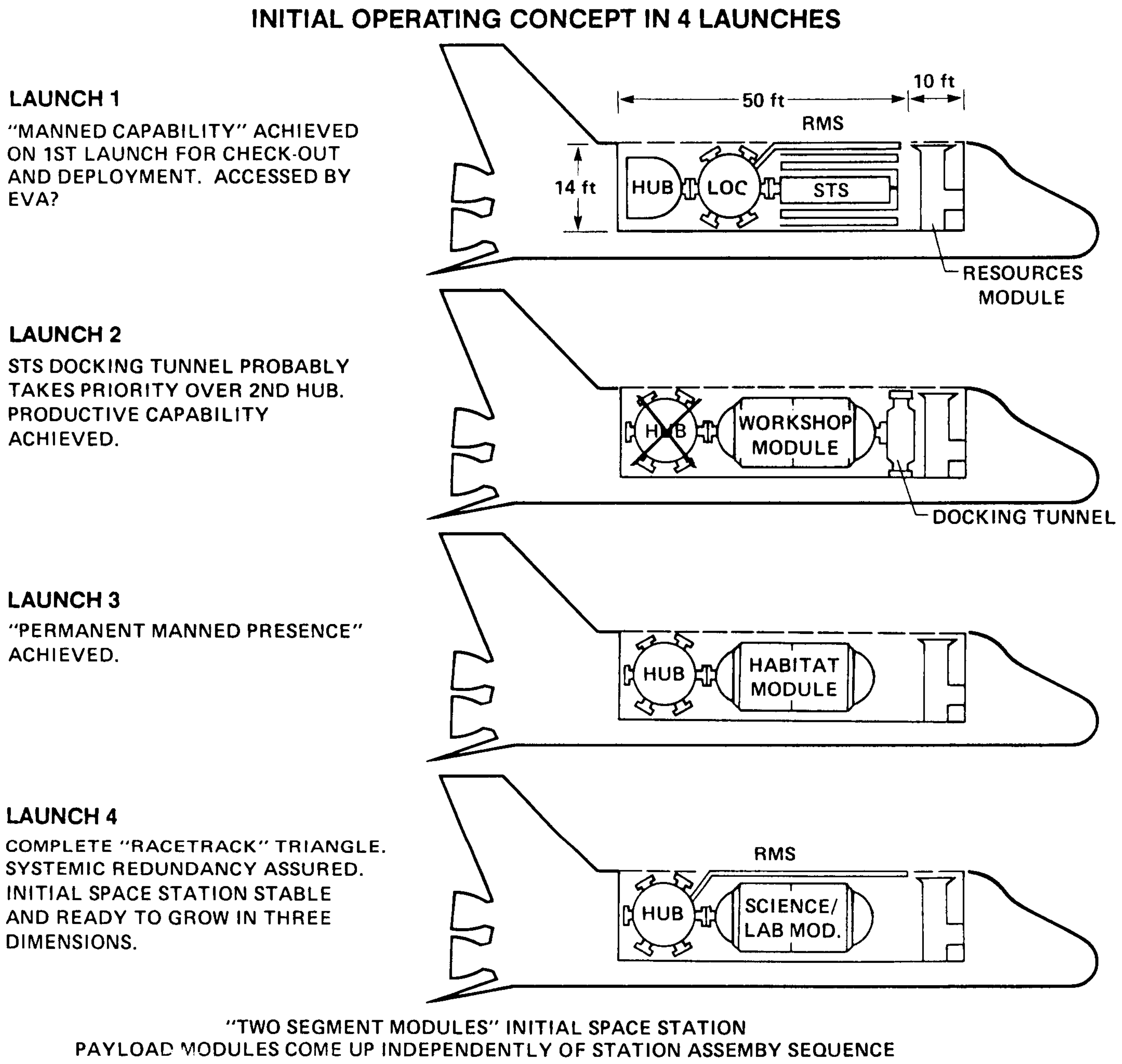
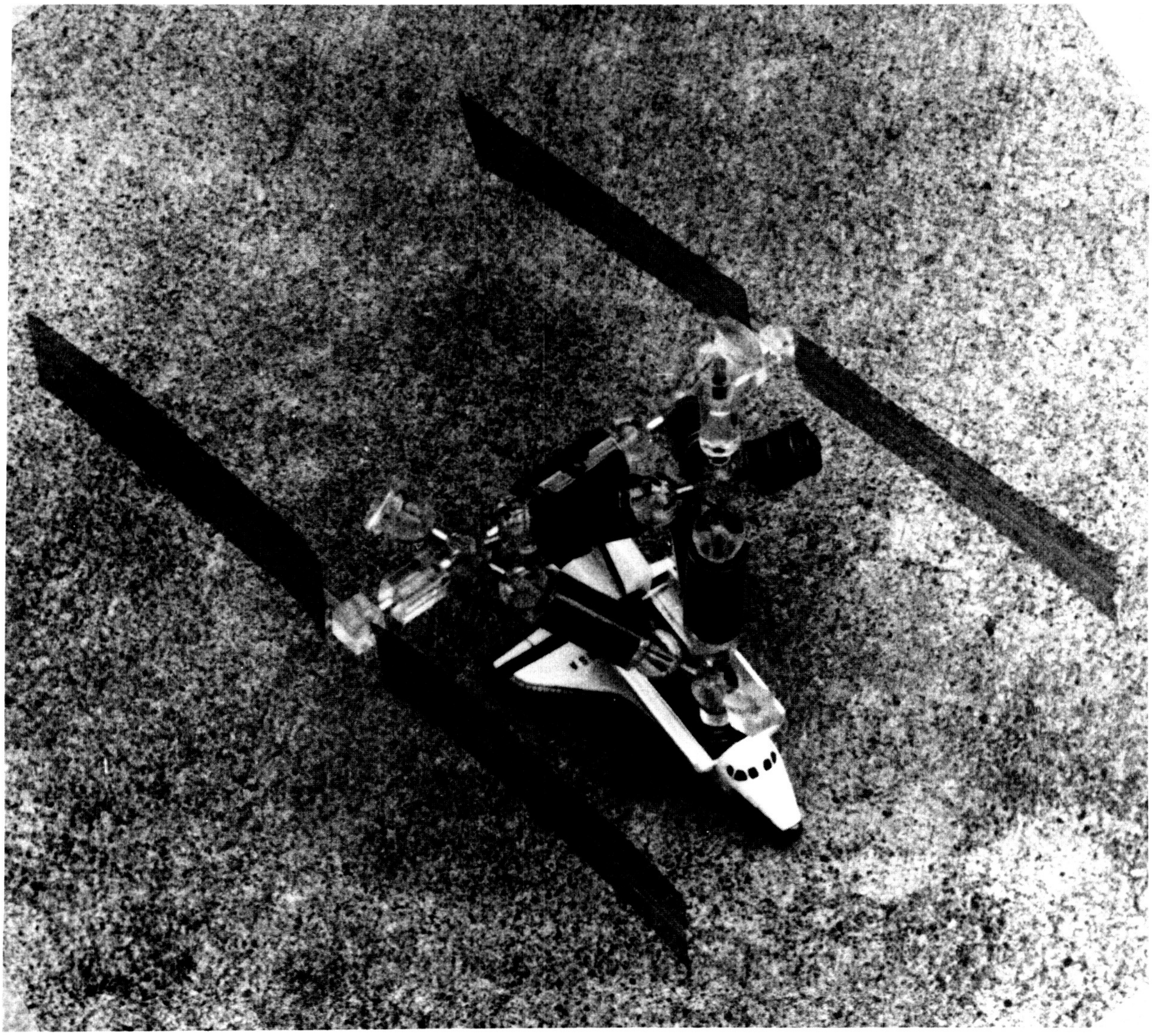


Figure 17.- Loading of Space Station payload launch elements in orbiter payload bay.



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 18.- Model of triangular/tetrahedral Space Station.

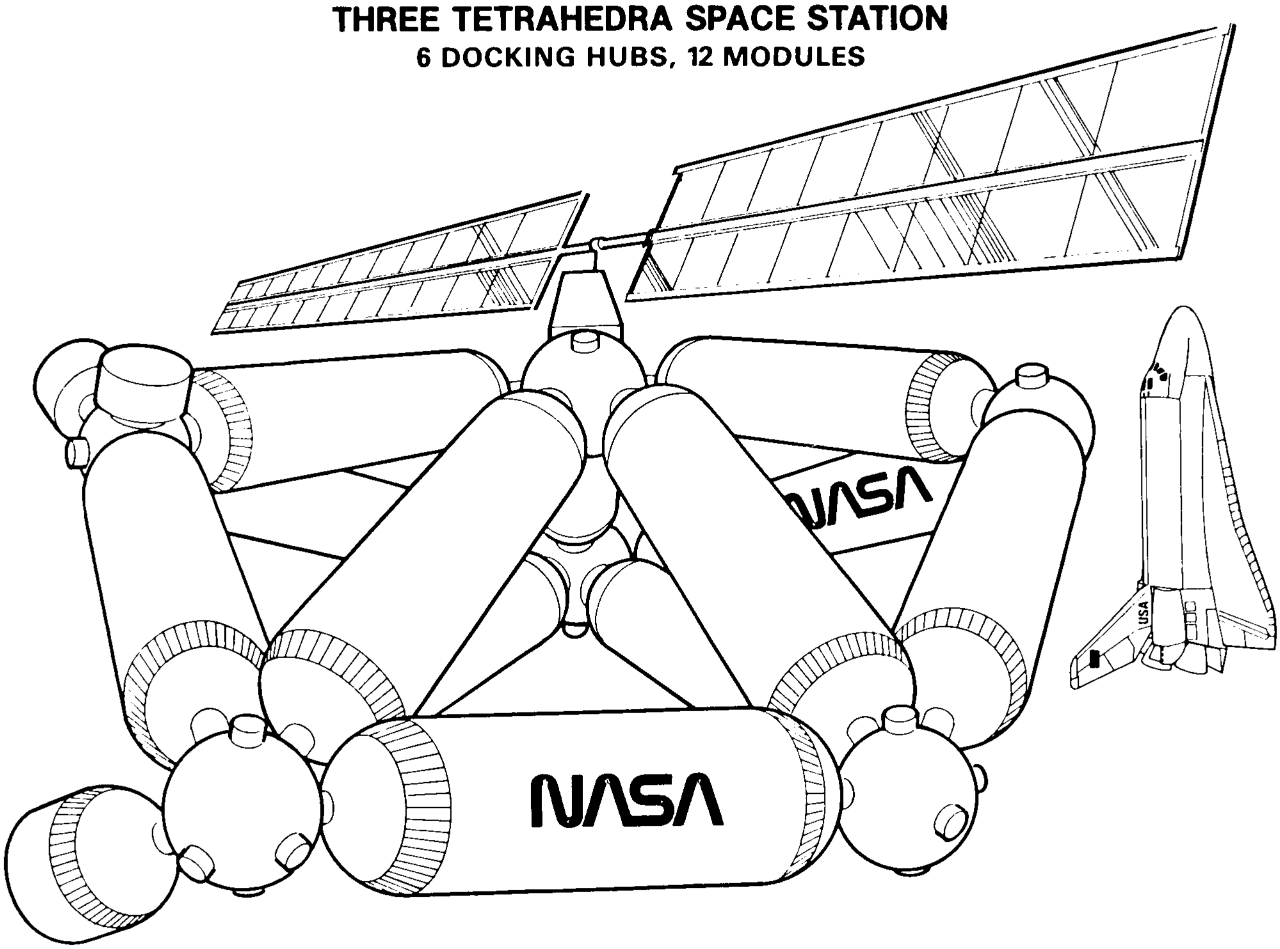


Figure 19.- Tetrahedral Space Station composed of three tetrahedral cells consisting of 6 hubs and 12 modules.

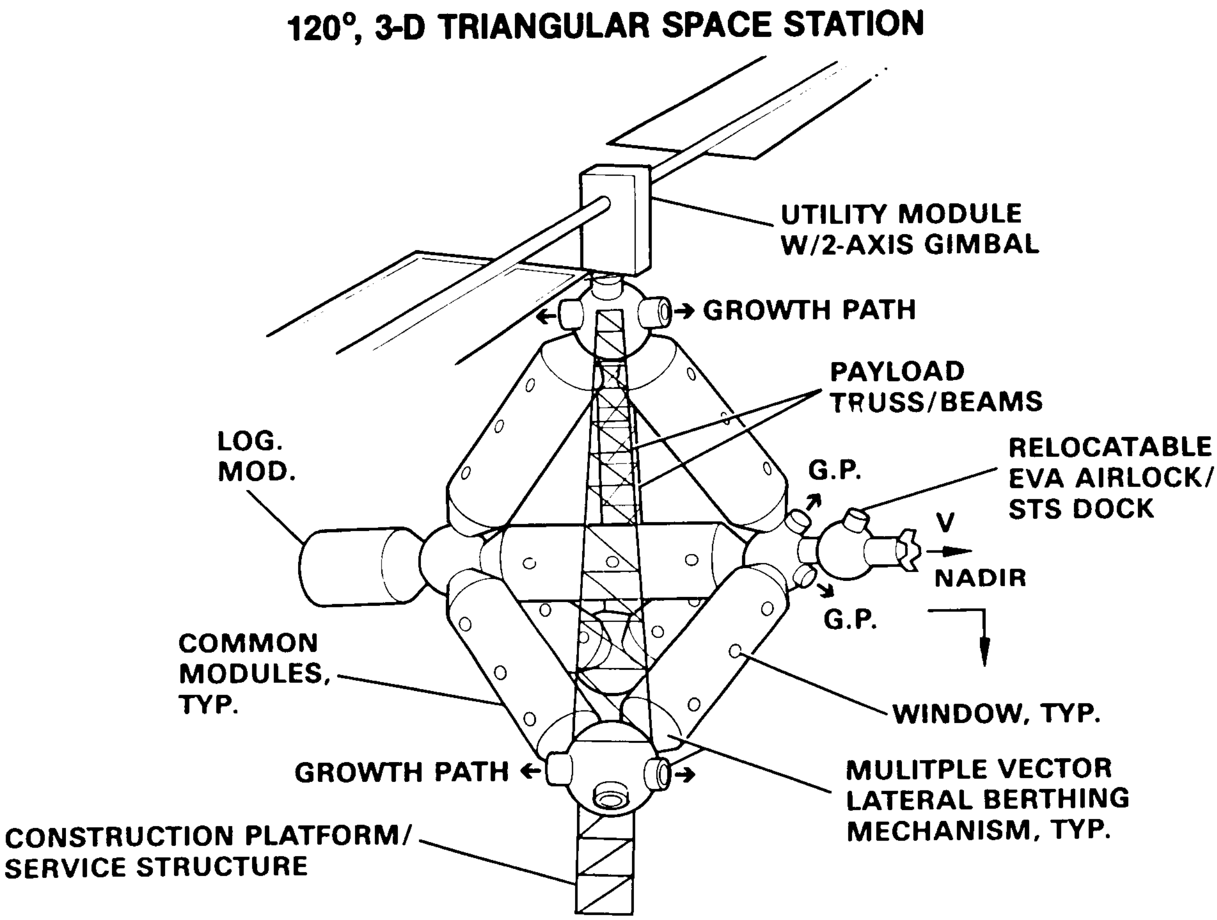


Figure 20.- 120° triangular Space Station, a variation on triangular/tetrahedral configuration.

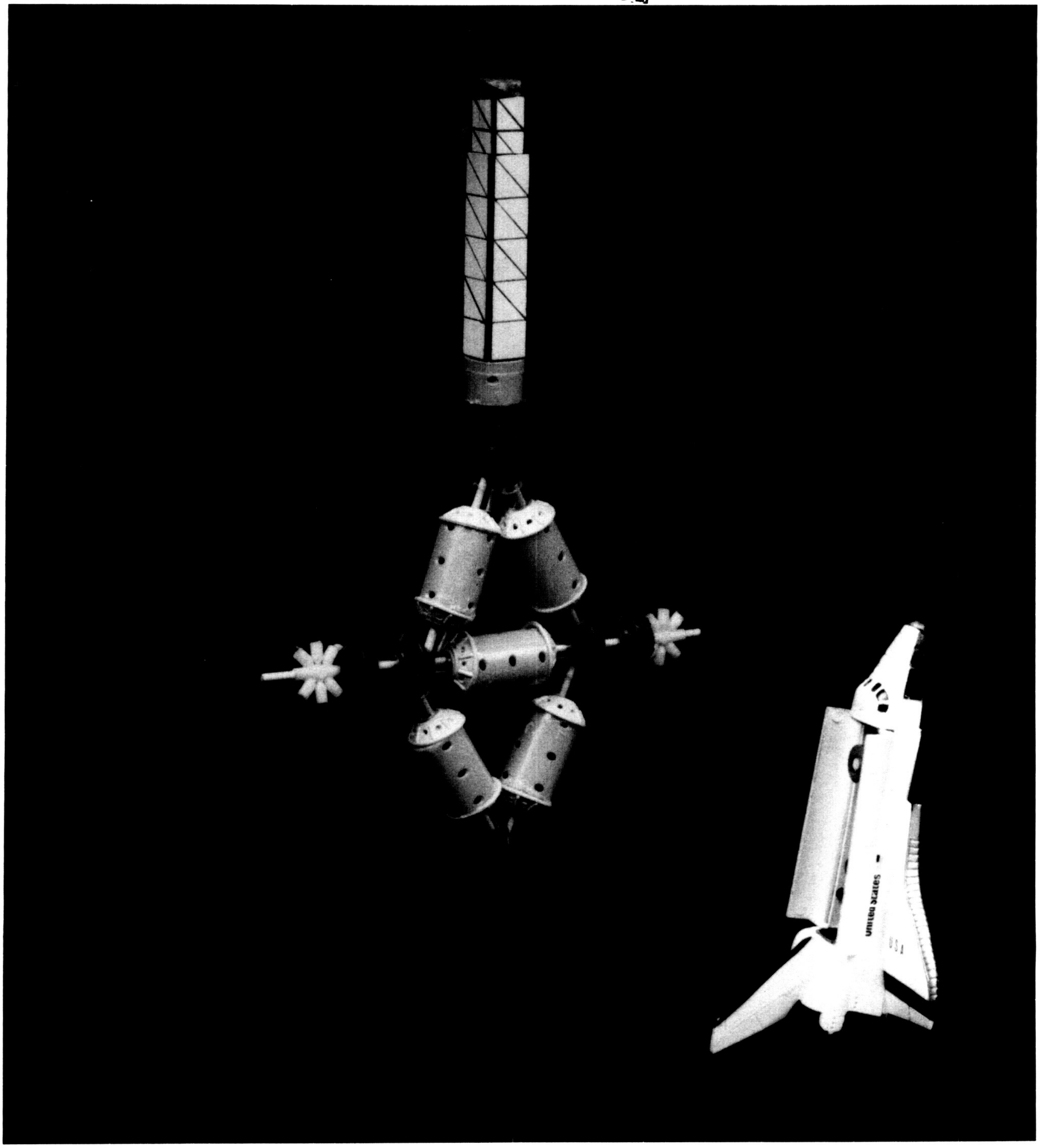


Figure 21.- Model of planar/triangular Space Station with "power tower" type truss.

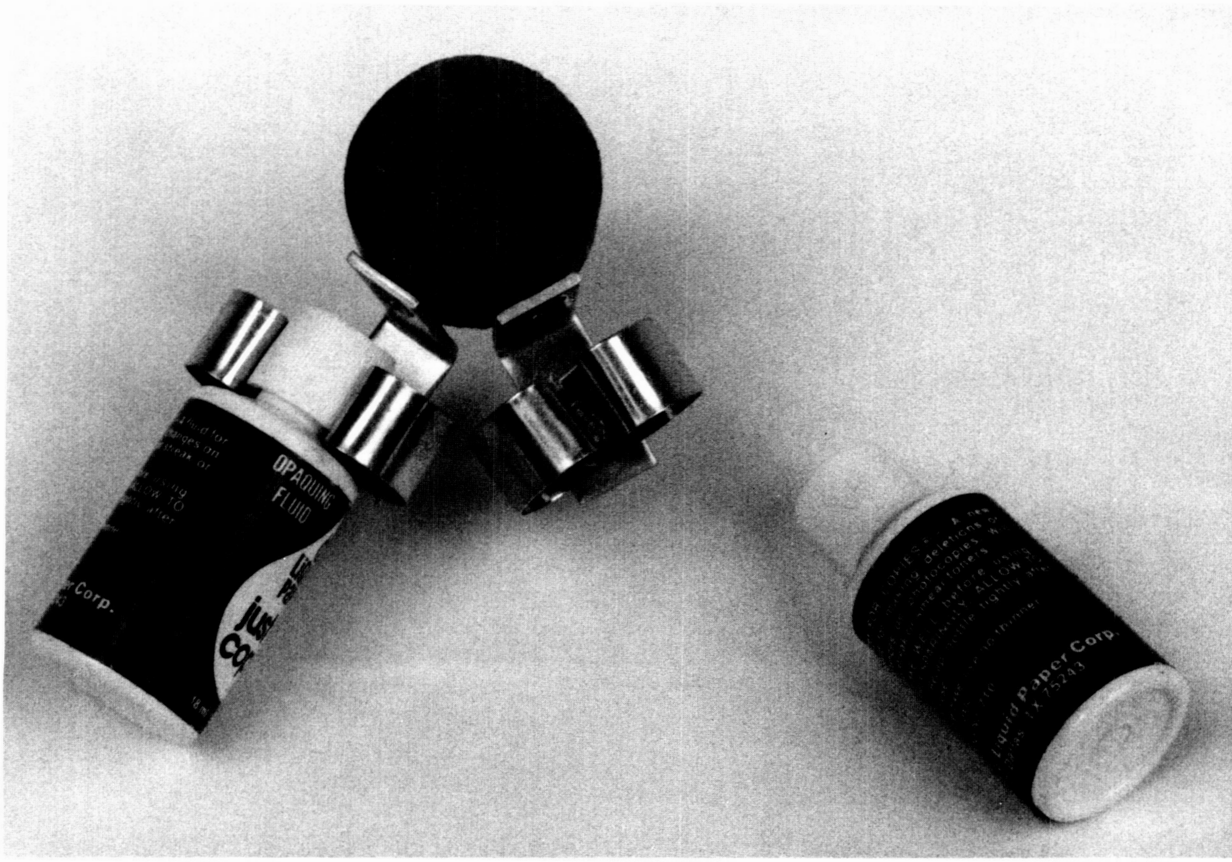


Figure 22.- Conceptual model showing berthing hub with active mechanisms and modules with passive mechanisms.

ORIGINAL PAGE IS
OF POOR QUALITY

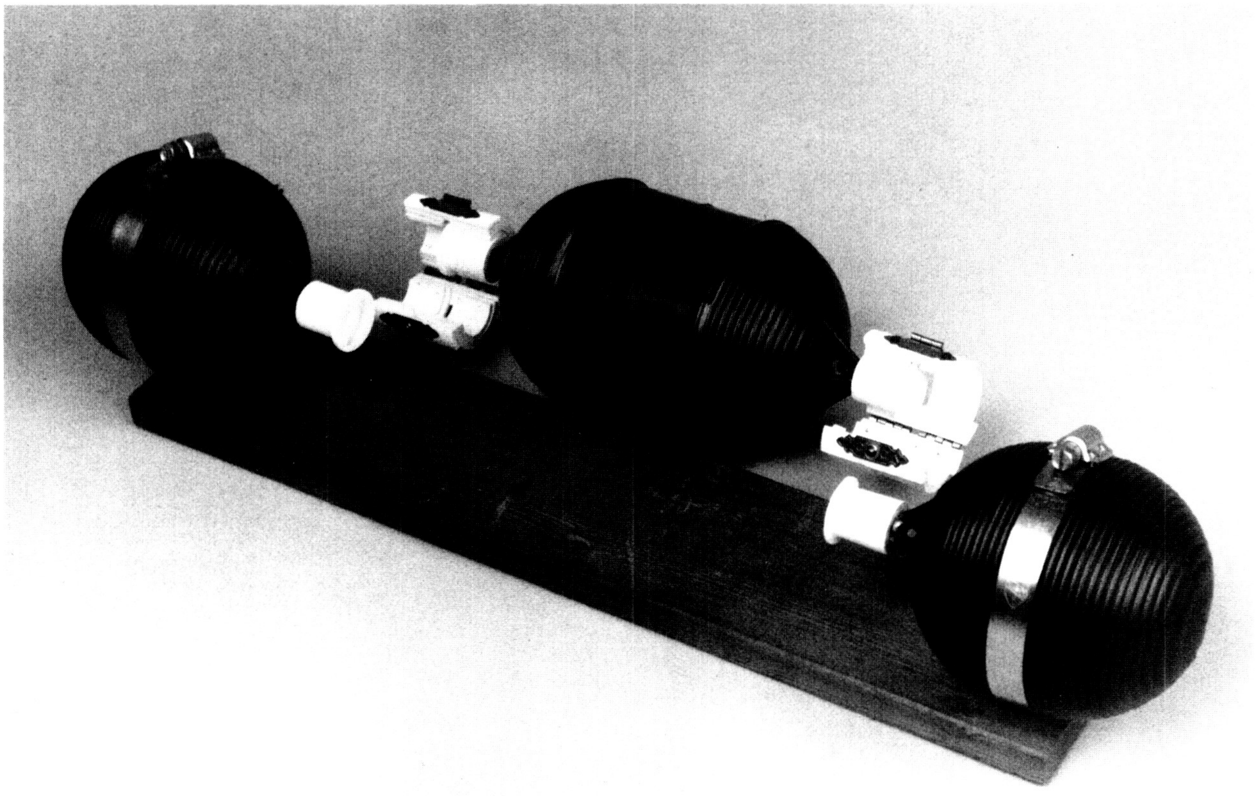


Figure 23.- Conceptual model showing module with active mechanisms and hubs with passive mechanisms.

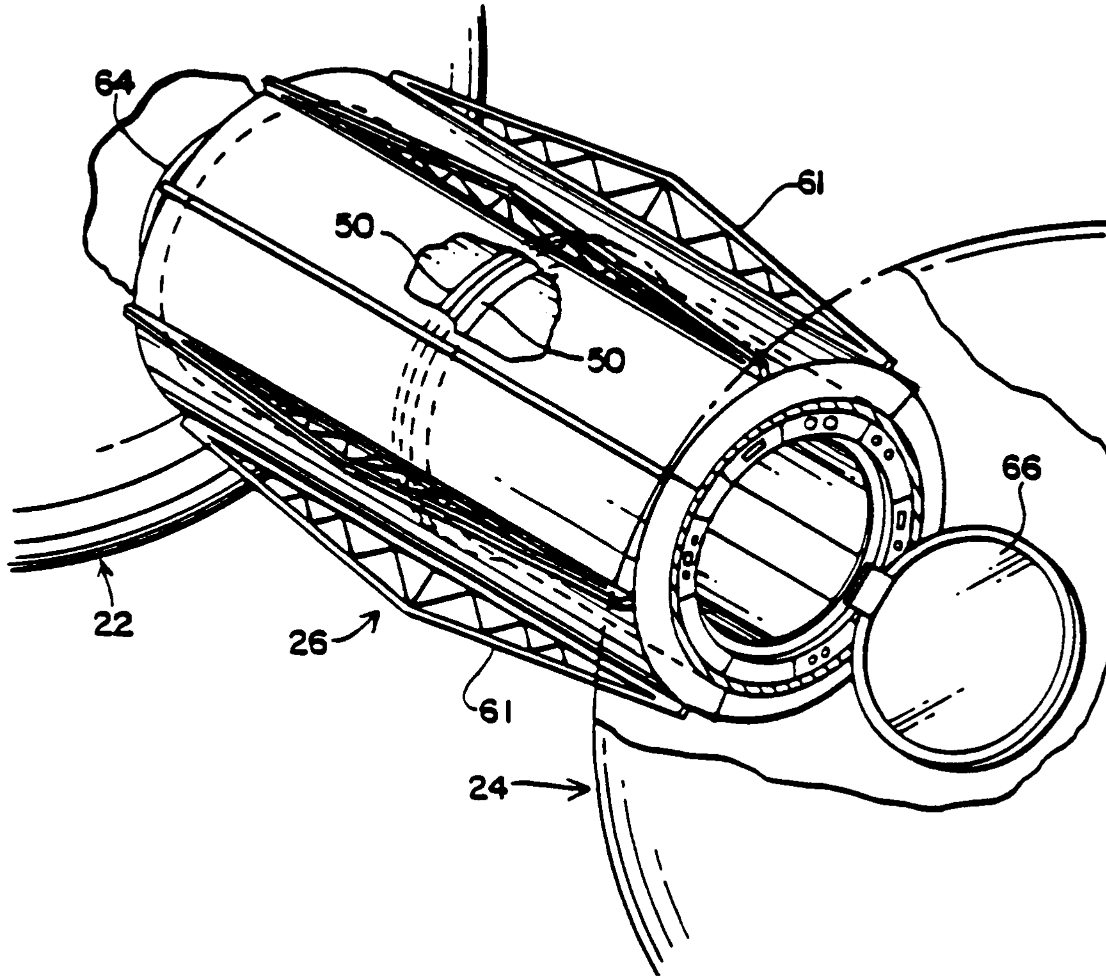


Figure 24.- Patent drawing detail of modules to hub connecting joint mechanism.

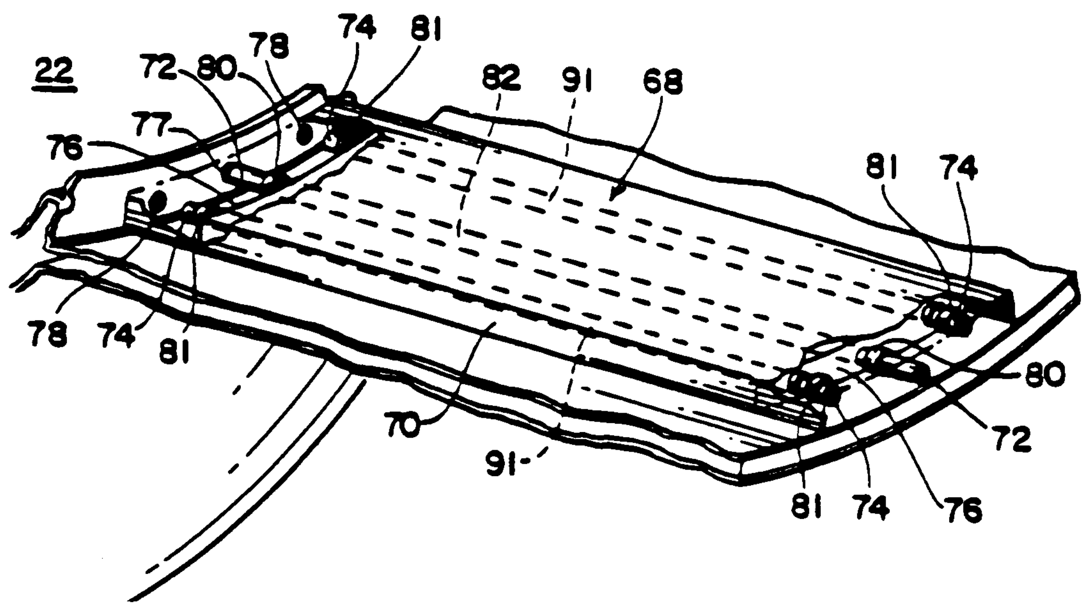


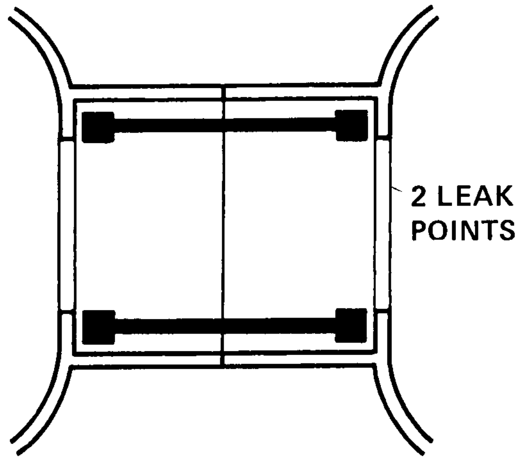
Figure 25.- Detail of manual utility connection channel.

UTILITY CONNECTION CASE STUDY

RESULTS OF TRIANGULAR-TETRAHEDRAL SPACE STATION STUDY:

MANUAL CHANNEL CONNECTION:

2 JOINT UNITS/PIECES – PREASSEMBLED CHANNEL INSTALLED BY HAND



REMOTE ACTUATED CONNECTION:

5 JOINT UNITS/PIECES – PREINSTALLED UTILITIES DEPLOYED AUTOMATICALLY

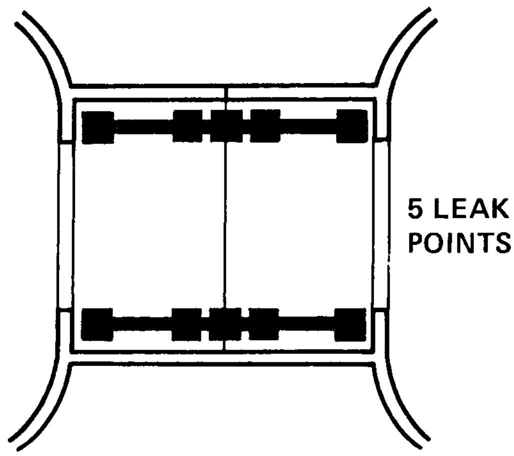


Figure 26.- Diagram showing comparison of manually assembled and remotely actuated utility connection channels.

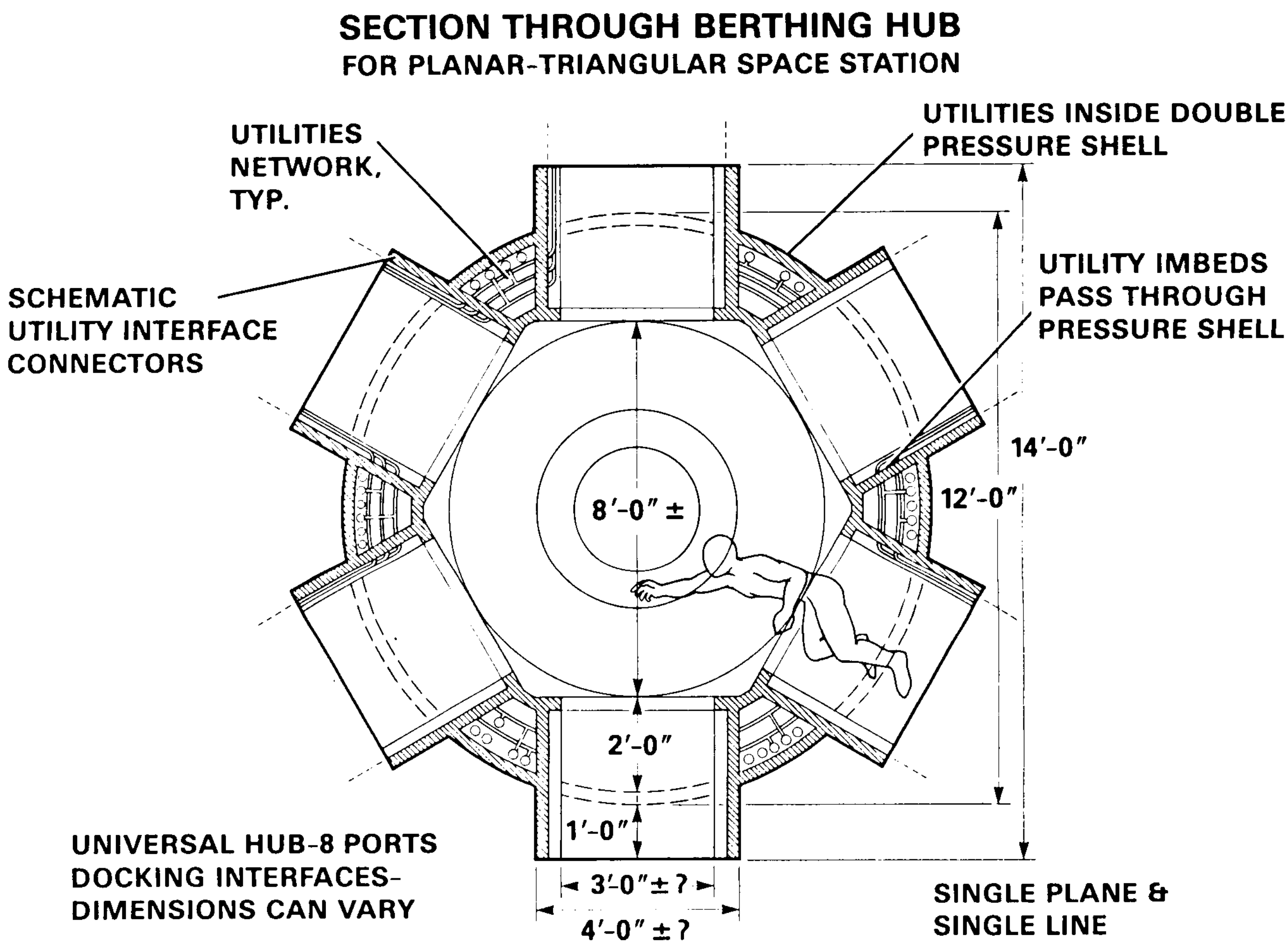


Figure 27.- Cross section through Space Station berthing hub in plane of planar/triangular configuration.

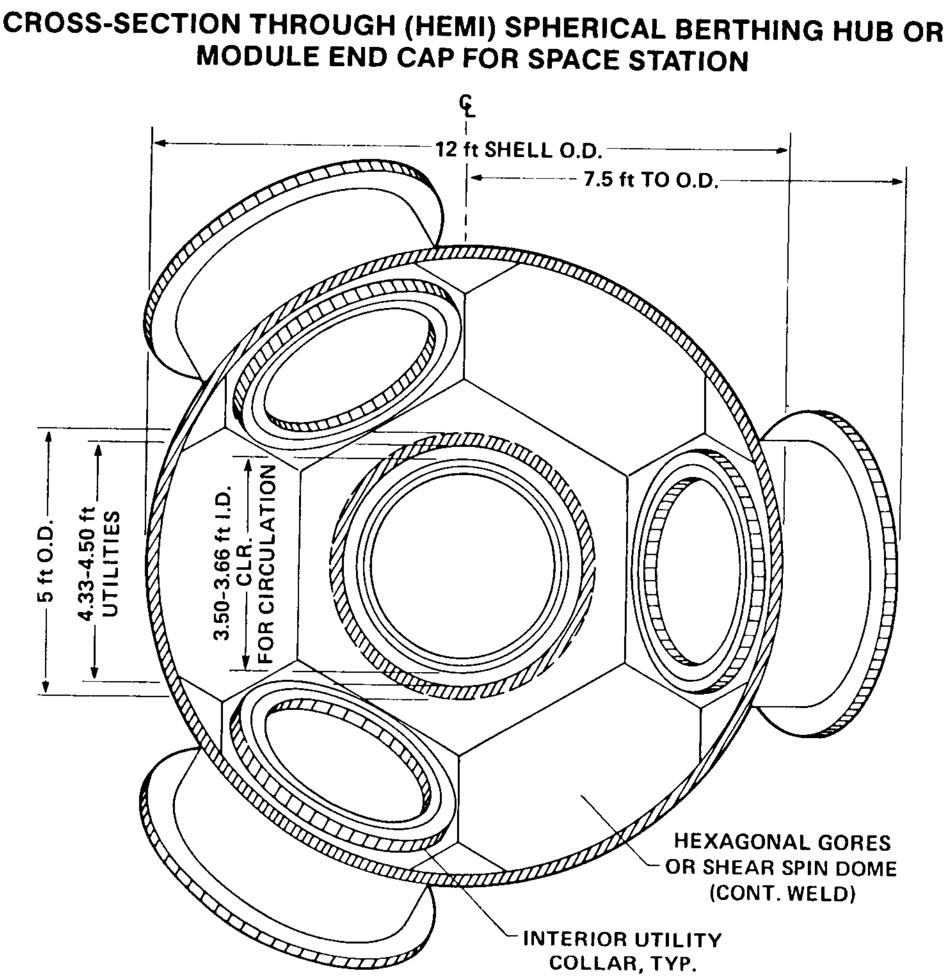
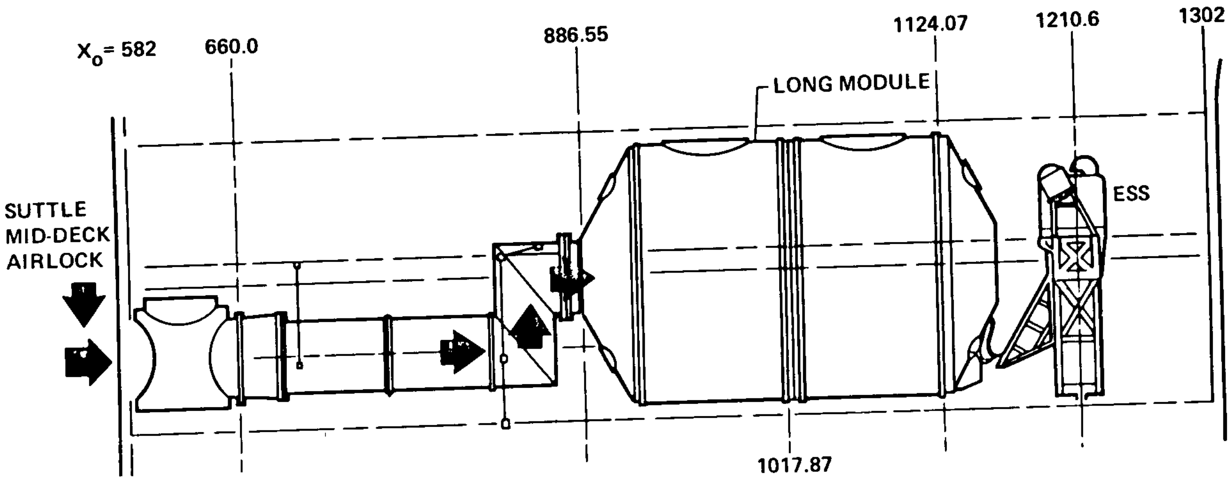


Figure 28.- Section through hemispherical berthing hub showing hexagonal gore lay-up.

SPACE LAB 3 MODULE IN STS CARGO BAY

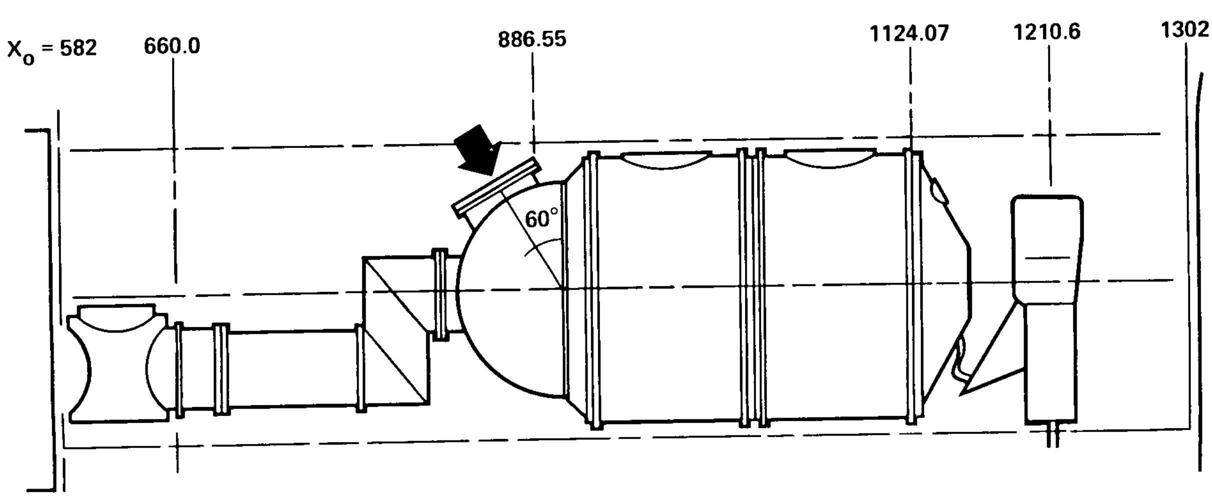


LIFE SCIENCES PAYLOADS (MICE, RATS, FROGS, MONKEYS)
MUST BE LOADED THROUGH THE STS MID-DECK
24 hours BEFORE LAUNCH

NOTE TIGHT ACCESS THROUGH AIRLOCK/TUNNEL

Figure 29.- Space Lab 3 module in orbiter cargo bay. Arrows show late access route down two bosun's chairs.

SPACELAB WITH HEMISPHERICAL END CAP IN STS CARGO BAY



LOAD LIFE SCIENCES FLIGHT EXPERIMENTS THROUGH
60° PORT IN HEMISPHERICAL END CAP

Figure 30.- Spacelab 3 with hemispherical end-cap and off-center port allowing more convenient late access.

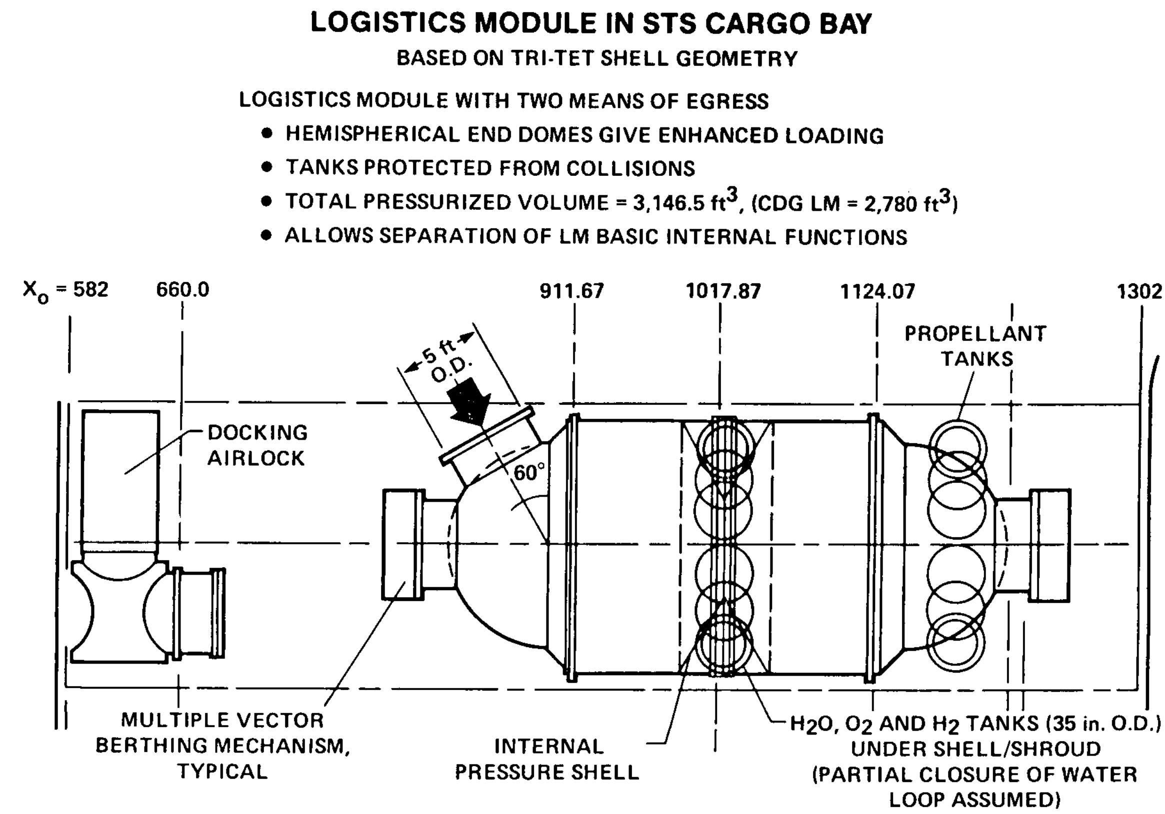


Figure 31.- Space Station logistics module with hemispherical end caps, one with off-center port allows convenient late access.

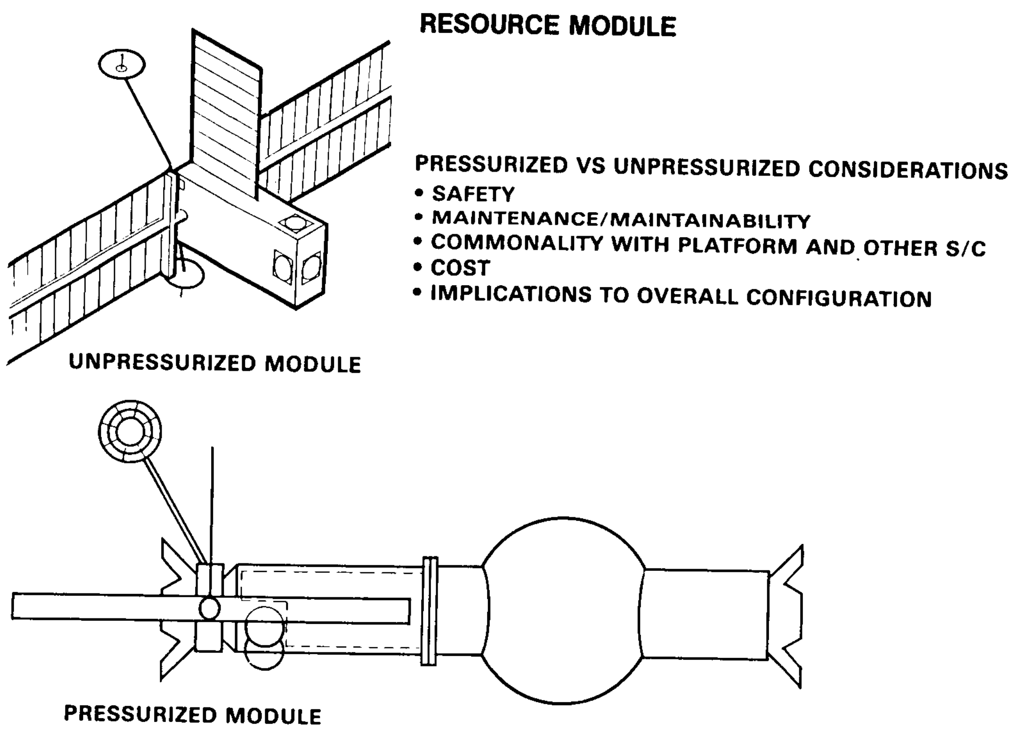


Figure 32.- Concepts for unpressurized and pressurized resource modules.

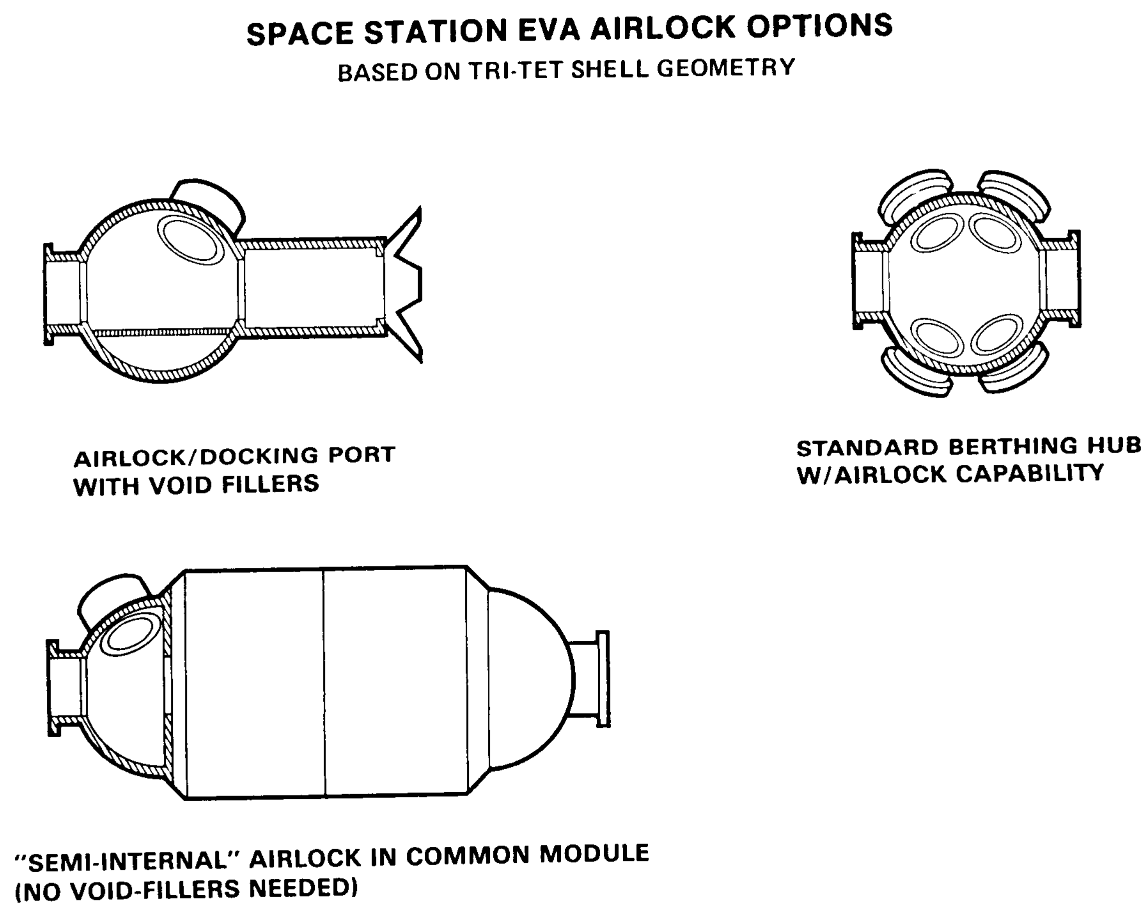


Figure 33.- Space Station airlock options using hemispherical end cap shells.

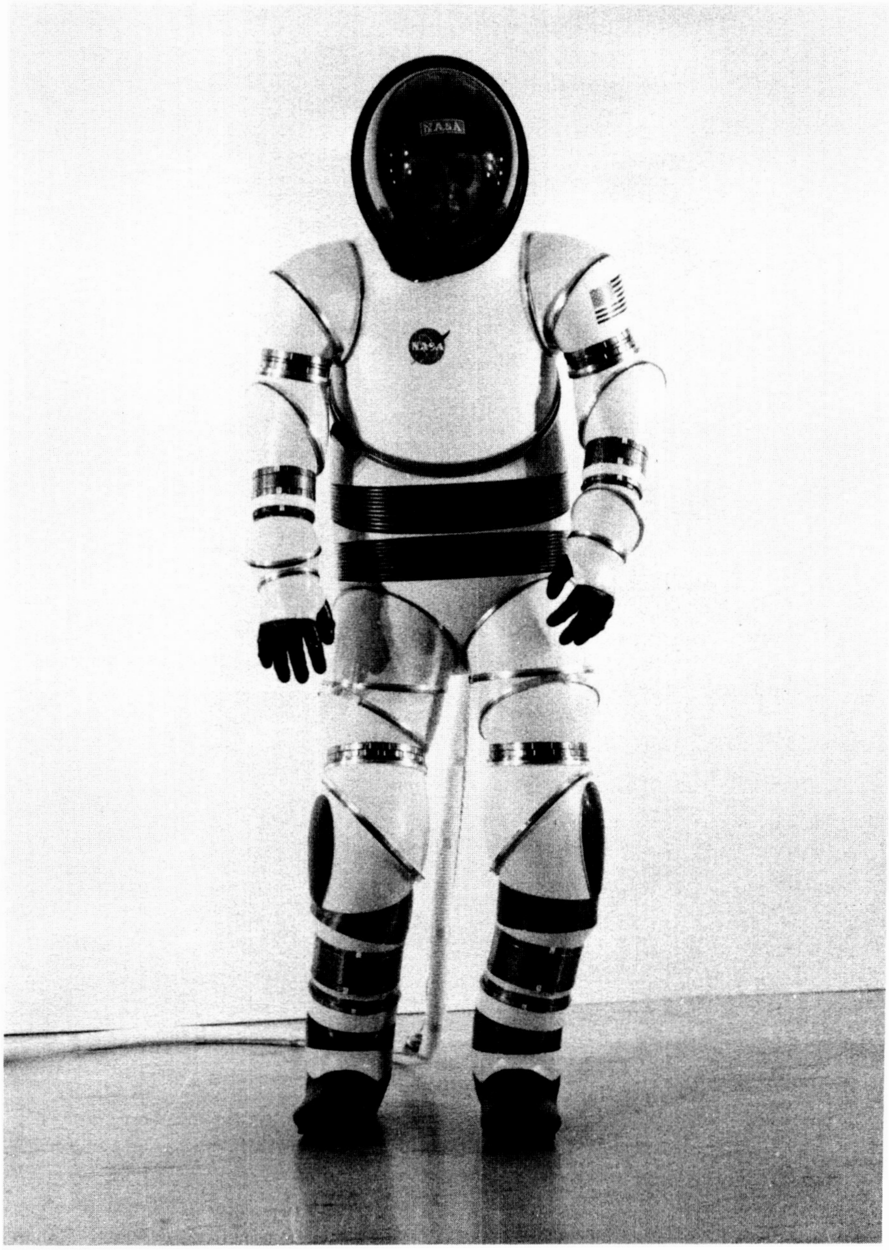


Figure 34.- Ames AX-2 experimental hard space suit designed by H. C. Vykukal, 1969.

AMES AX-5 HARD SPACE SUIT

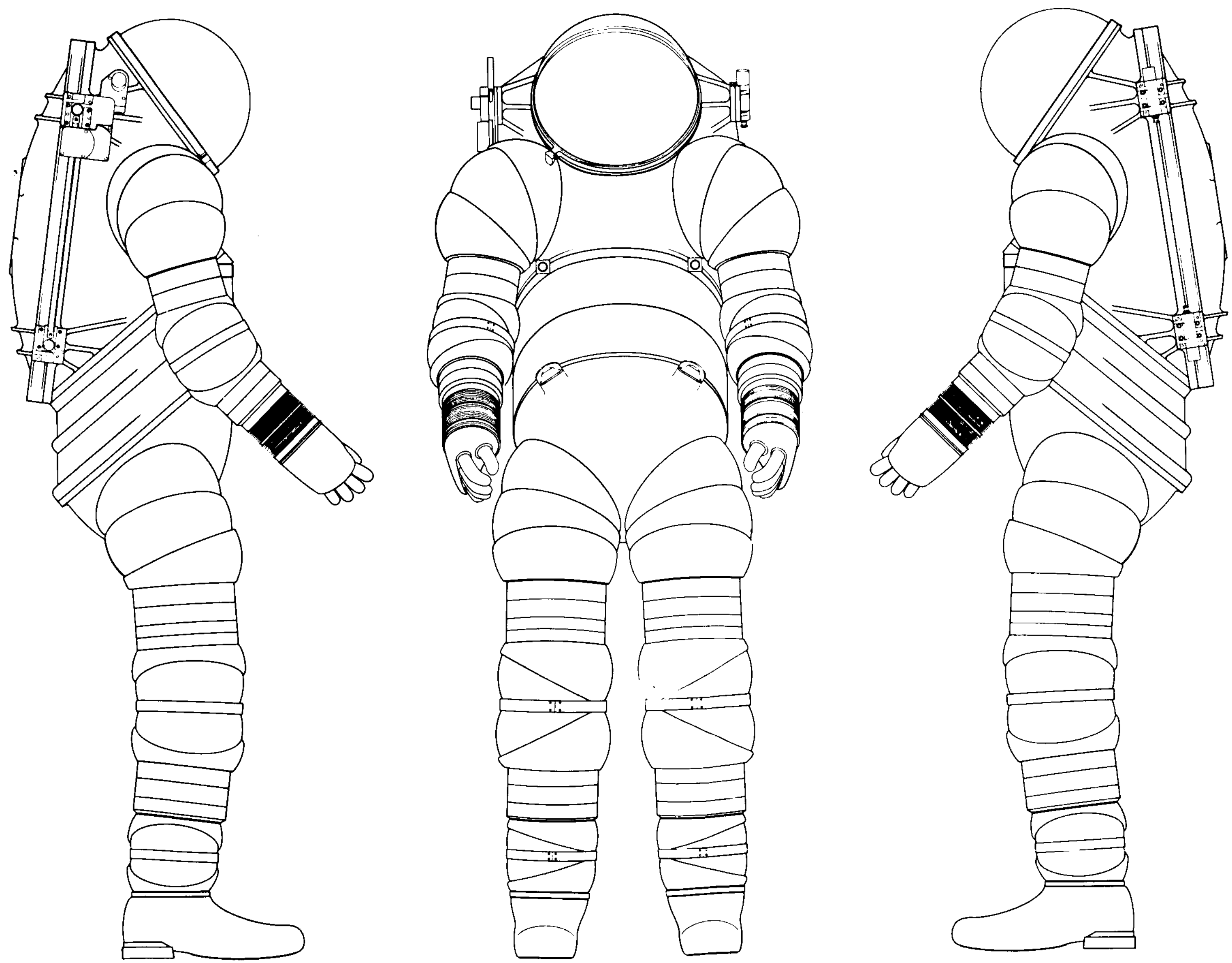


Figure 35.- Ames AX-5 experimental hard, high pressure space suit designed by H. C. Vykukal, 1985.

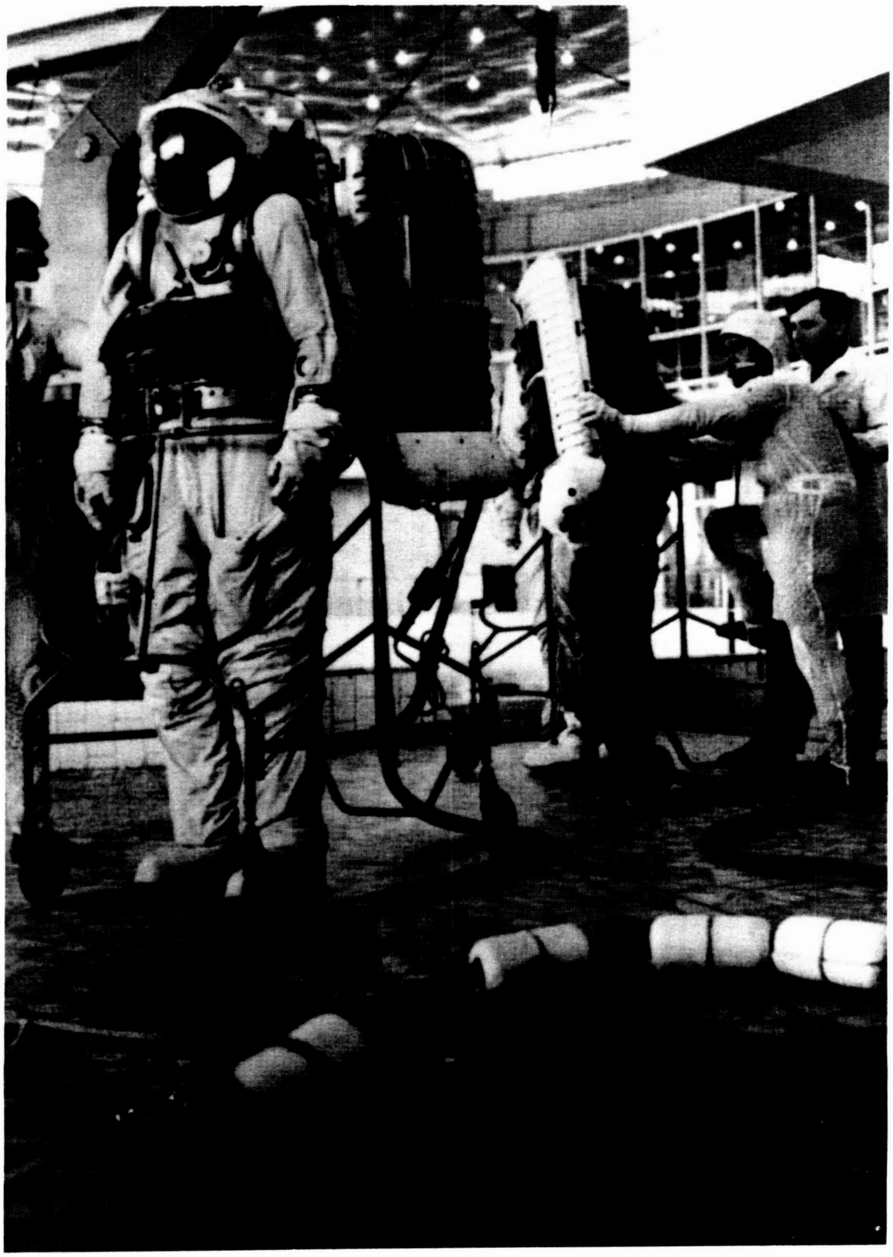


Figure 36.- Soviet space suit, a soft suit with rear-entry hatch.

EVA ACCESS FACILITY
A COMPARATIVE ANALYSIS OF FOUR CONCEPTS

PRE-DONNING SUIT PREP

SPACESUIT DONNING, SERVICING AND EVA ACCESS PROCEDURES:

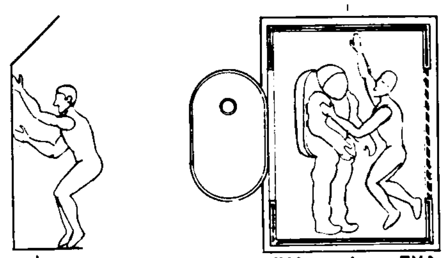
Crewmember assembles suit at storage/donning fixture and refers to adjacent status display for automated checkout of suit systems.

STEP 1

A

STS-TYPE AIRLOCK

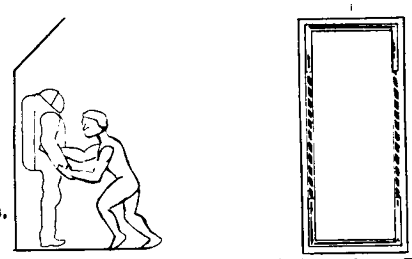
Crewmember retrieves sizing parts and spares by leaving airlock unit. Checkout equipment and status display are located inside airlock. All assembly and checkout is performed with suit and crewmember inside airlock.



B

TRANSIT AIRLOCK

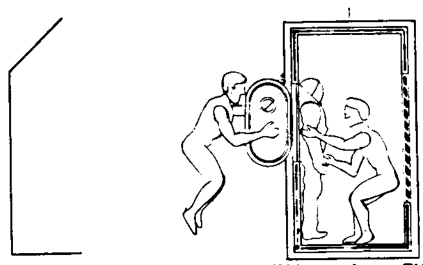
Crewmember performs suit assembly and checkout outside the airlock. Sizing parts, spares, checkout equipment, and status display are adjacent to storage/donning fixture.



C

SUITPORT

Crewmember performs suit assembly and checkout with suit attached to suitport. Sizing parts and spares are retrieved from outside the airlock. Suit status display and checkout equipment are located on wall of airlock.



D

CREWLOCK

Crewmember performs suit assembly and checkout outside airlock. Sizing parts, spares, equipment and status display are adjacent to storage/donning fixture.

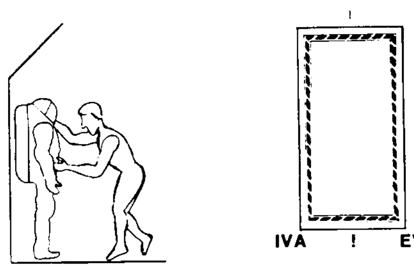


Figure 37.- Story board representation of four comparative concepts for EVA access facility, Step 1.

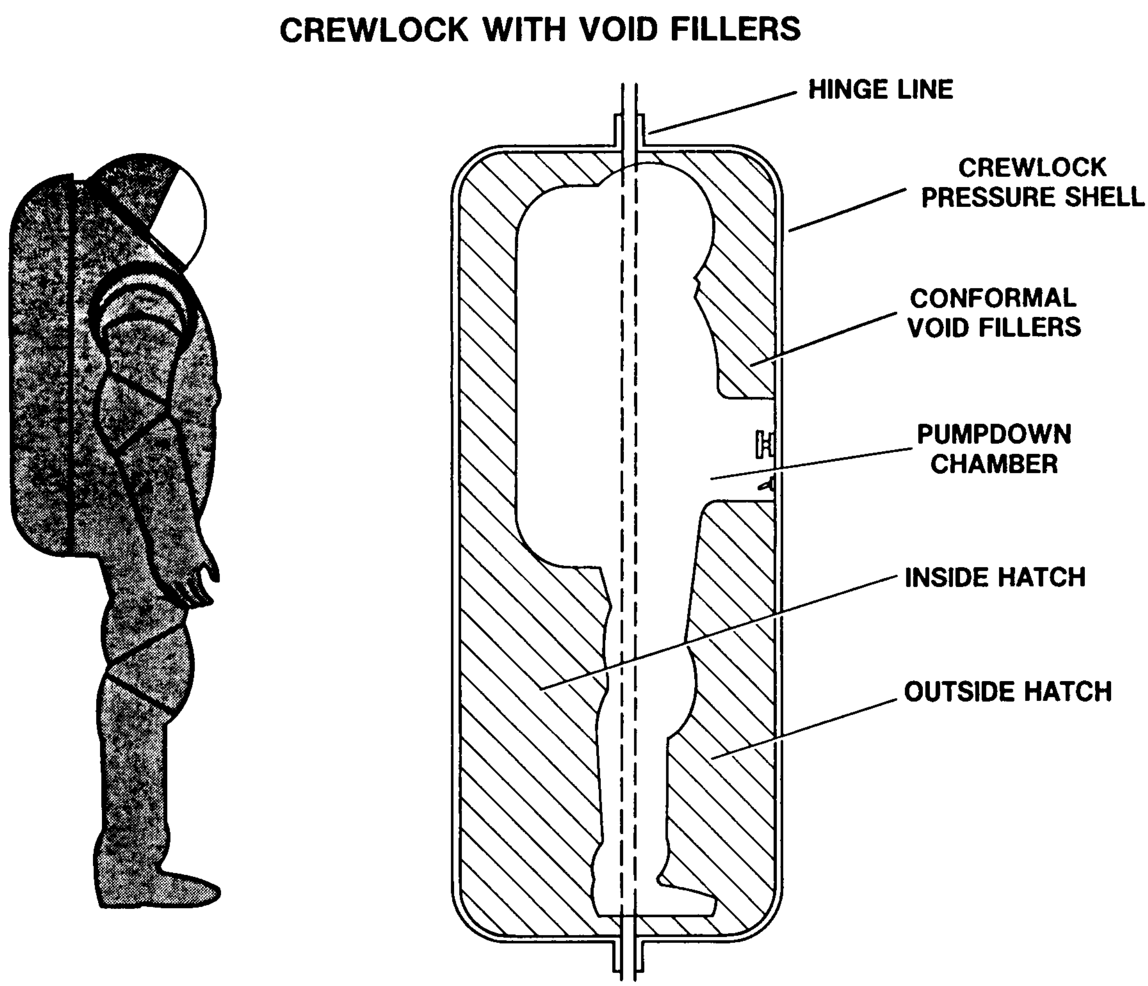


Figure 38.- Crewlock conformal airlock for one space-suited astronaut.

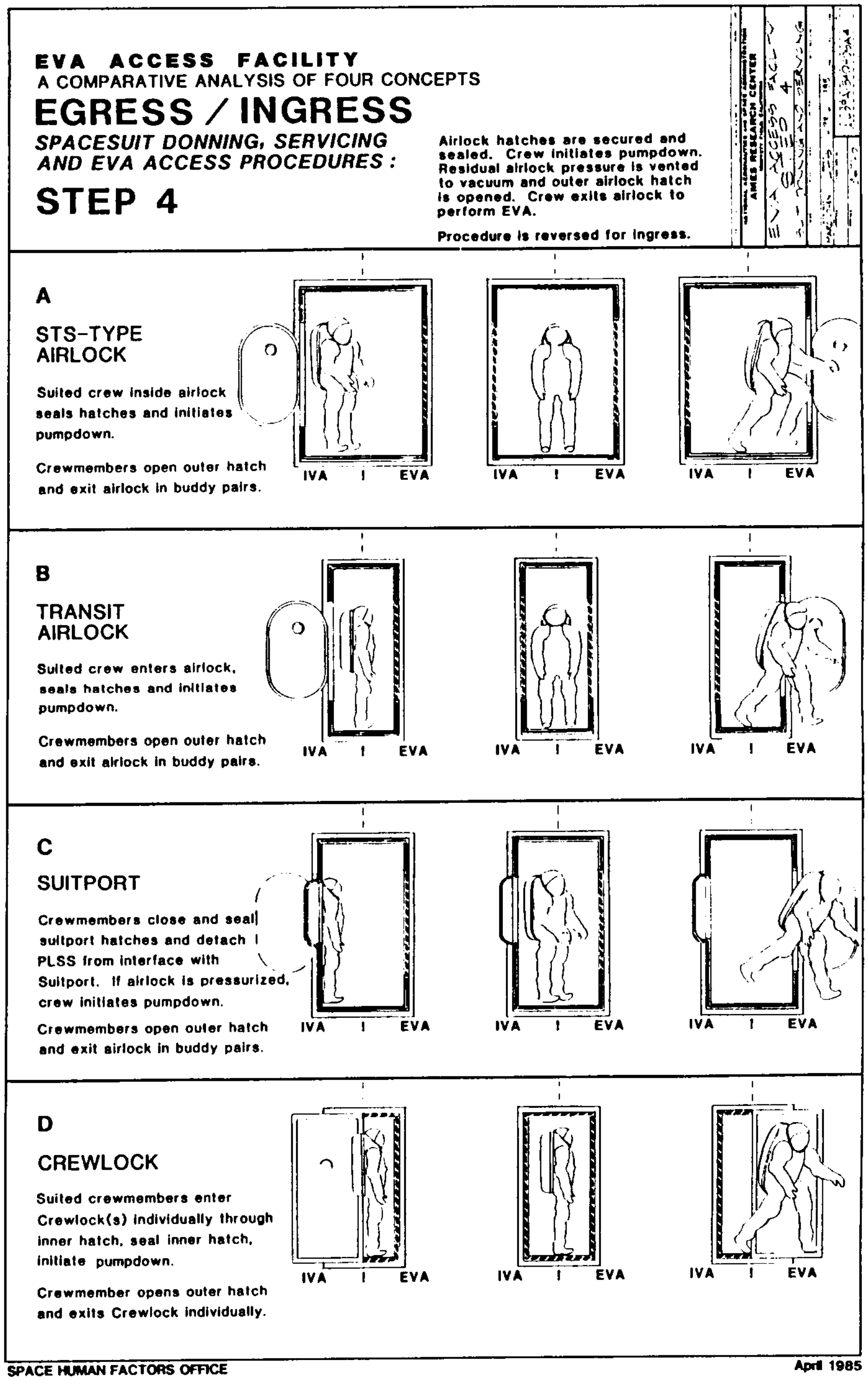


Figure 39.- Step 4, EVA access facility egress/ingress comparison.

ORIGINAL PAGE IS
OF POOR QUALITY

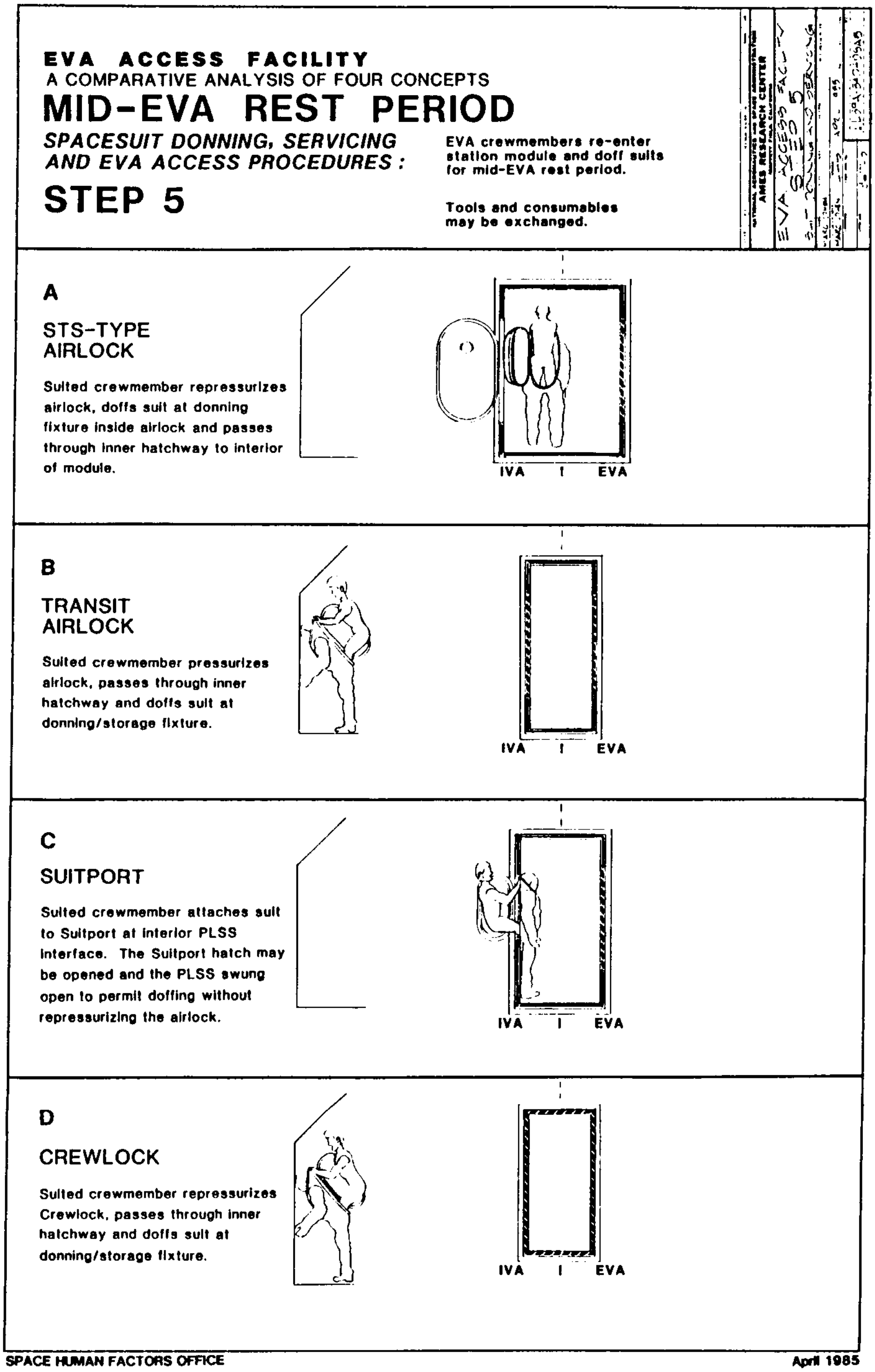


Figure 40.- Step 5, EVA access facility mid-EVA rest period comparison.

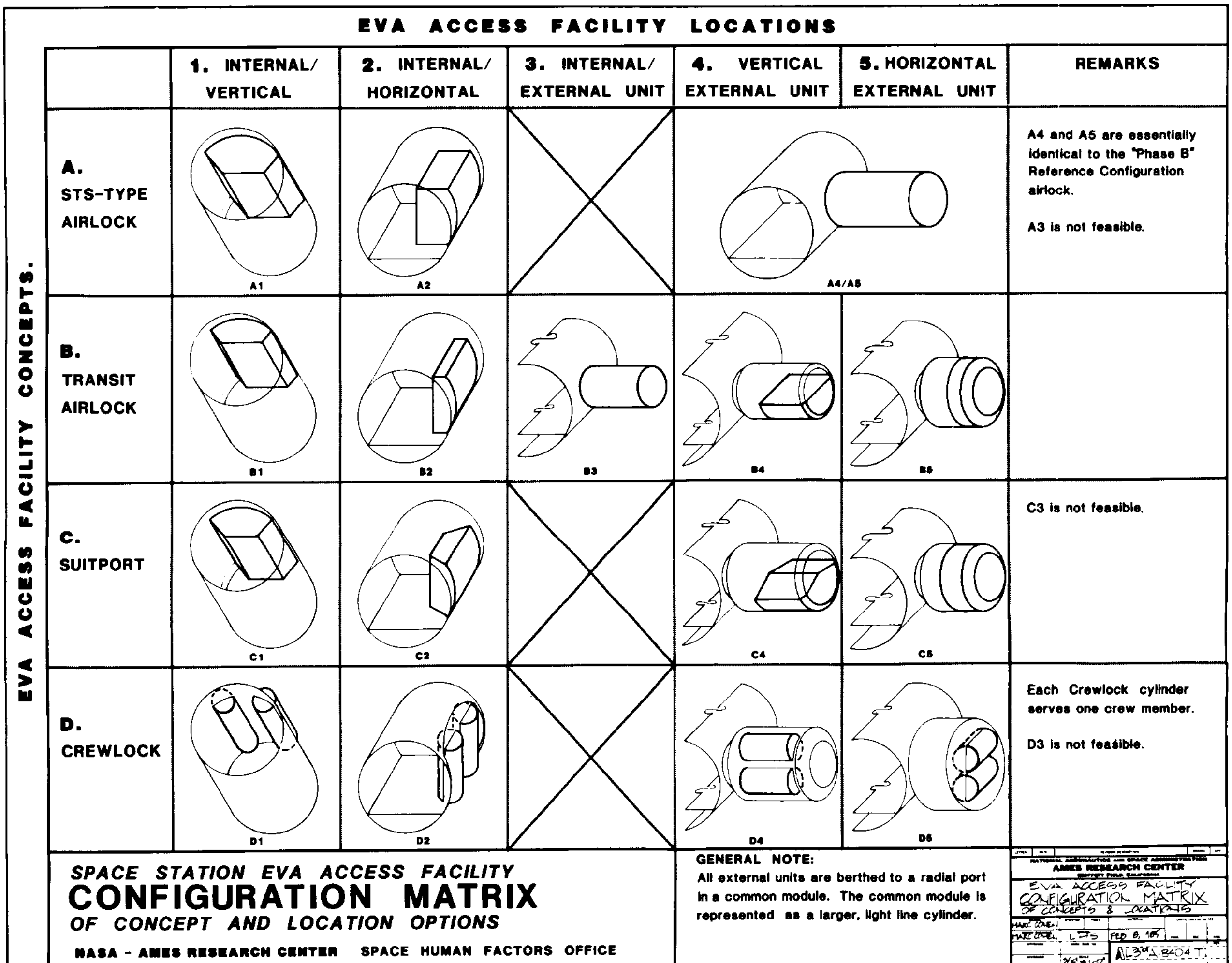


Figure 41.- EVA access facility configuration matrix.

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

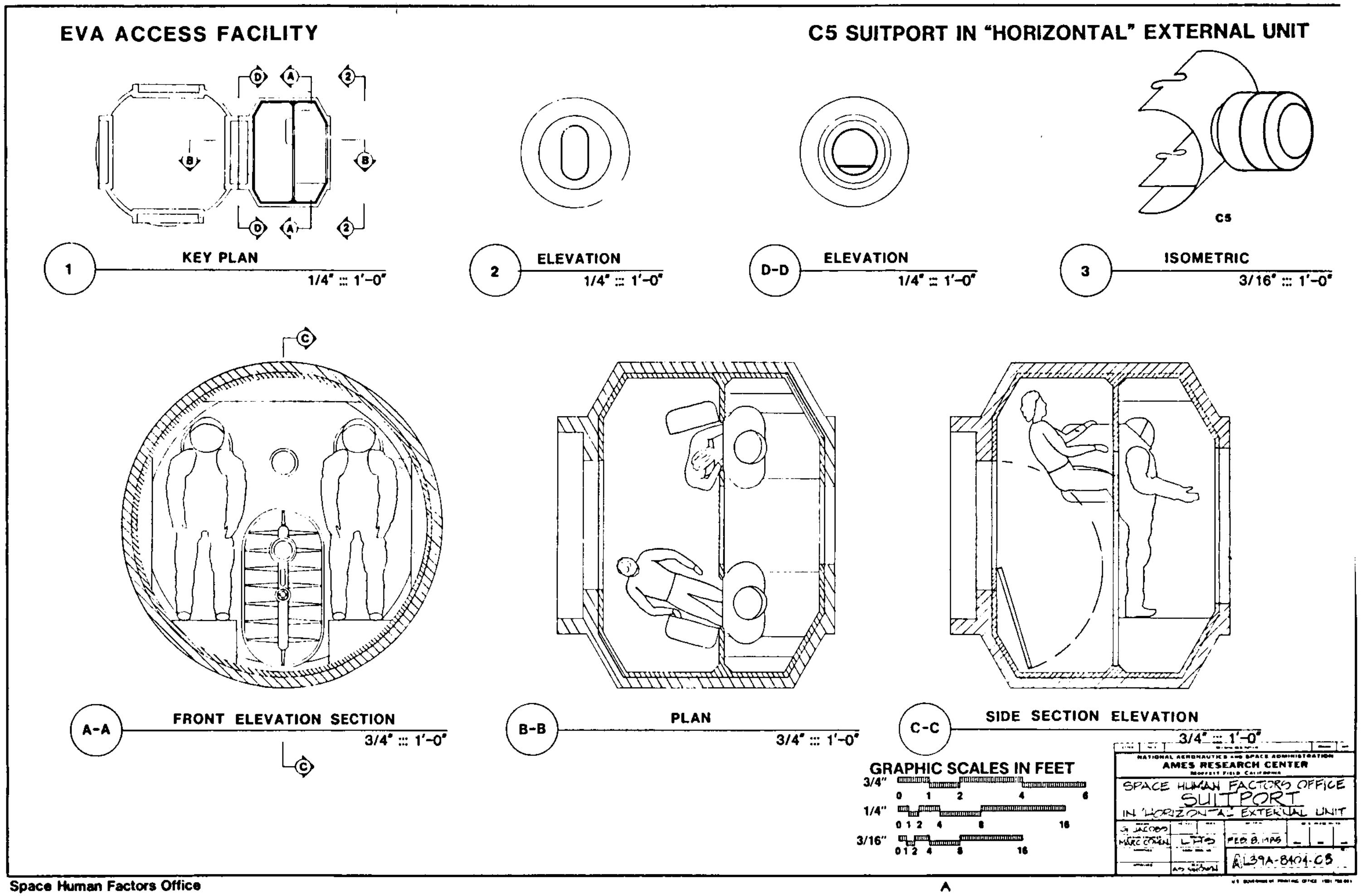


Figure 42.- Concept detail of suitport EVA access facility horizontal external unit.

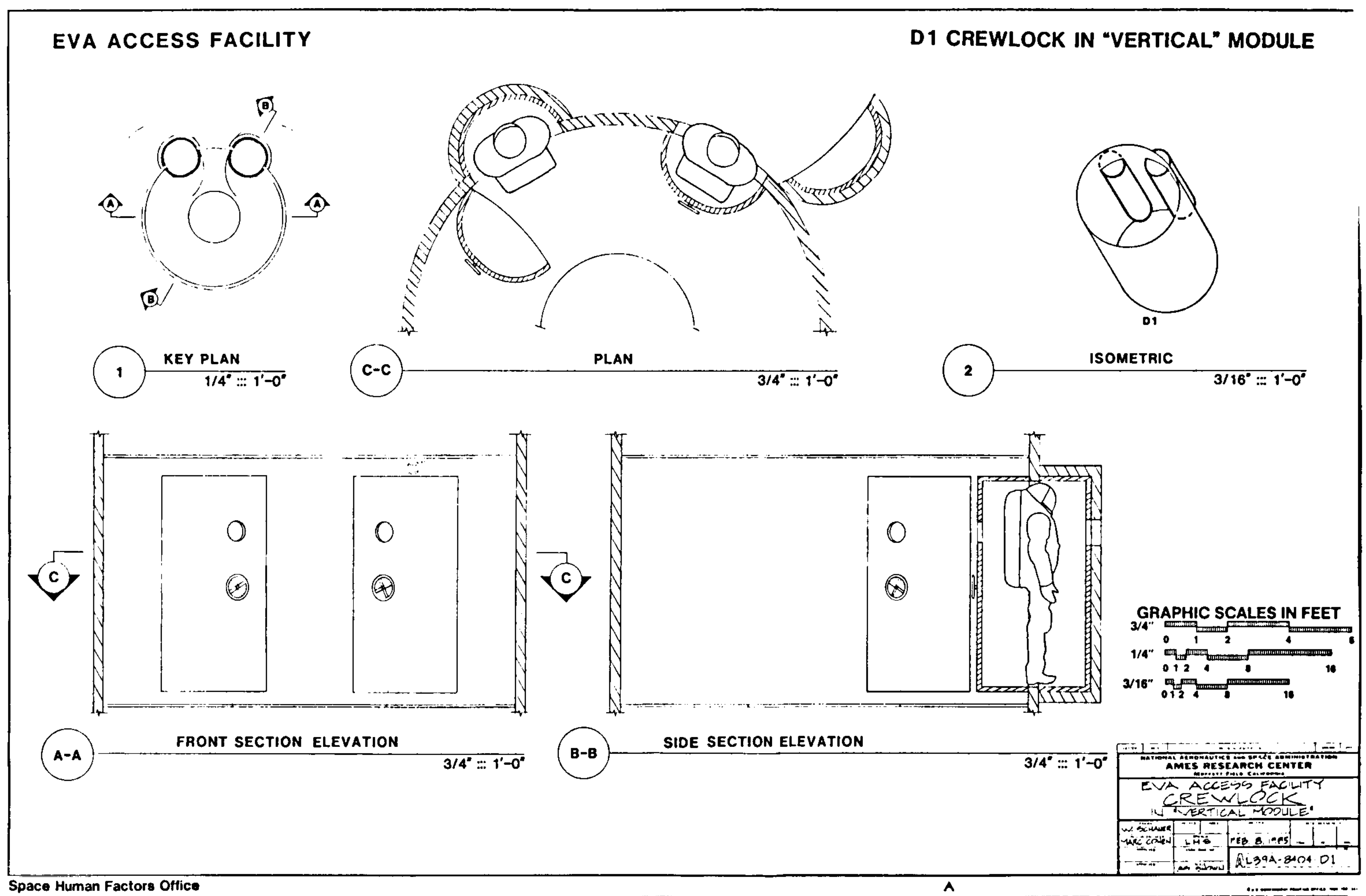


Figure 43.- Concept detail of crewlock EVA access facility vertical external unit.

ORIGINAL PAGE IS
OF POOR QUALITY

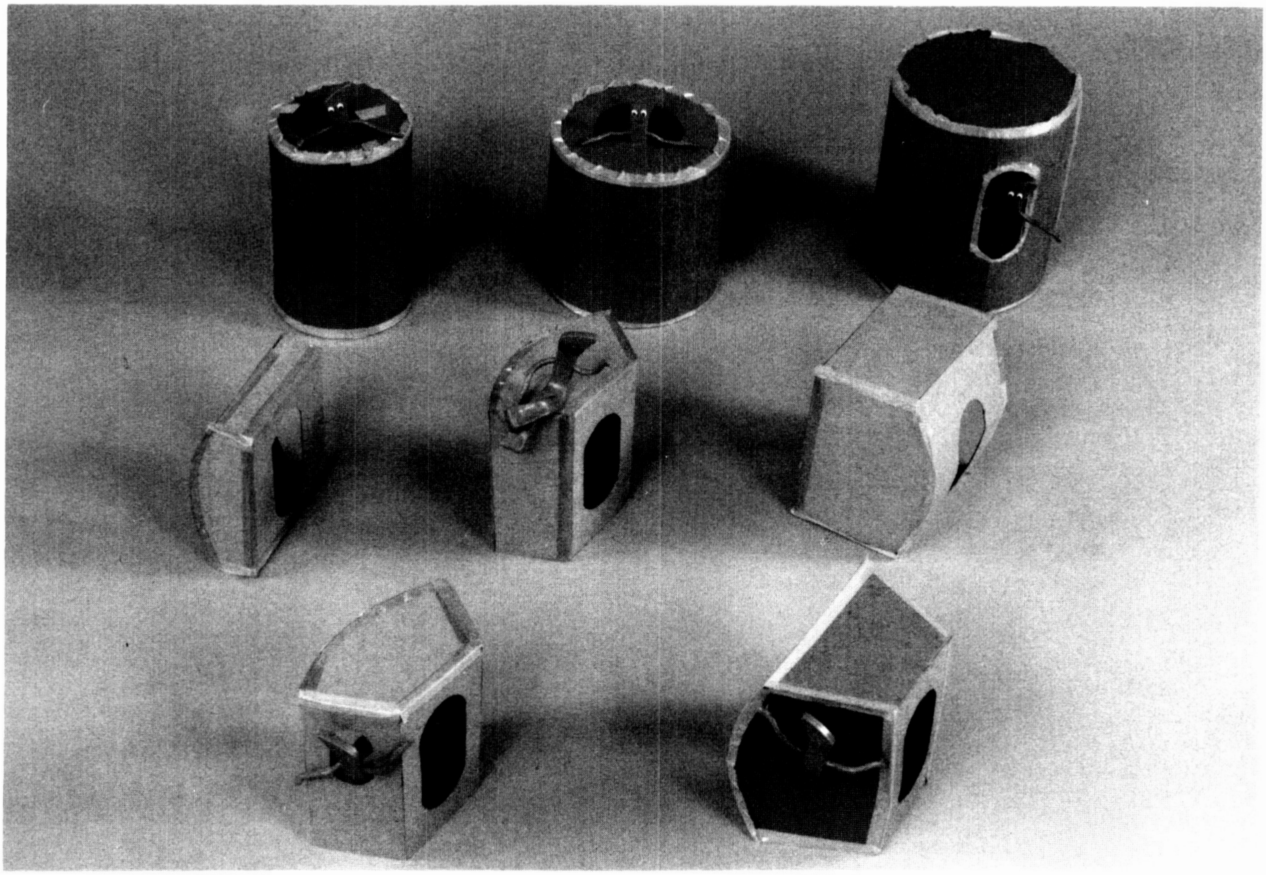


Figure 44.- Conceptual models of various EVA access facility volumetric configuration options.

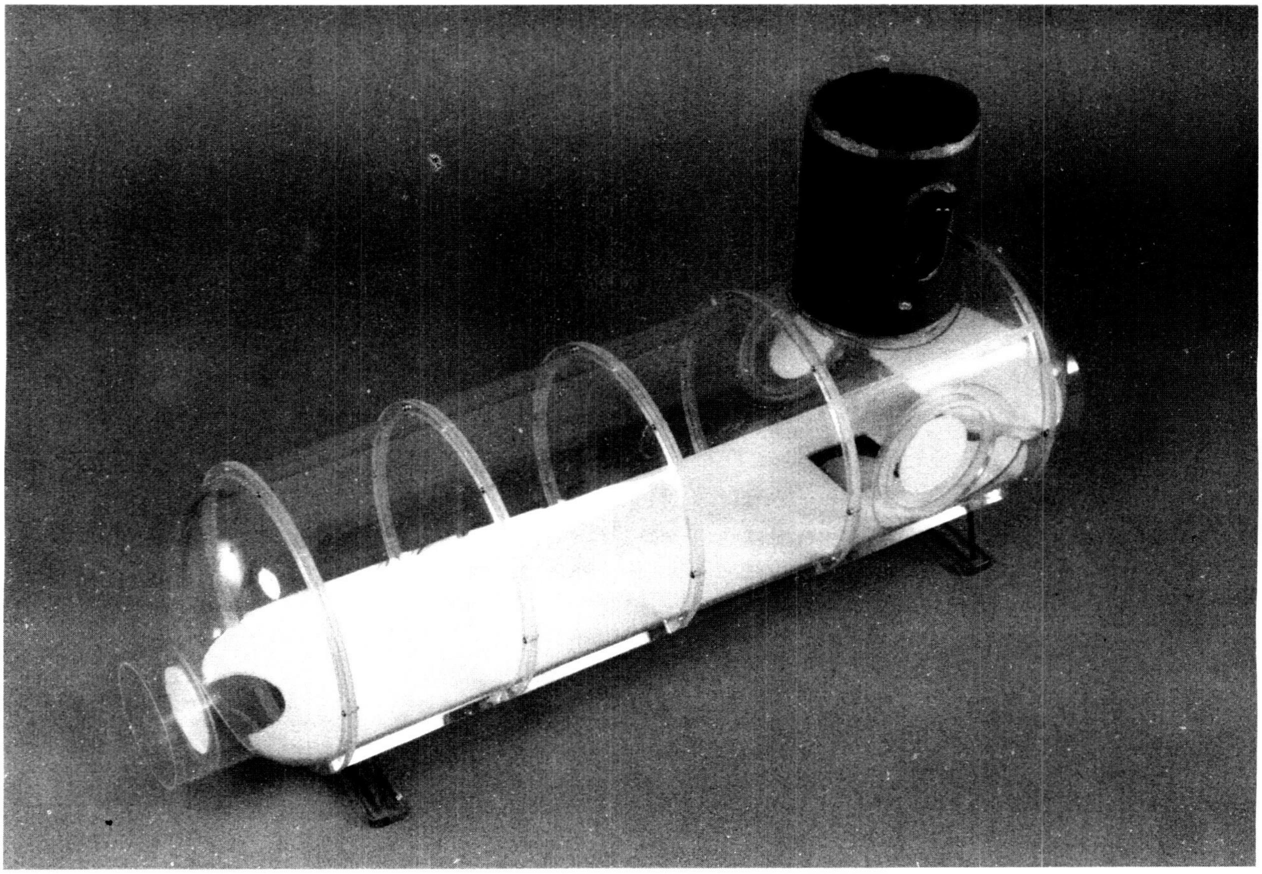


Figure 45.- External airlock concept model attached to outside of common module model.

EVA ACCESS FACILITY

VOLUMETRIC EFFICIENCY RATIO

(SUITED CREW VOLUME = 0.22 m^3 (8.0 ft^3), FOR ONE CREW MEMBER)

$$V.E.R. = \frac{\text{SUITED CREW VOLUME}}{\text{PUMP-DOWN VOLUME}}$$

	AIRLOCK OPTION	PUMP DOWN, m^3 (ft^3)	V.E.R.
A	STS-TYPE AIRLOCK	3.63 (129)	.062
A'	STS EXISTING AIRLOCK	2.59 (92)	.087
B	TRANSIT AIRLOCK	1.86 (66)	.120
C	SUITPORT WITH PLSS SEAL	.014 (0.5)	16.0
C'	SUITPORT NO PLSS SEAL	2.28 (81)	.098
D	CREWLOCK WITH VOID FILLER	.056 (2.0)	4.00
D'	CREWLOCK NO VOID FILLER	1.49 (53)	.150

Figure 46.- Table of volumetric efficiency ratios (VER) for seven EVA access facility configuration options.

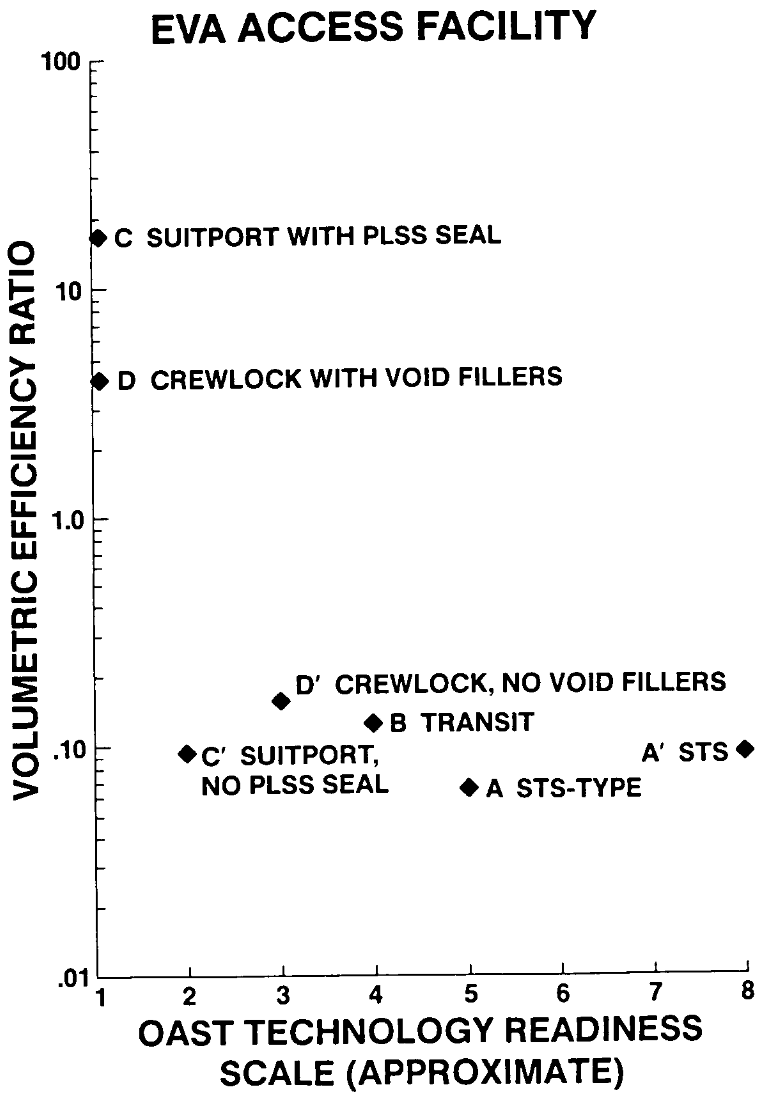


Figure 47.- Table of volumetric efficiency ratios vs. OAST technology readiness scale.

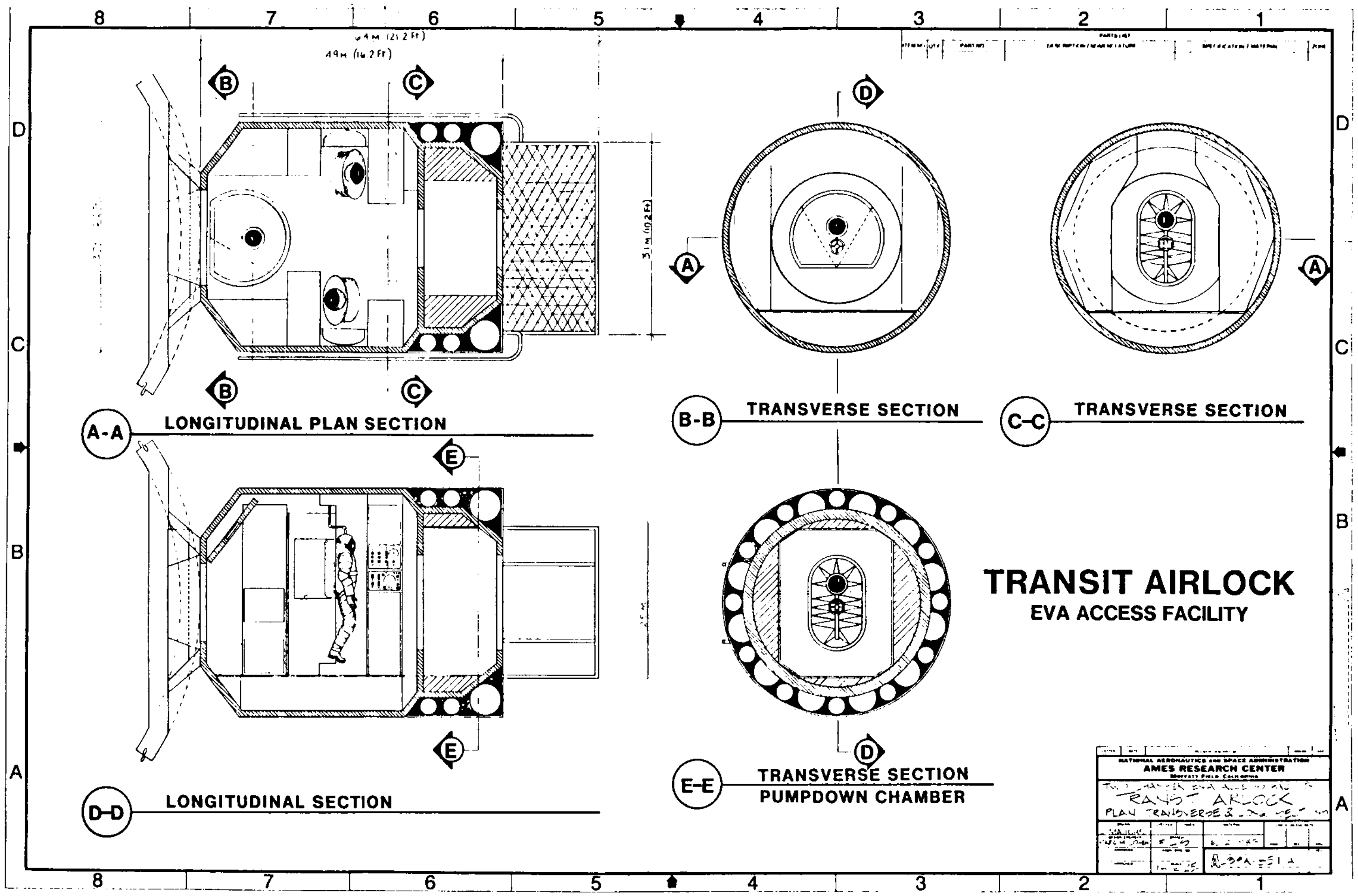


Figure 48.- Concept detail of transit airlock EVA access facility option, external unit, with internal views.

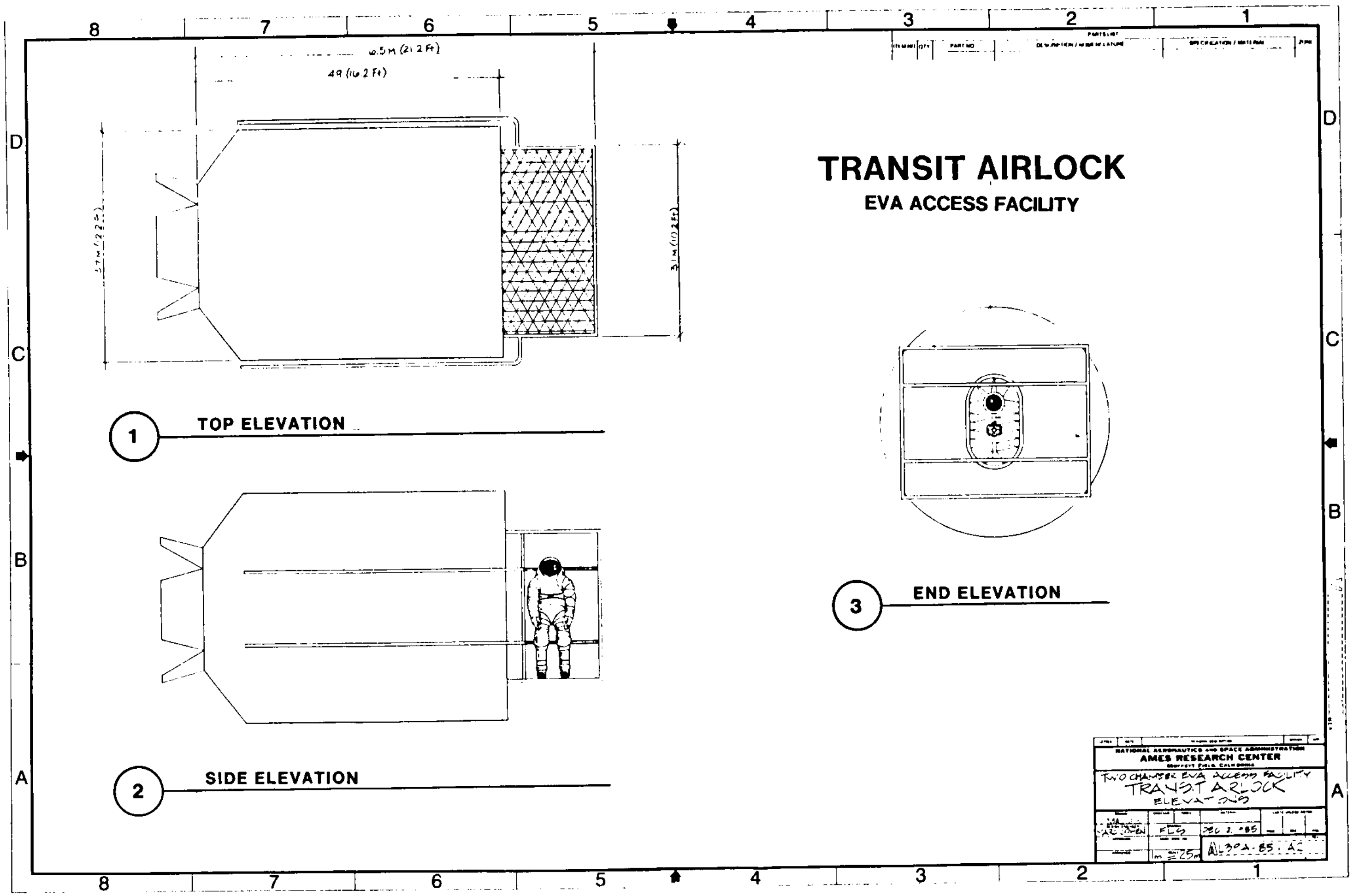


Figure 49.- Concept detail for transit airlock EVA access facility, external unit, external views showing "front porch" at airlock hatch.

ORIGINAL PAGE IS
OF POOR QUALITY

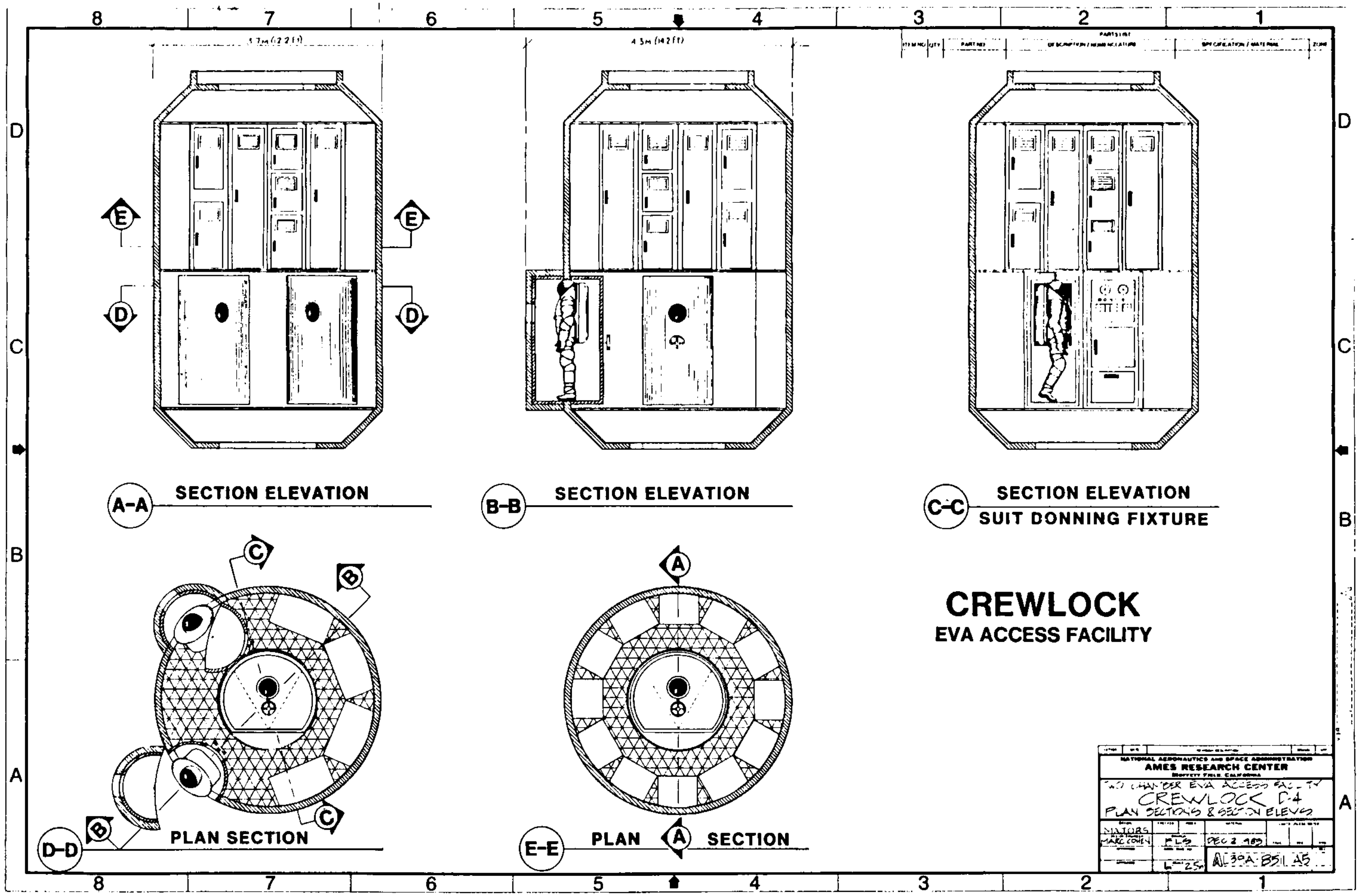


Figure 50.- Concept detail of crewlock EVA access facility, internal section views.

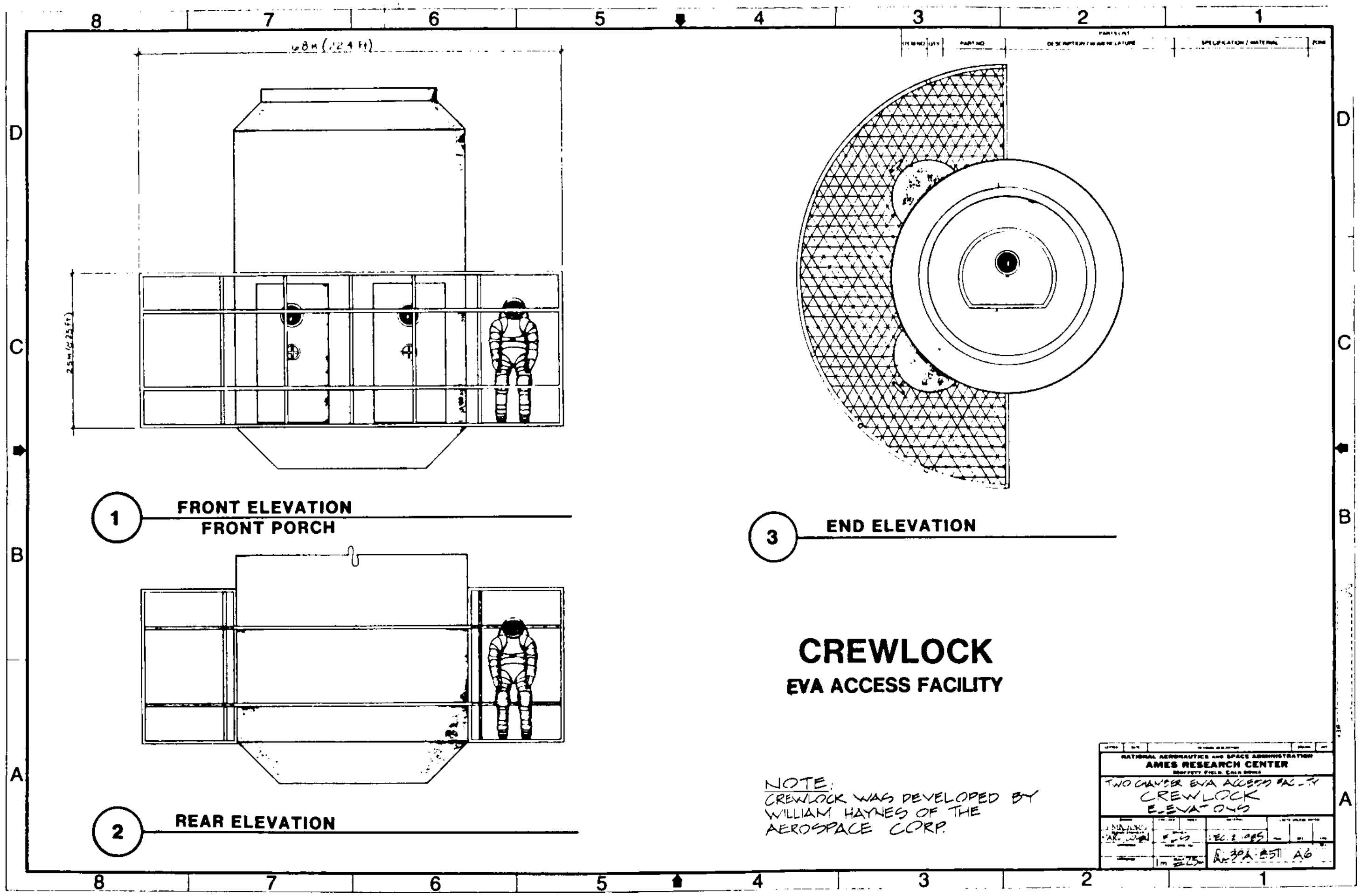


Figure 51.- Crewlock EVA access facility, concept detail showing "front porch" in external views.

ORIGINAL PAGE IS
OF POOR QUALITY

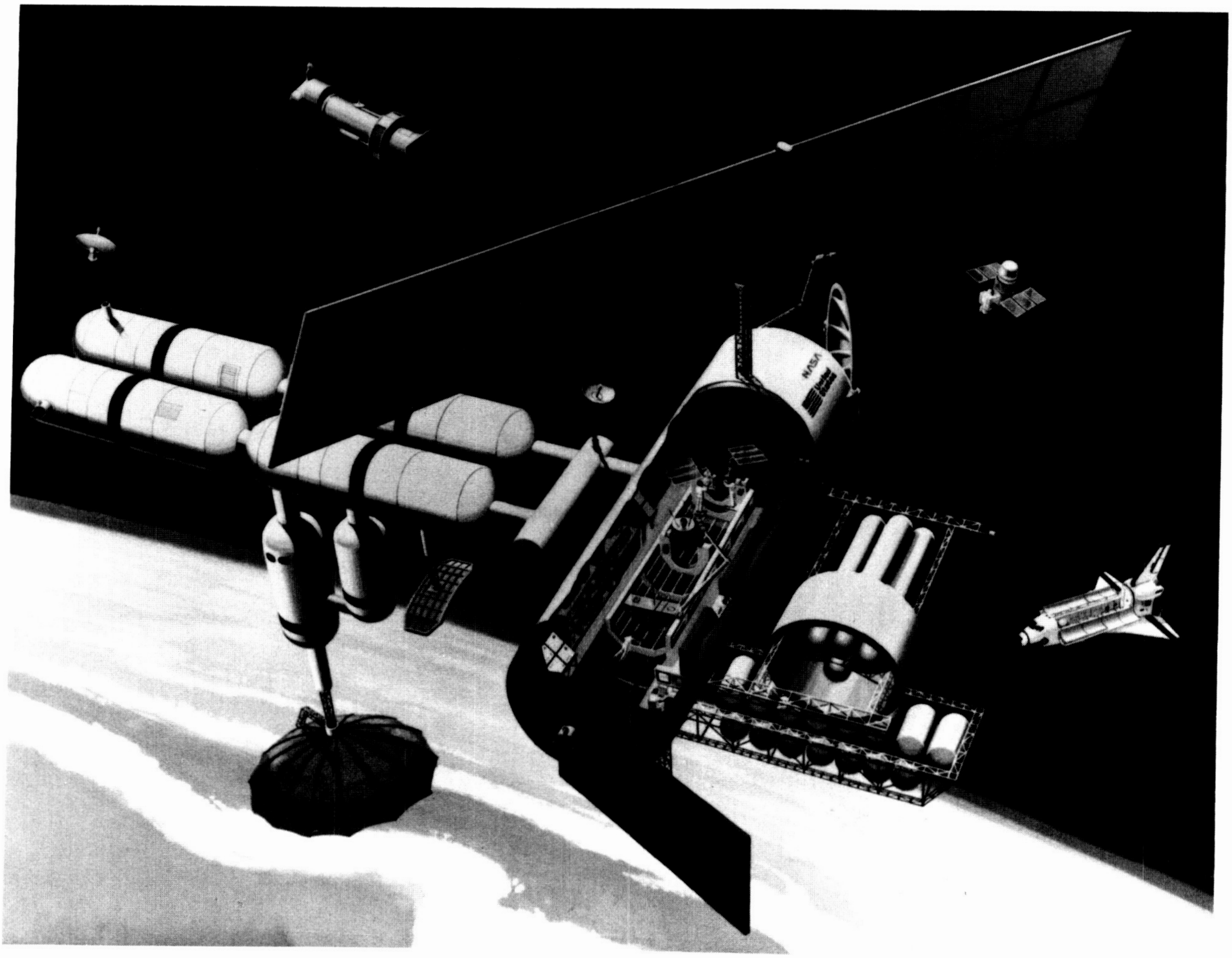


Figure 52.- GSFC concept of post-IOC Space Station as a busy servicing center.

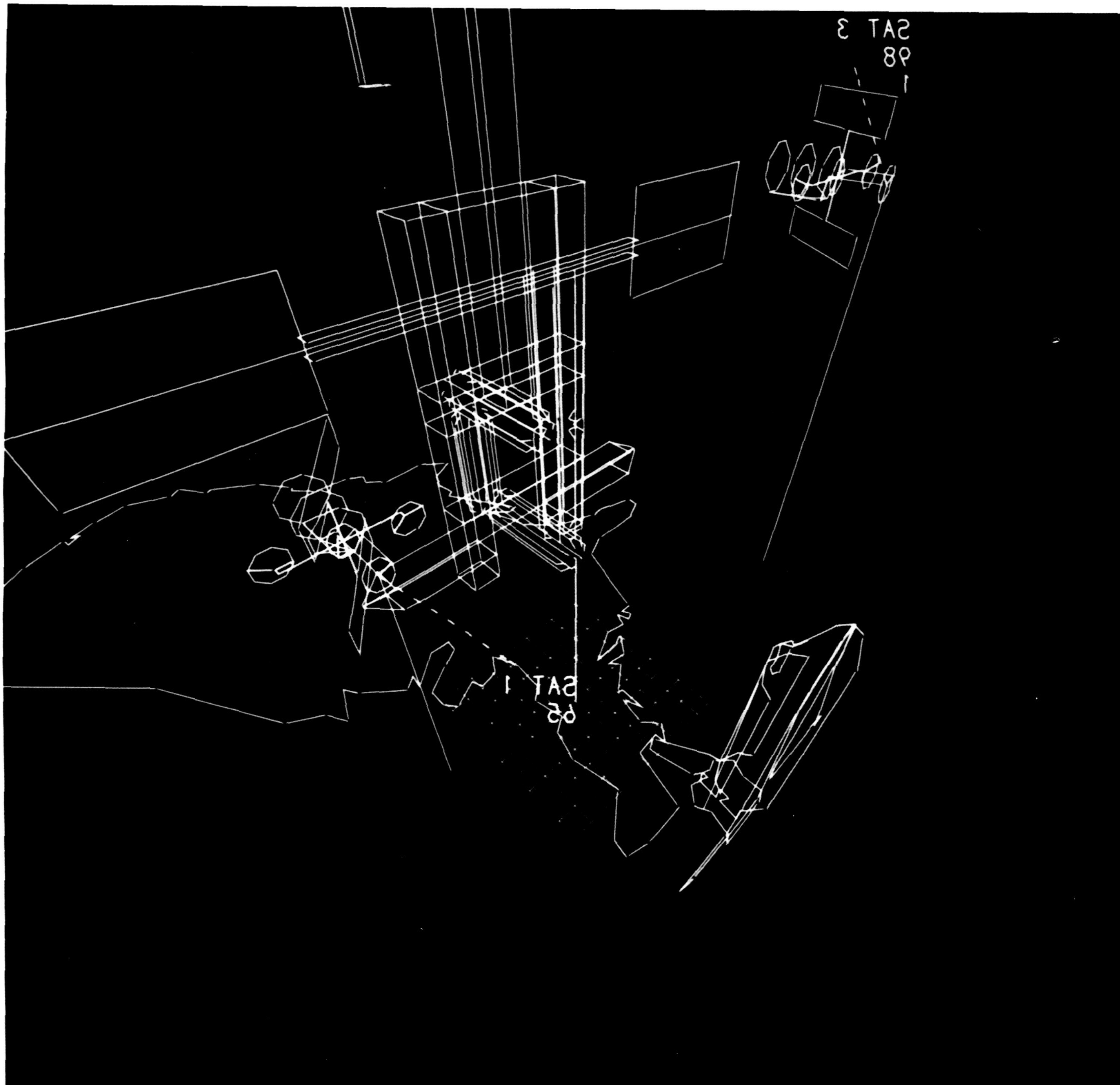


Figure 53.- Ellis and McGreevy's 3-D perspective orbital traffic control display, showing vertical altitude measuring lines.

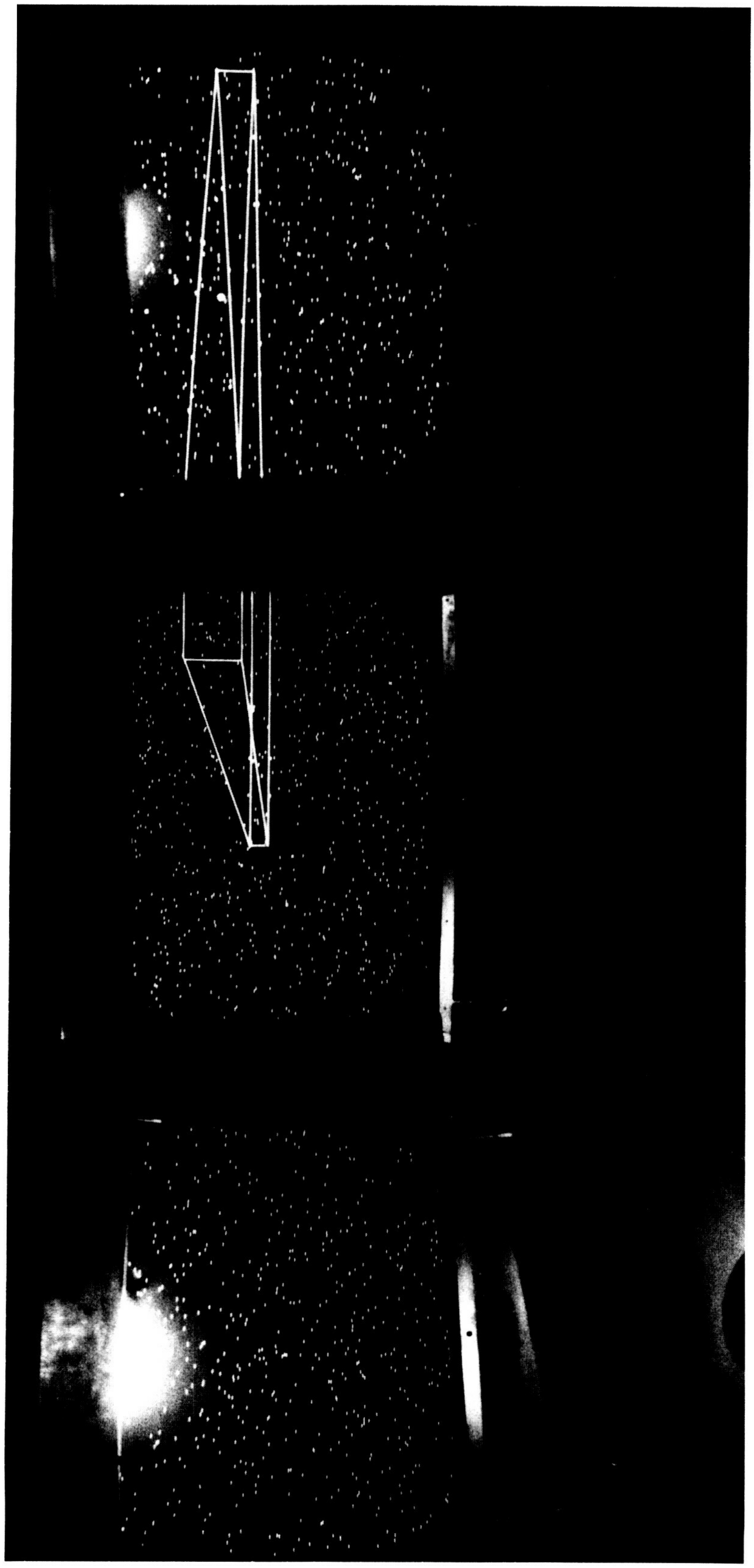


Figure 54.- Three-screen computer graphics simulator in Richard Haine's laboratory.

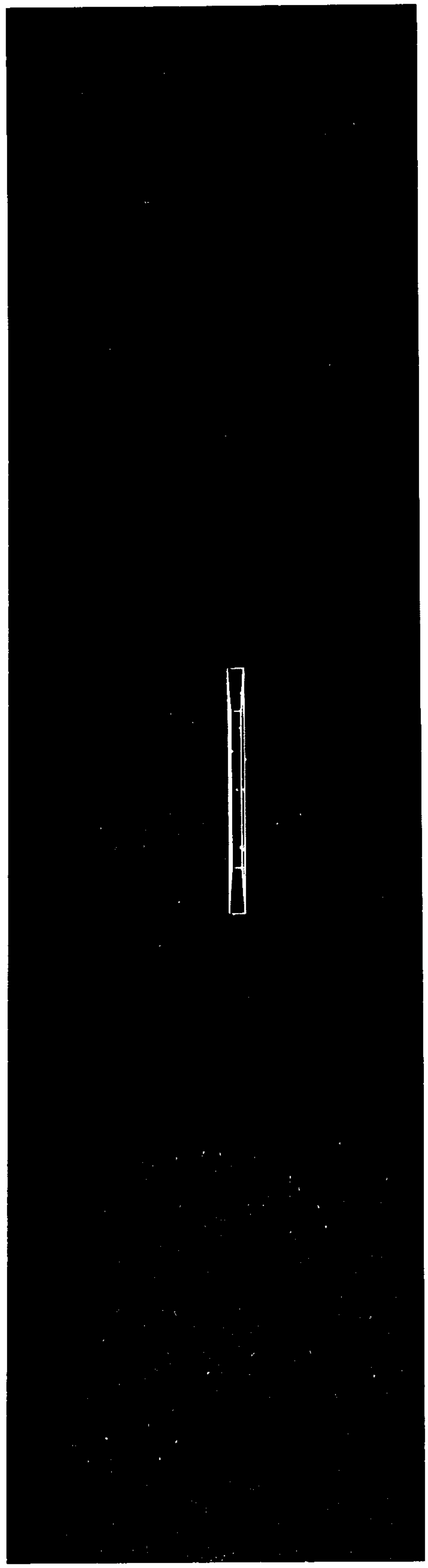


Figure 55.- Space platform approach sequence.

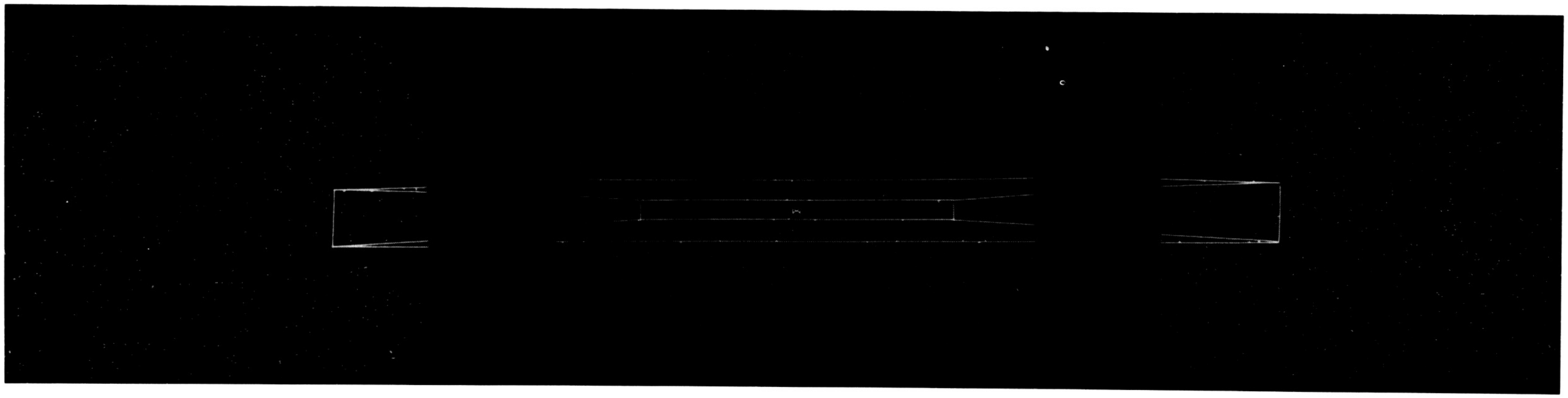


Figure 56.- Space platform approach sequence.

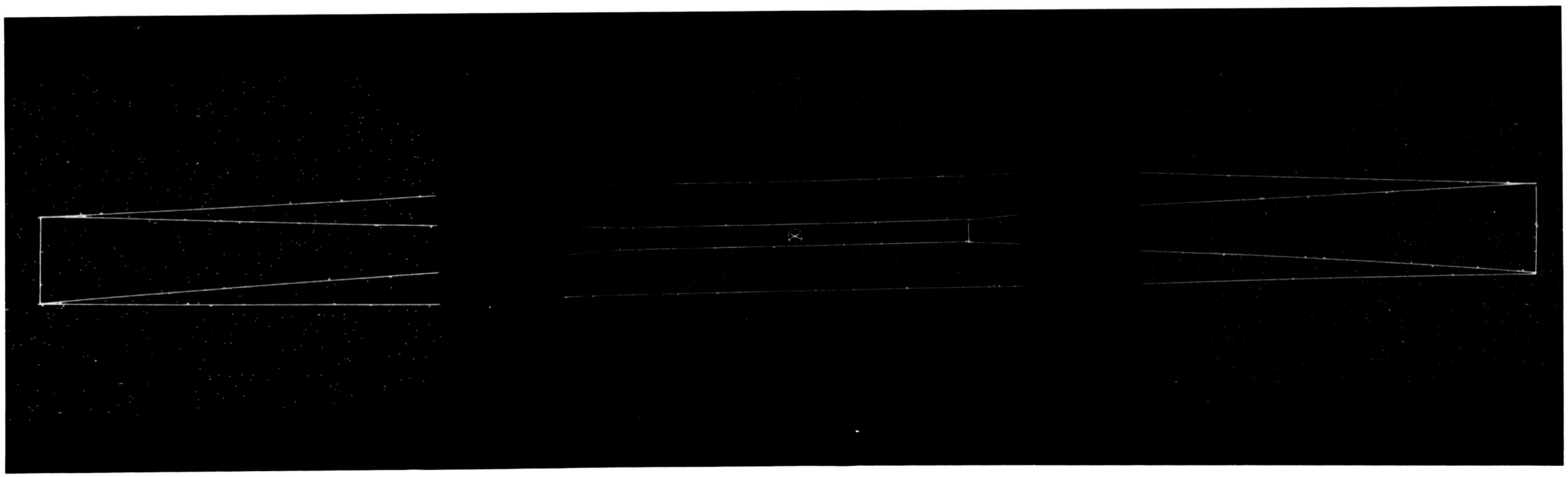


Figure 57.- Space platform approach sequence.

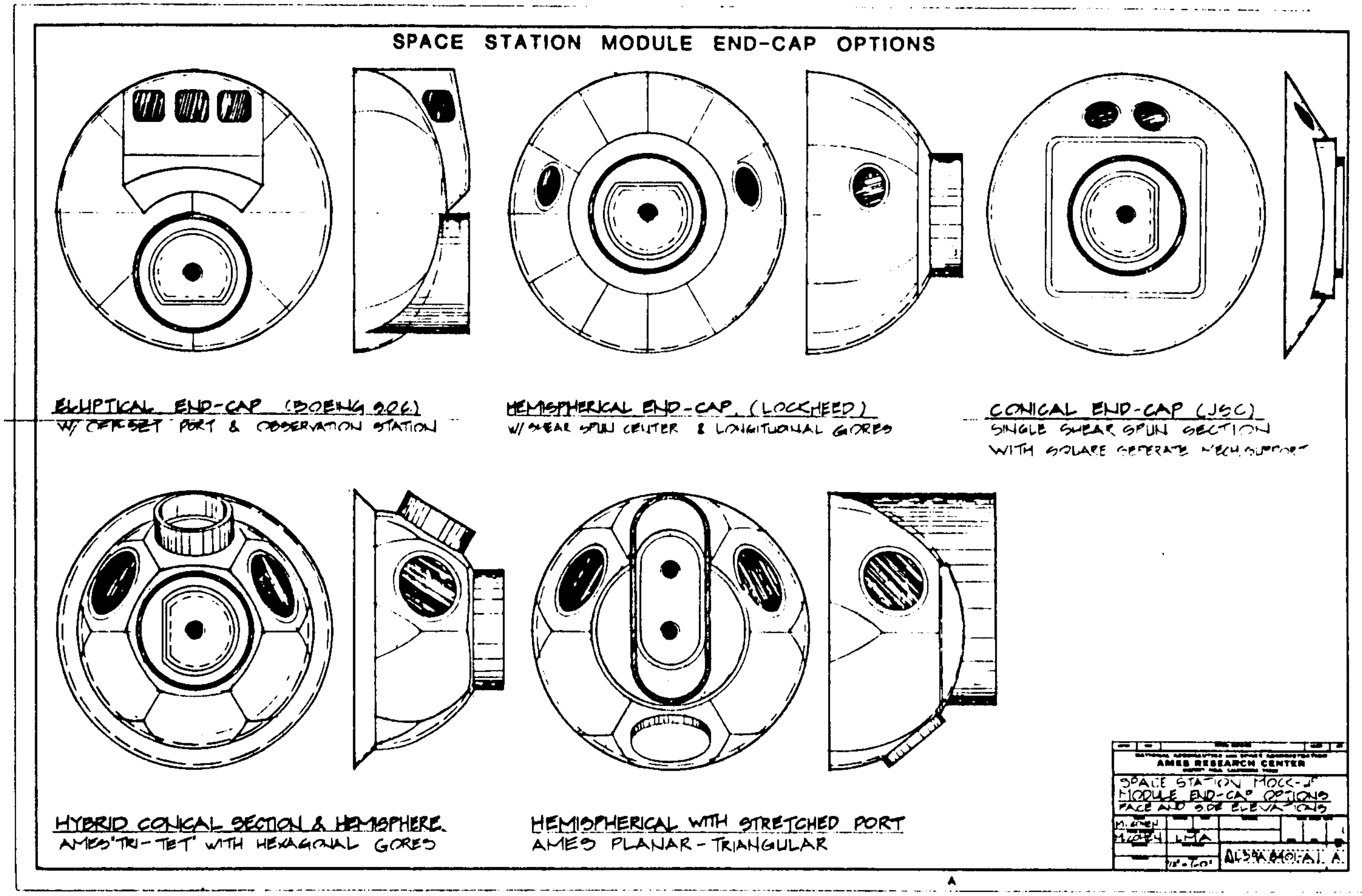


Figure 58.- Space Station windows in module end cap options.

SPACE STATION WINDOW/CONFIGURATION MATRIX ANALYSIS TAXONOMY

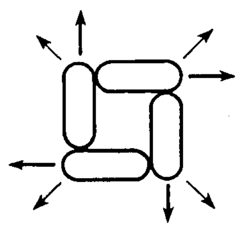
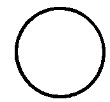
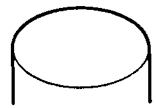
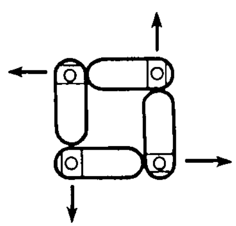
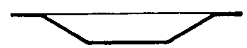
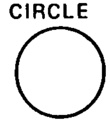
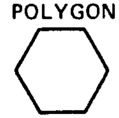
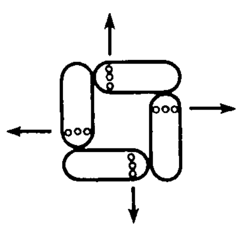
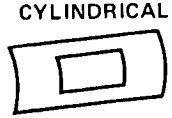
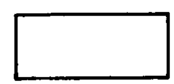
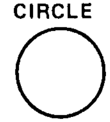
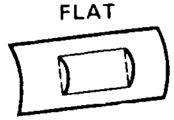
LOCATION/ VIEW ANGLES	FENESTRATION SURFACE	VIEW ORIENTATION	WINDOW SHAPE (IN ORDER OF STRUCTURAL PREFERENCE)	MAXIMUM WINDOW SIZE (APPROX.)
END CAP 	CONICAL 	AXIAL ON DOCKING VECTOR	1. TRAPEZOID  2. CIRCULAR 	20"
	ELLIPSOIDAL 	AXIAL ON DOCKING VECTOR AND MULTIPLE DIRECTION		
RADIAL PORT 	FLAT 	SINGLE DIRECTION OFF-AXIS ON DOCKING VECTOR	1. CIRCLE  2. POLYGON 	48" (FITS IN 50" HATCH FRAME)
	BUBBLE 			
CYLINDRICAL SIDE 	CYLINDRICAL 	RANDOM MULTIPLE DIRECTION	1. RECTANGLE  2. CIRCLE 	20" x 28"
	FLAT 			

Figure 59.- Space Station window configuration matrix analysis table.

WINDOW LOCATION EVALUATION

LOCATIONS	ADVANTAGES	DISADVANTAGES	REMARKS
END CAP	1. PROVIDES AXIAL, VELOCITY VECTOR DOCKING VIEWS 2. CAN ADAPT TO ALL VIEWING TASKS WITH SINGLE SHELL GEOMETRY 3. CAN SERVE AS VIEWING LOUNGE 4. OUT OF TRAFFIC FLOW	1. CANNOT BE ADJACENT TO WARDROOM 2. POTENTIAL CONFLICT WITH EXTERNAL TANKAGE AND INTERNAL HATCH STORAGE 3. SMALLEST WINDOWS (20")	1. BEST USE OF END CAP VOLUME
RADIAL PORT	1. LARGEST WINDOW POSSIBLE (48") 2. LEAST SPECIAL STRUCTURE REQUIRED 3. SUITABLE FOR TEMPORARY GROUP VIEWING	1. LOCATED IN MAJOR CIRCULATION ZONE 2. NOT APPROPRIATE FOR TASKS THAT USE DELICATE EQUIPMENT 3. CLOSE BUT CANNOT BE PART OF WARDROOM	1. THE LARGER WINDOW SIZE DOES NOT HAVE A PRACTICAL PURPOSE WHERE LOCATED
CYLINDRICAL SIDE	1. WELL SUITED FOR PRIVATE CABINS 2. MOST FLEXIBLE CHOICE OF LOCATIONS	1. NOT SUITABLE FOR MOST WORK STATIONS REQUIRING PRECISION POINTING 2. MOST ADDITIONAL STRUCTURE 3. WINDOW PLACEMENT MAY CONFLICT WITH WALL SPACE FOR RACKS AND OTHER EQUIPMENT	1. SYSTEMATICALLY PLACED WINDOW RING IS POSSIBLE IN COMMON MODULE, BUT SOME WINDOWS MIGHT BE WASTED IN LAB OUTFITTING

Figure 60.- Space Station window location evaluation table.

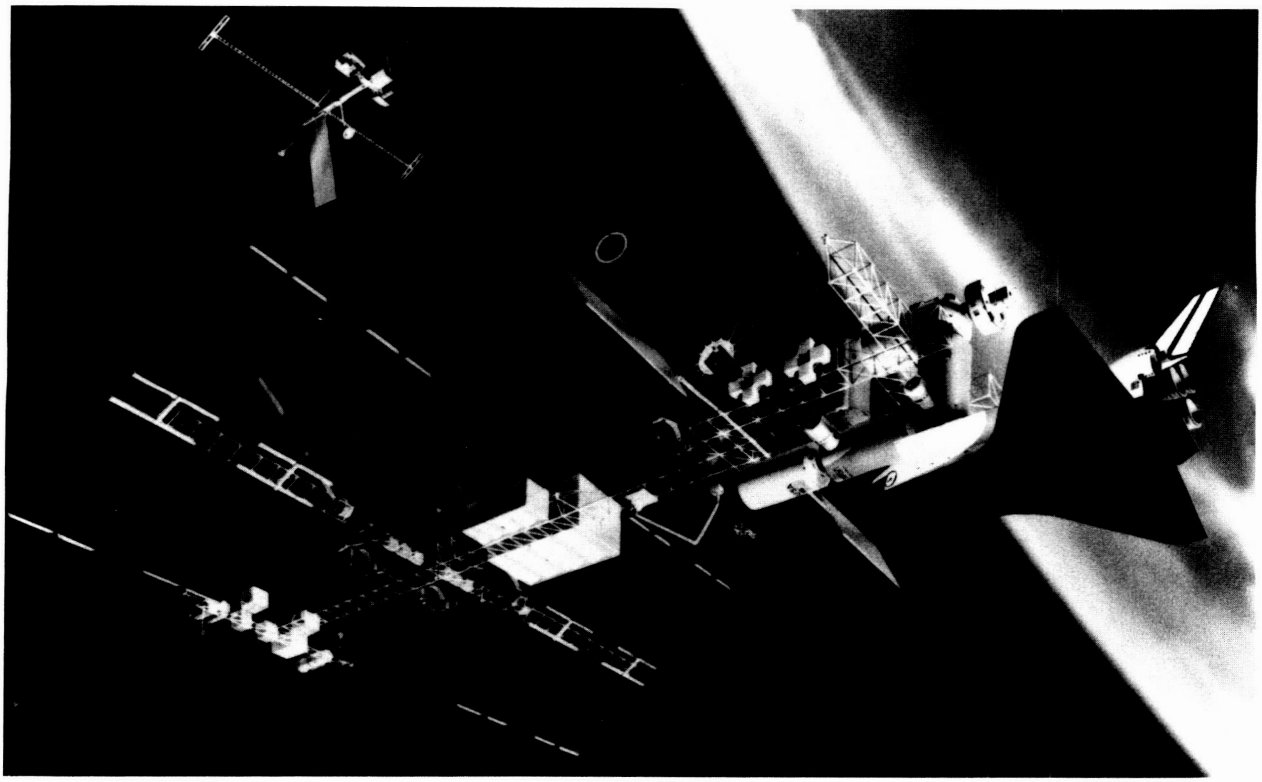


Figure 61.- Space Station reference configuration, December 1984.

ORIGINAL PAGE IS
OF POOR QUALITY

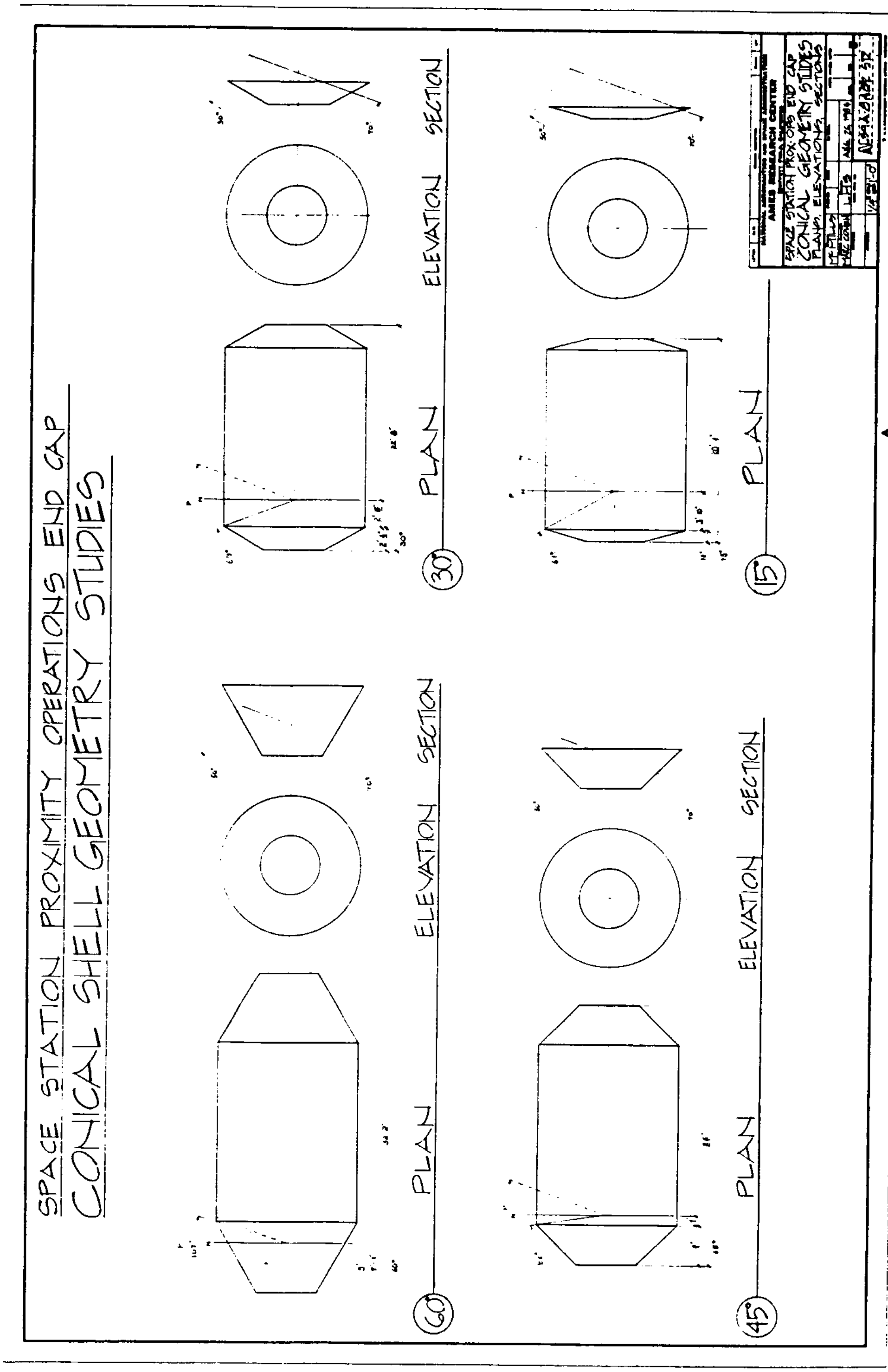


Figure 62.- Geometric analysis of frusto-conical end-cap options.

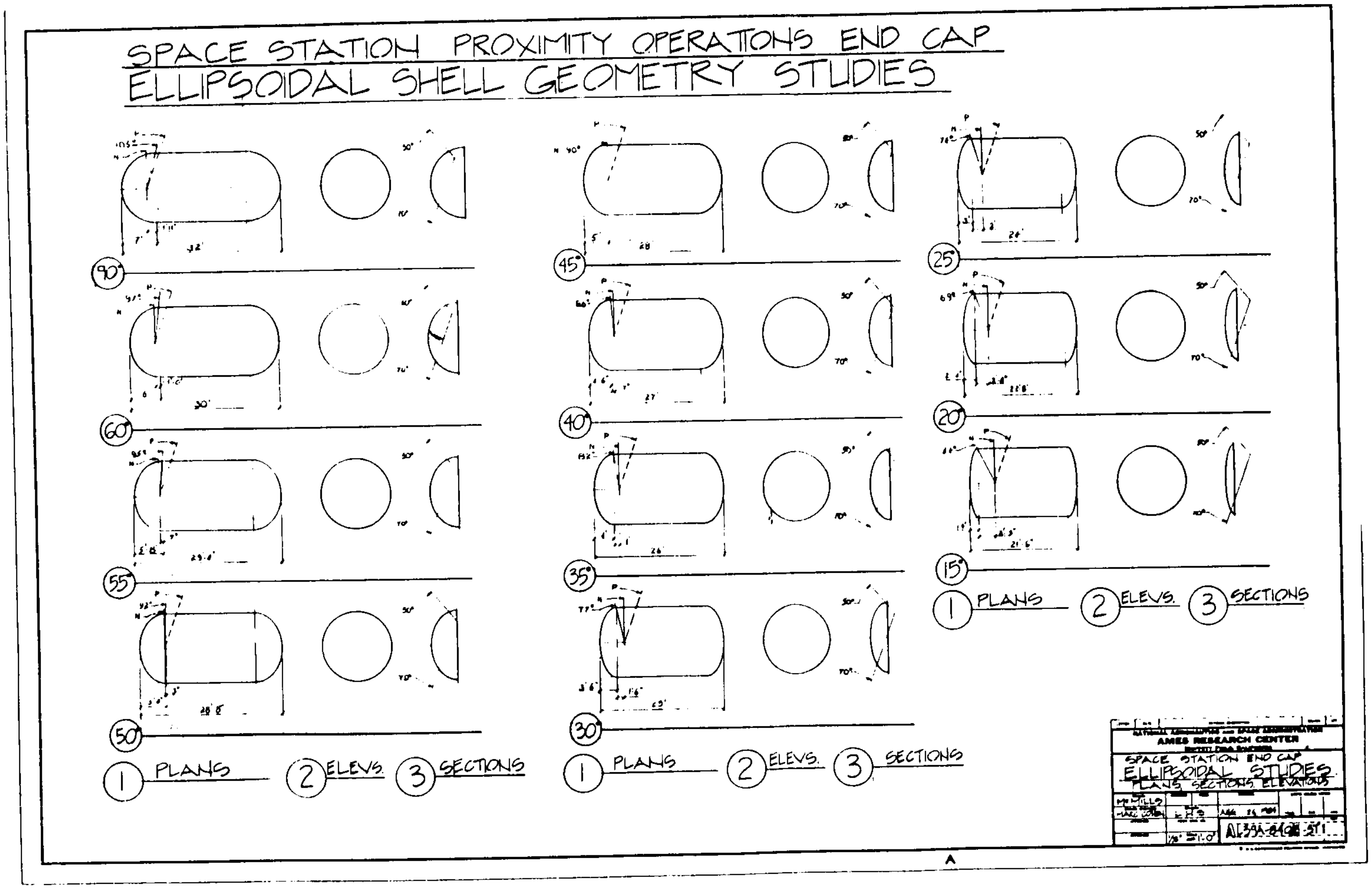


Figure 63.- Geometric analysis of ellipsoidal series end-cap options.

ORIGINAL PAGE IS
OF POOR QUALITY

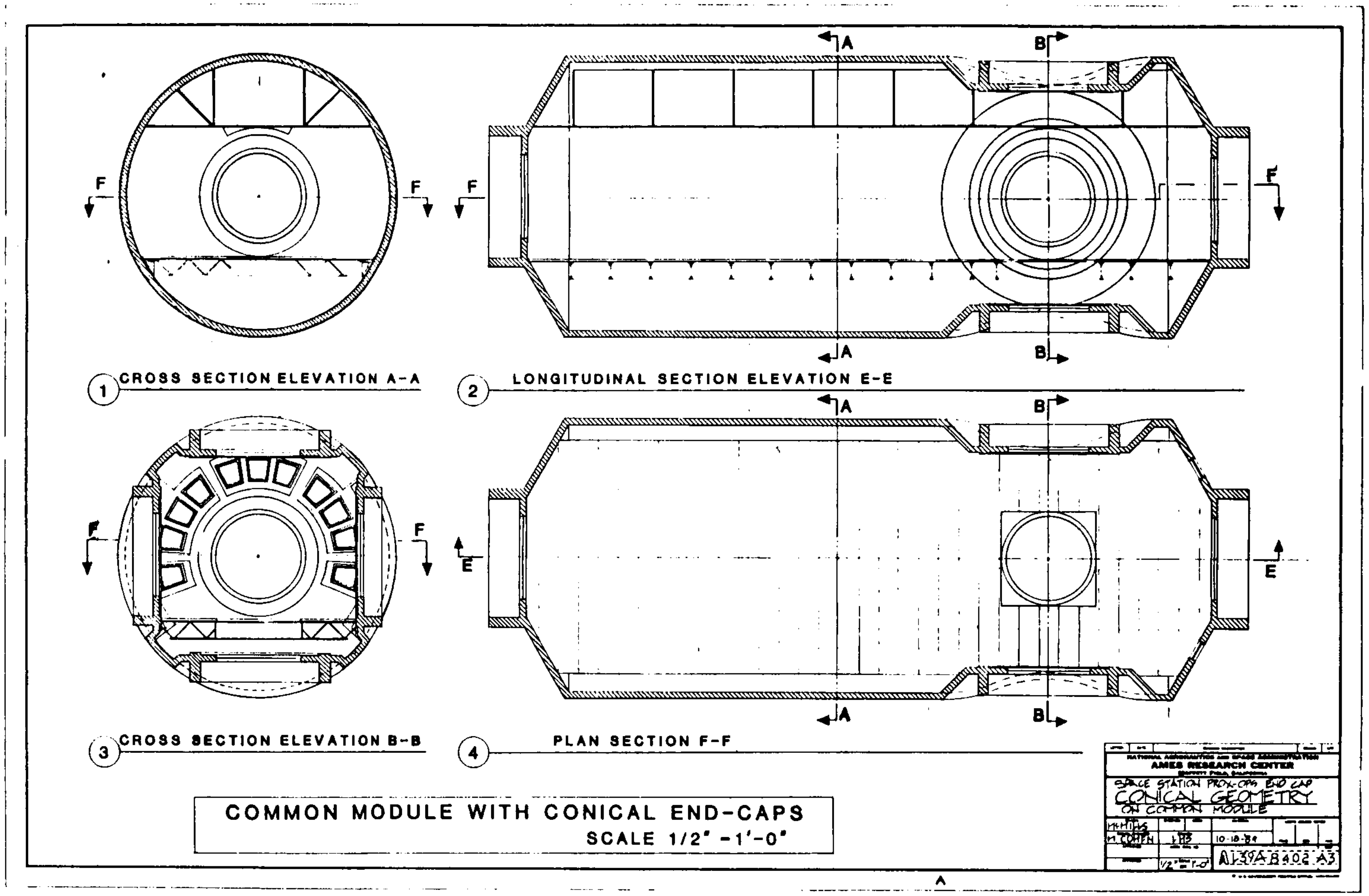


Figure 64.- Schematic of common module with conical end caps and 3-screen window design paradigm.

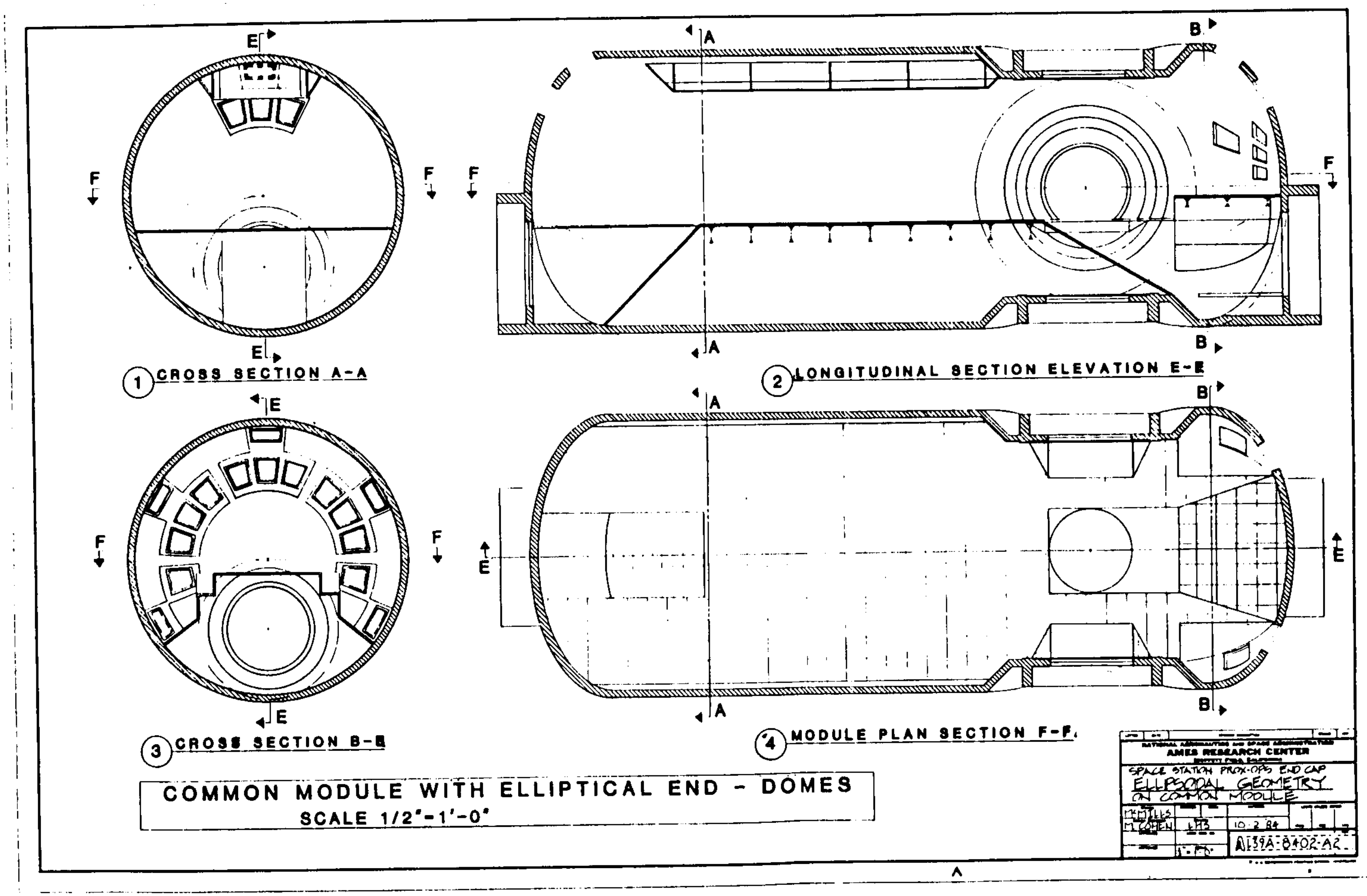


Figure 65.- Schematic of common module with ellipsoidal end caps and 3-screen window design paradigm.

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

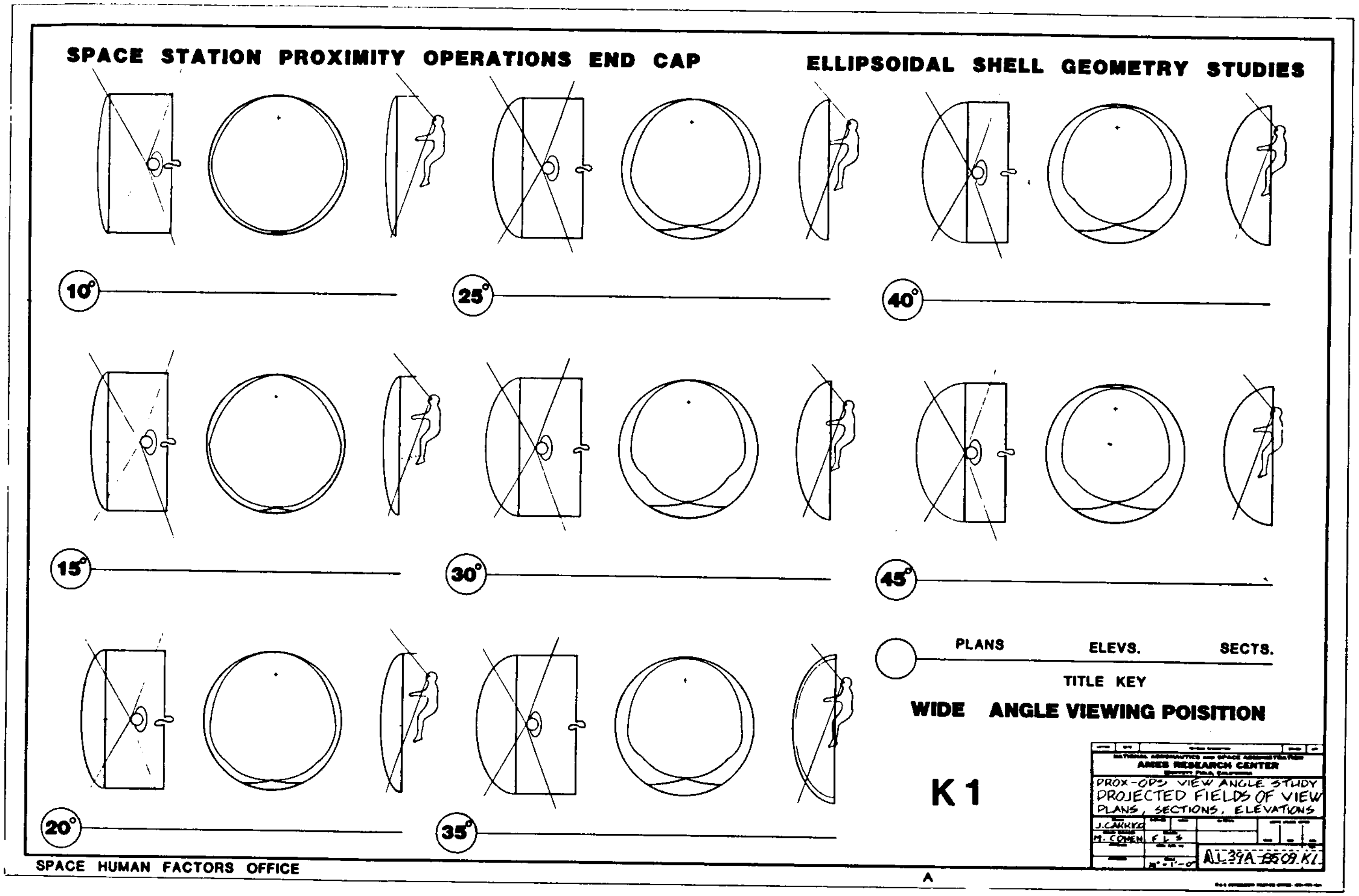


Figure 66.- Space Station prox-ops end cap ellipsoidal shell geometry studies Series K, with eye point 60" from shell inner surface, 10° to 45° projections.

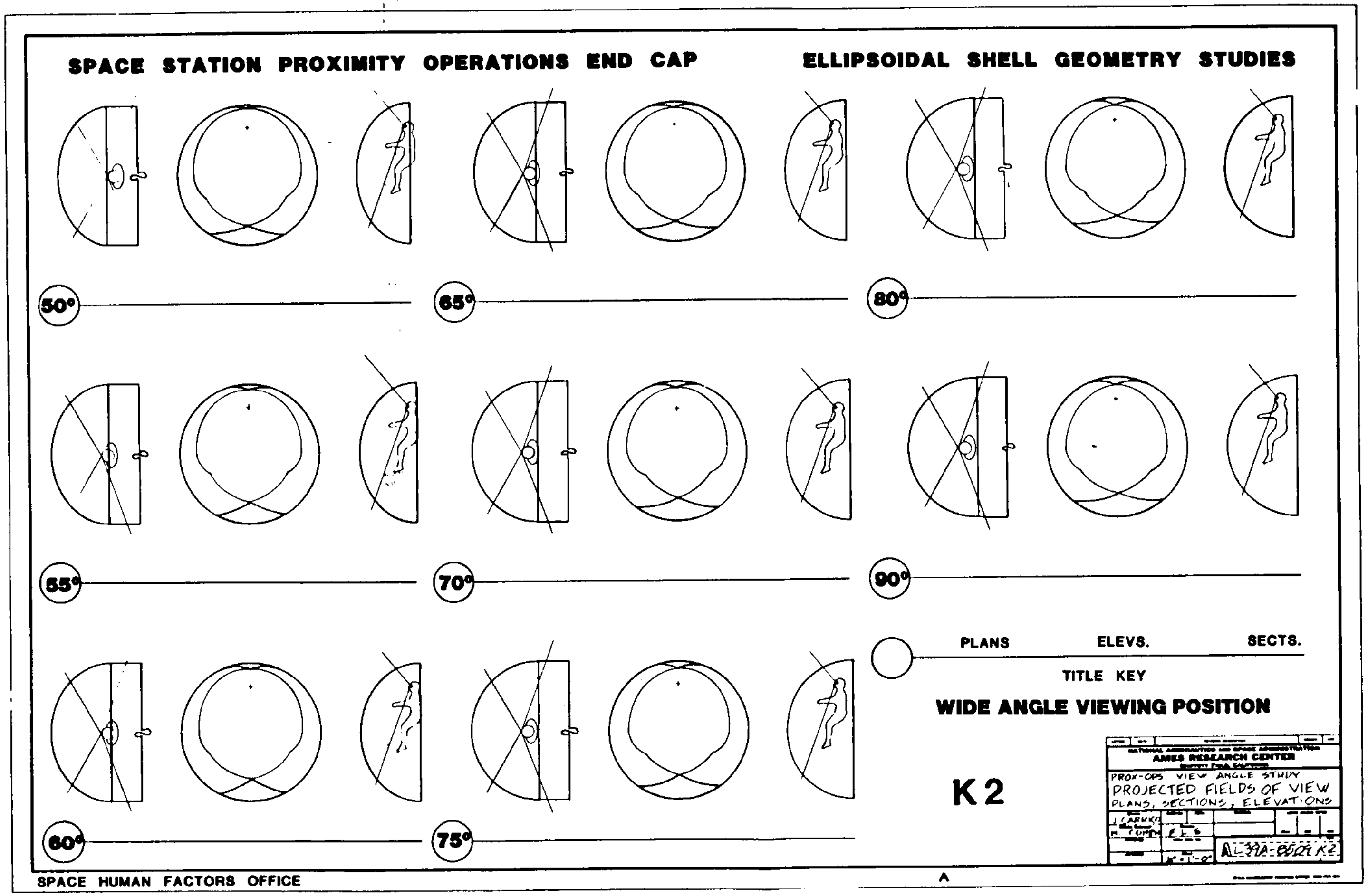


Figure 67.- Space Station prox-ops end cap ellipsoidal shell geometry studies, Series K, with eye point 60" from shell inner surface, 50° to 90° projections.

Figure 68.- Frusto-conical end cap mounted on radial port segment of common module.

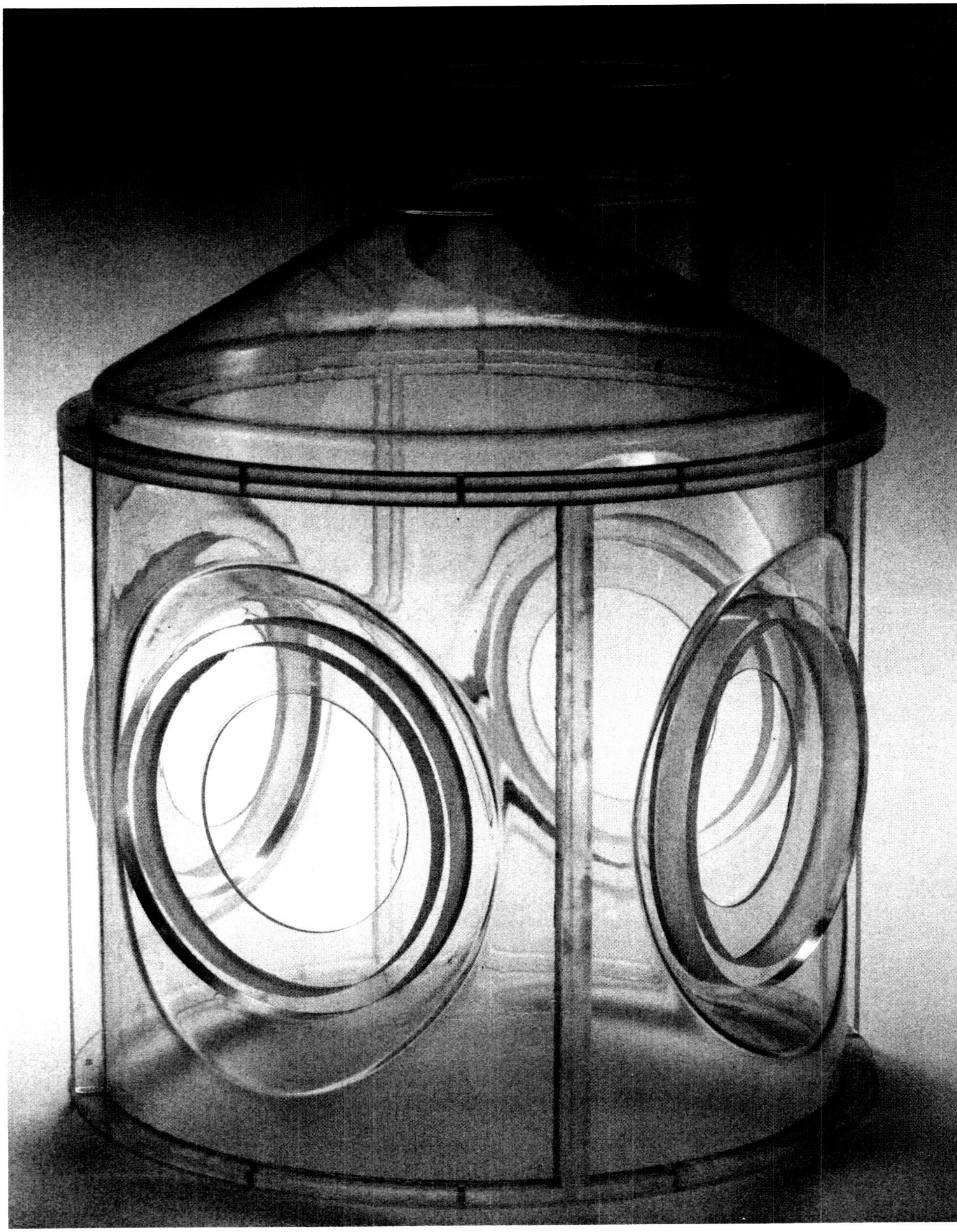


Figure 69.- Frusto-conical end cap with off-center port mounted on radial port segment.

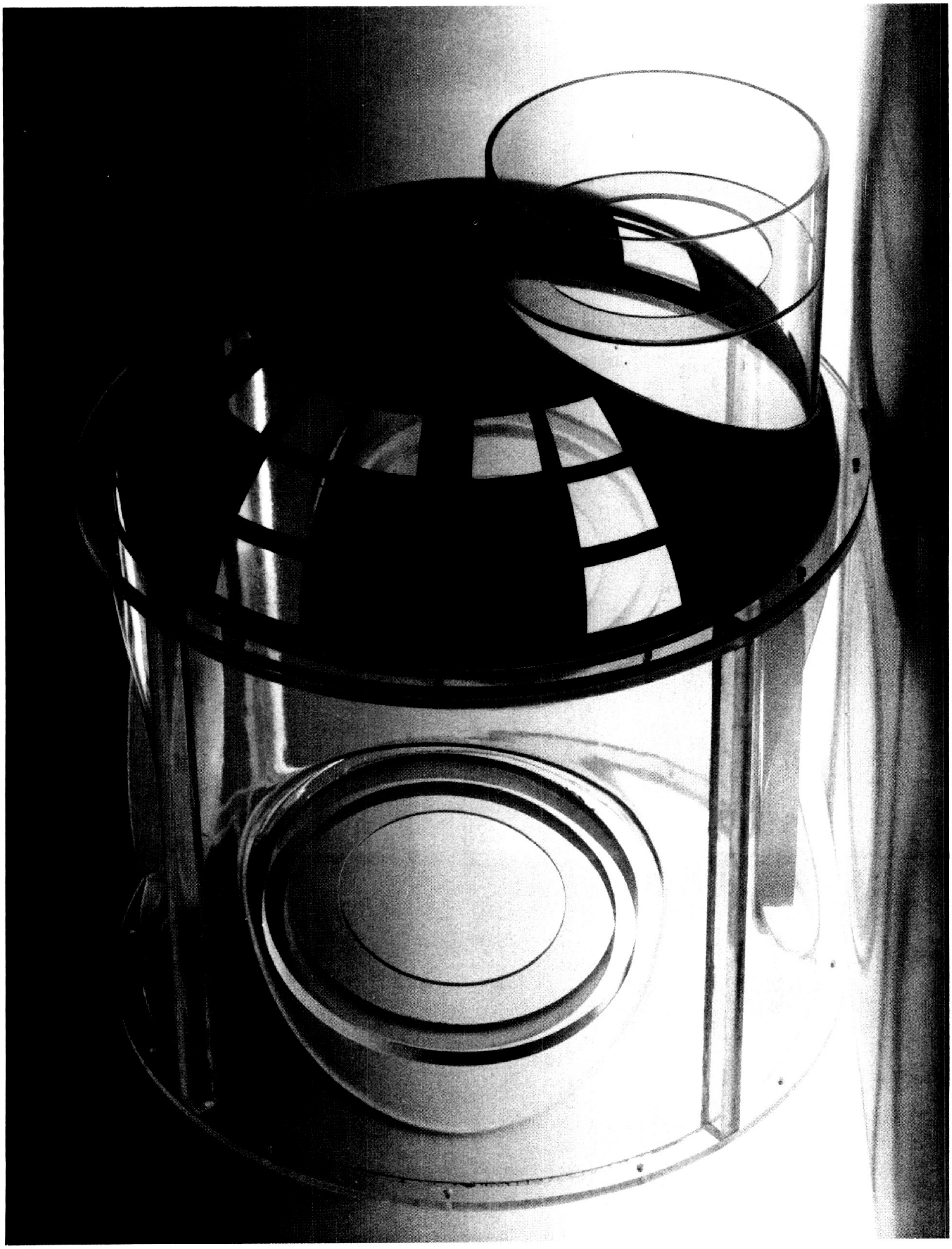


Figure 70.- Ellipsoidal end cap with window design paradigm for maximum wide-angle viewing.

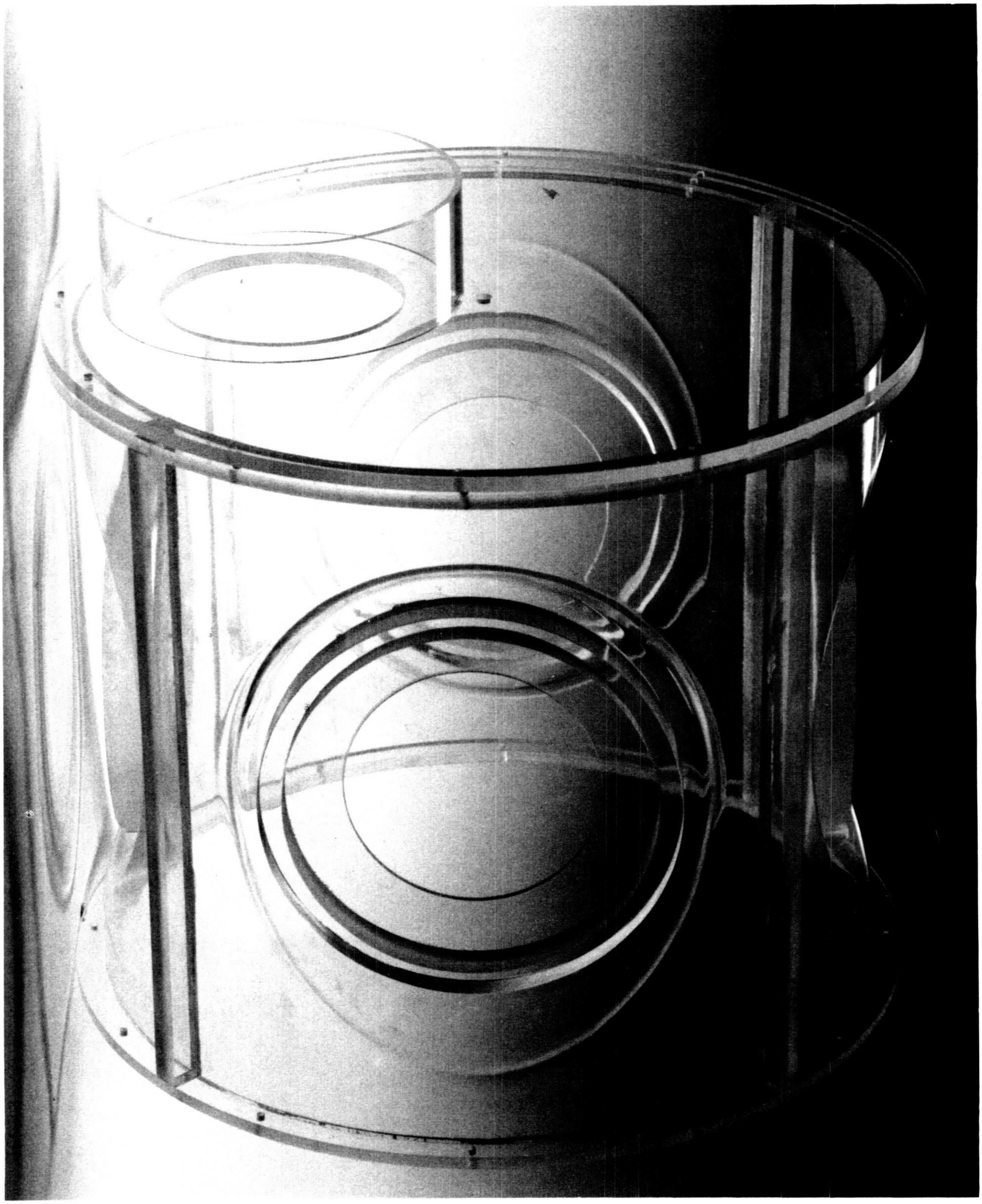


Figure 71.- Flat end cap proposed by Chas. Willets of Rockwell.

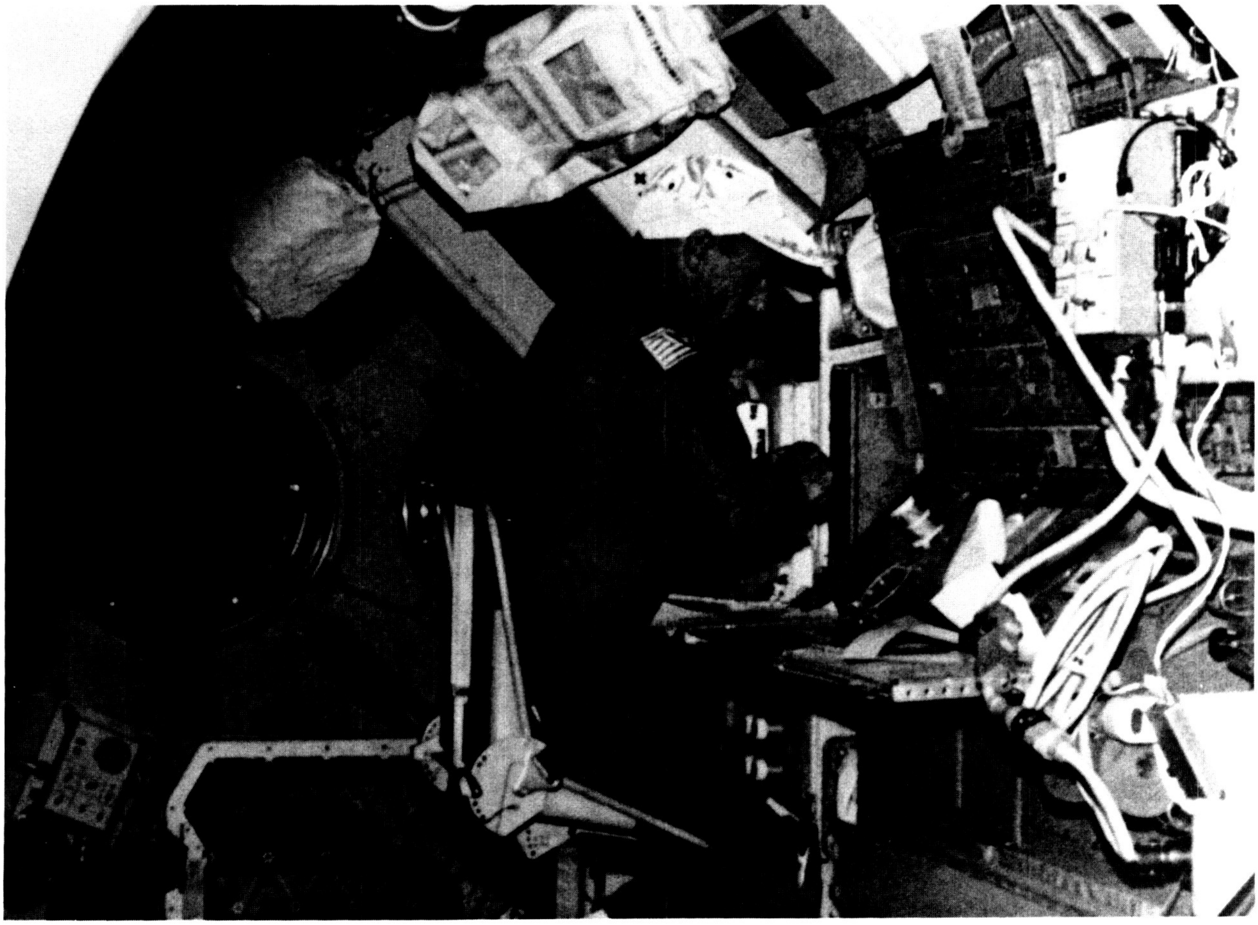


Figure 72.- View of Apollo telescope mount work station in the Sklylab "0-G" multiple docking adapter.

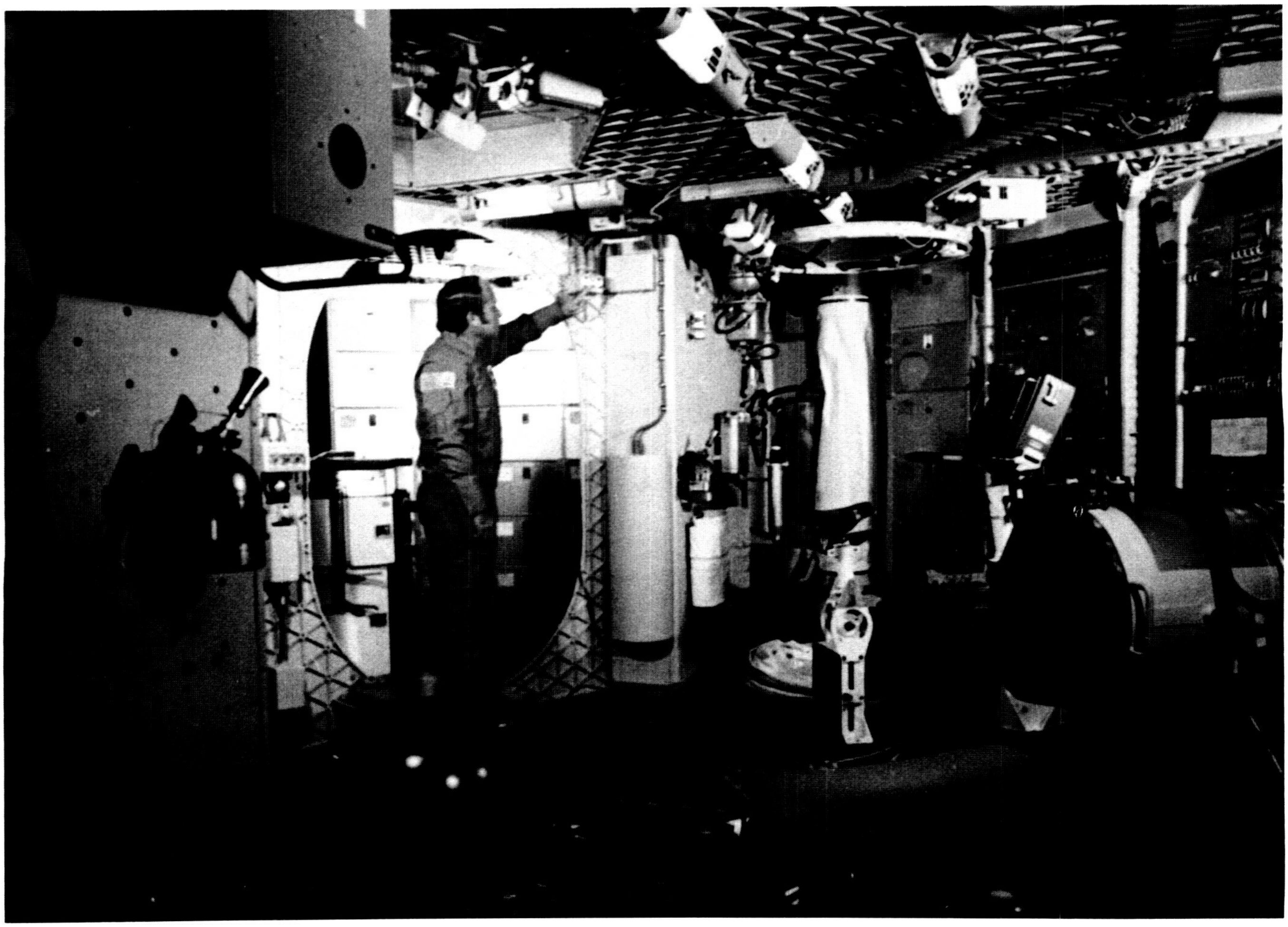


Figure 73.- View of crew quarters deck in the "1-G" Skylab Saturn workshop.

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 74.- Overhead view of Marshall Space Flight Center mockup of Skylab crew quarters deck.

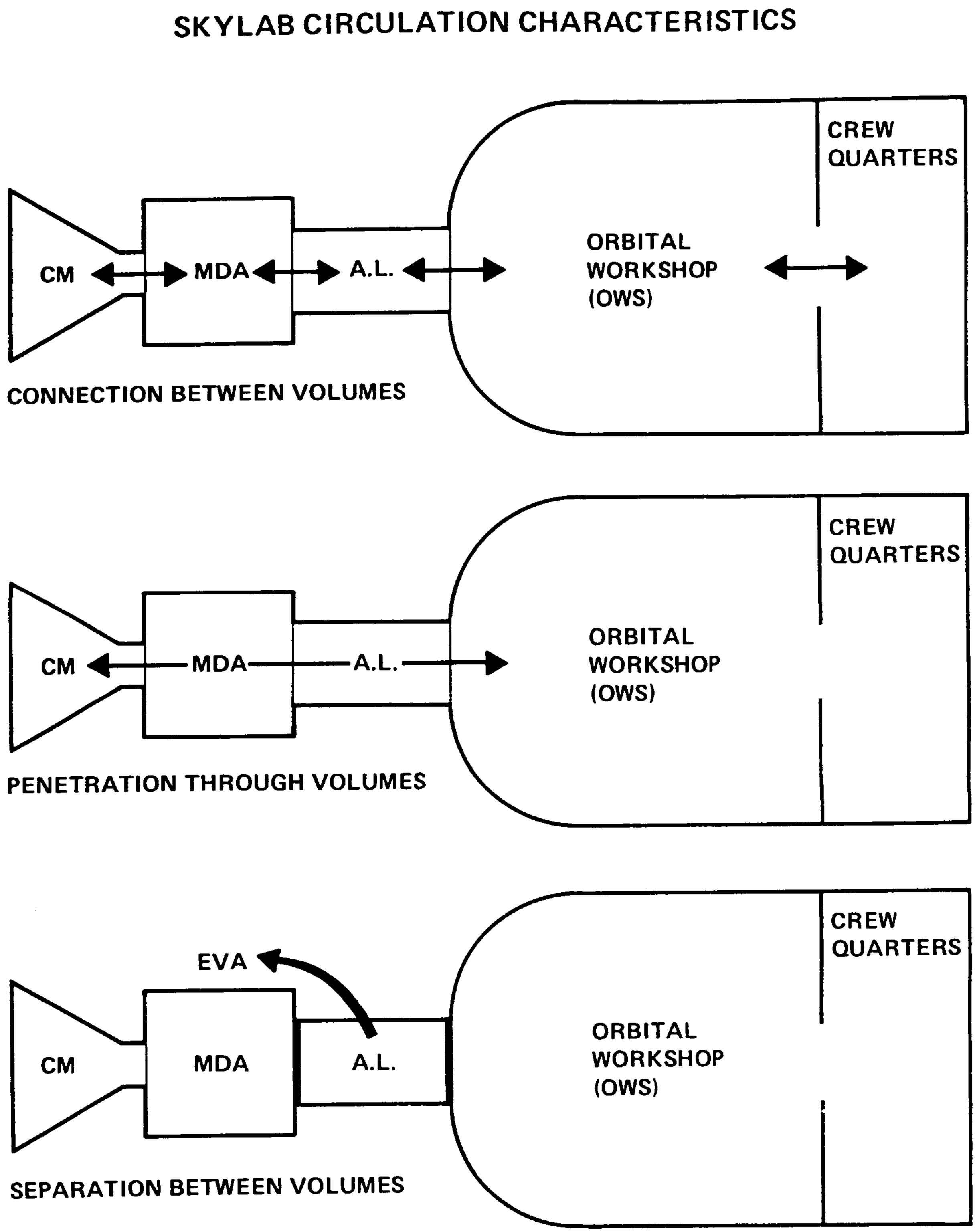


Figure 75.- Diagram of Skylab circulation characteristics.

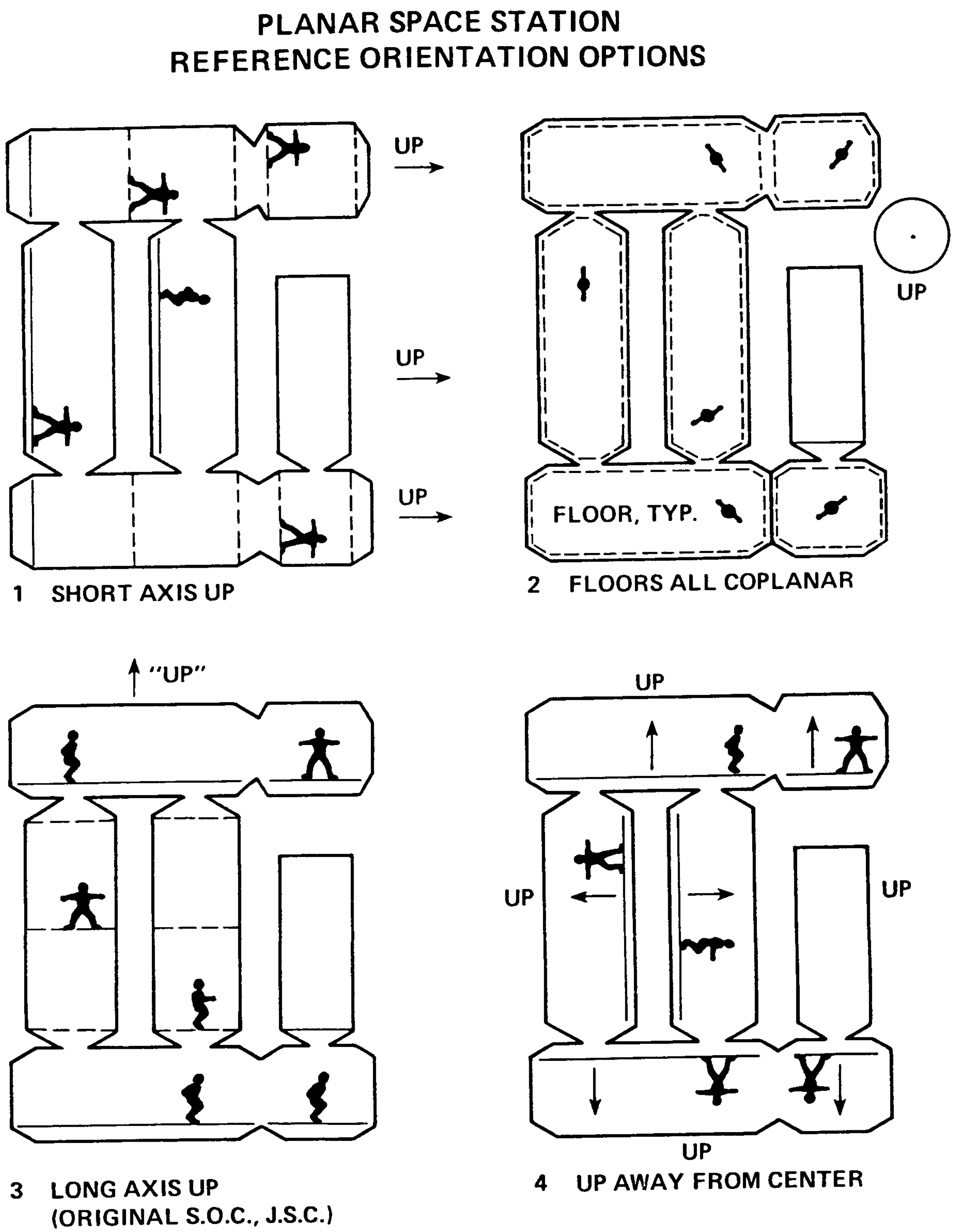


Figure 76.- Generic Space Station orientation options.

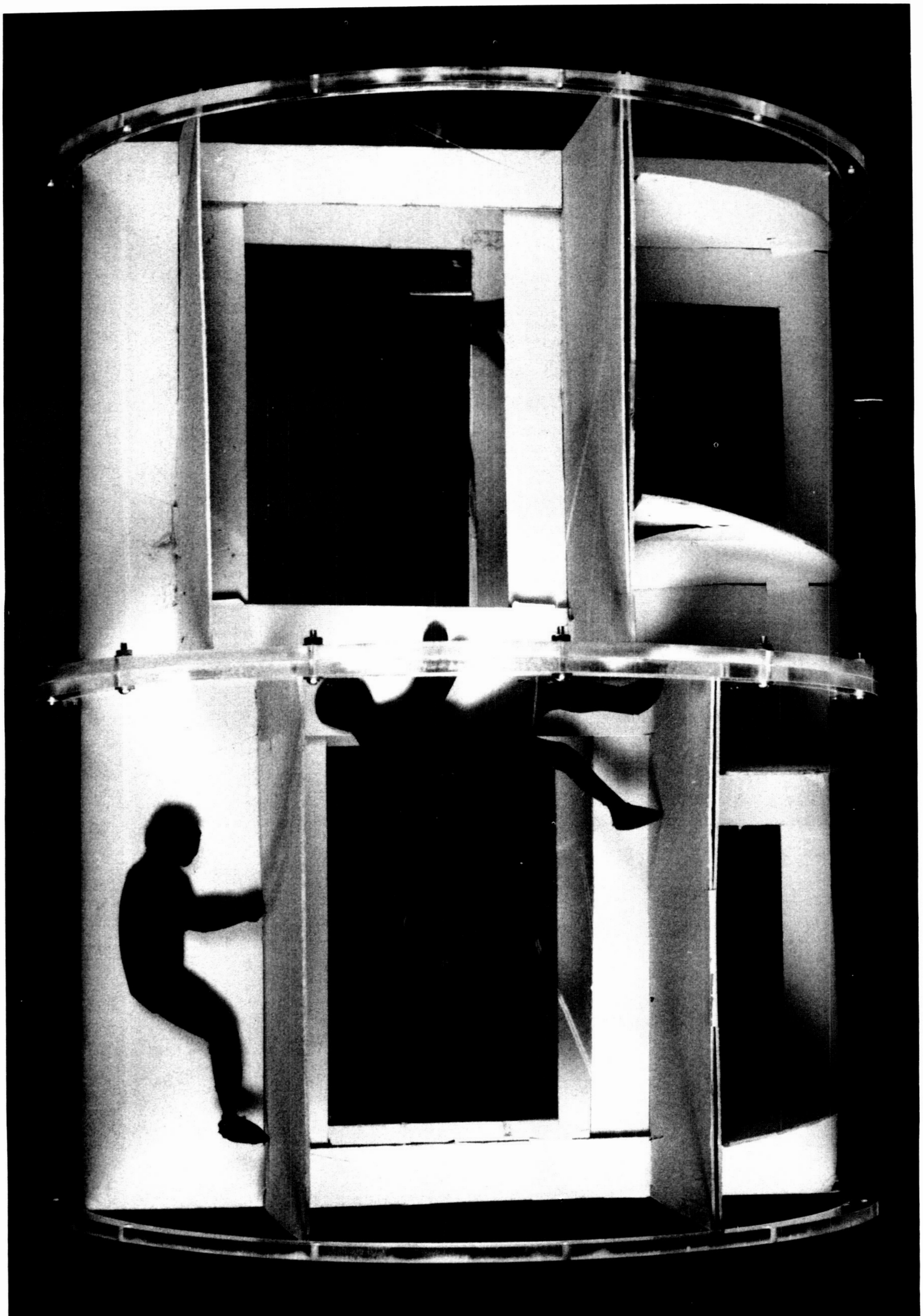


Figure 77.- Space Station module interior circulation study model.

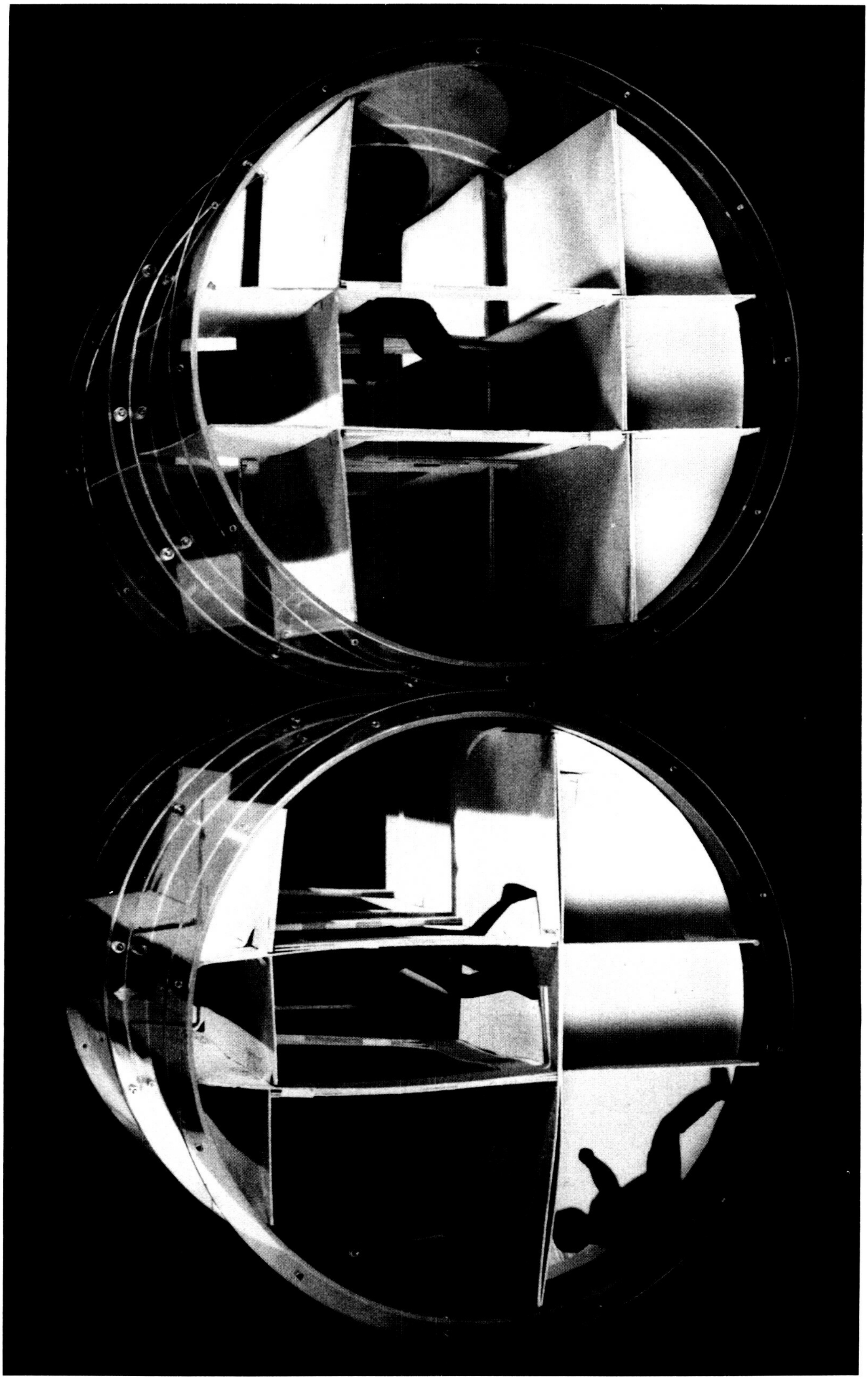


Figure 78.- Space Station interior horizontal circulation models.

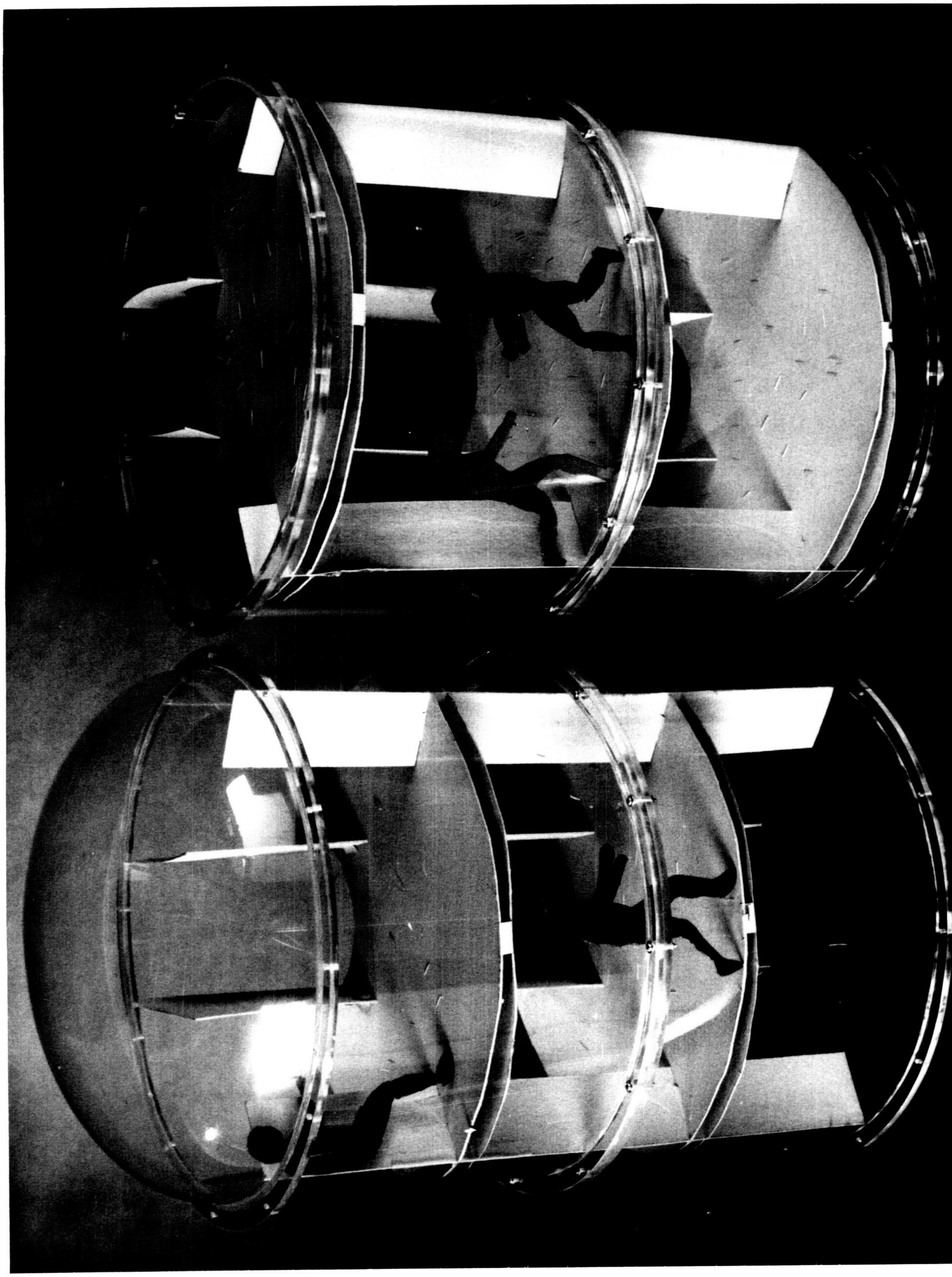


Figure 79.- Space Station interior vertical circulation models.

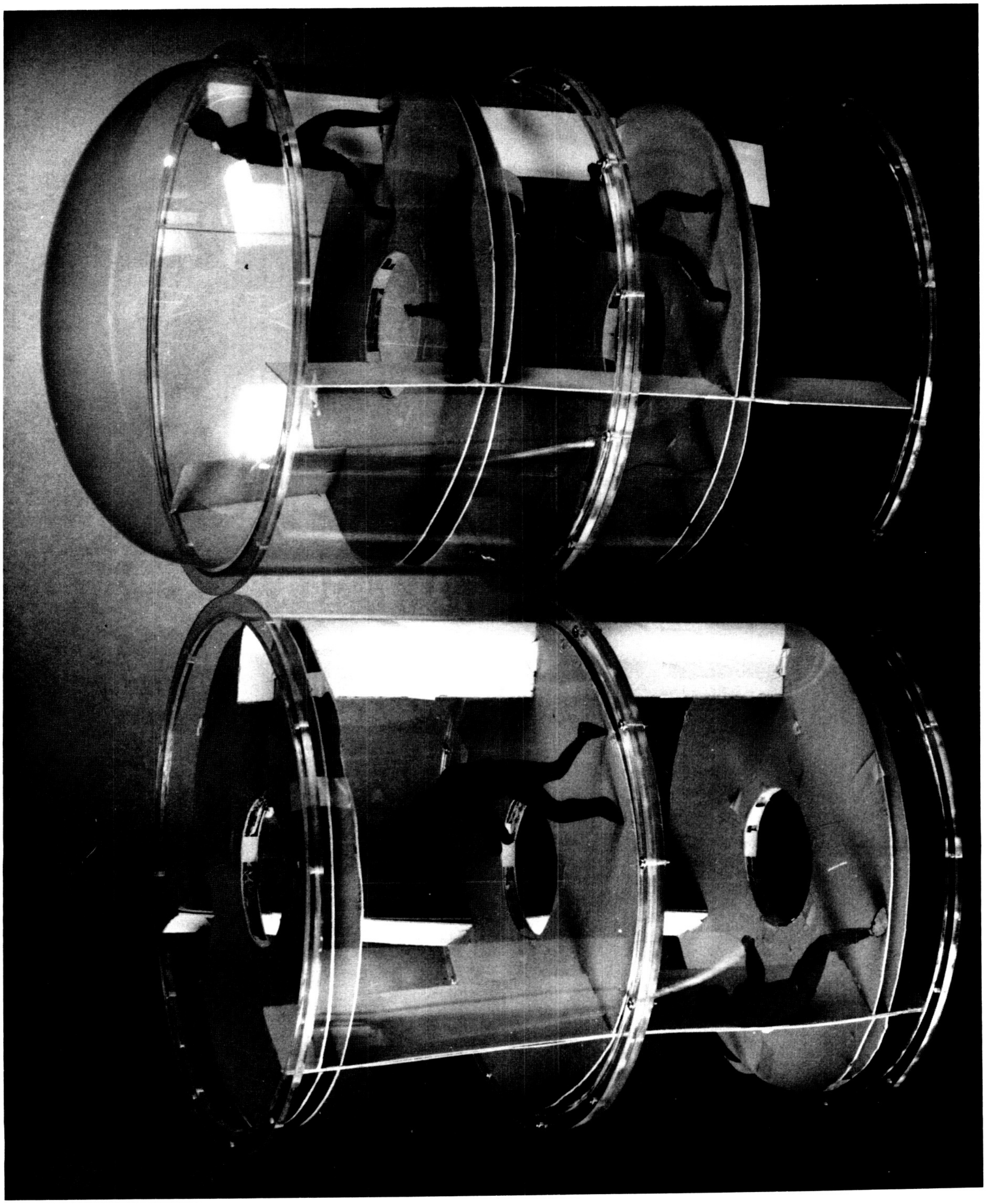


Figure 79.- Concluded.

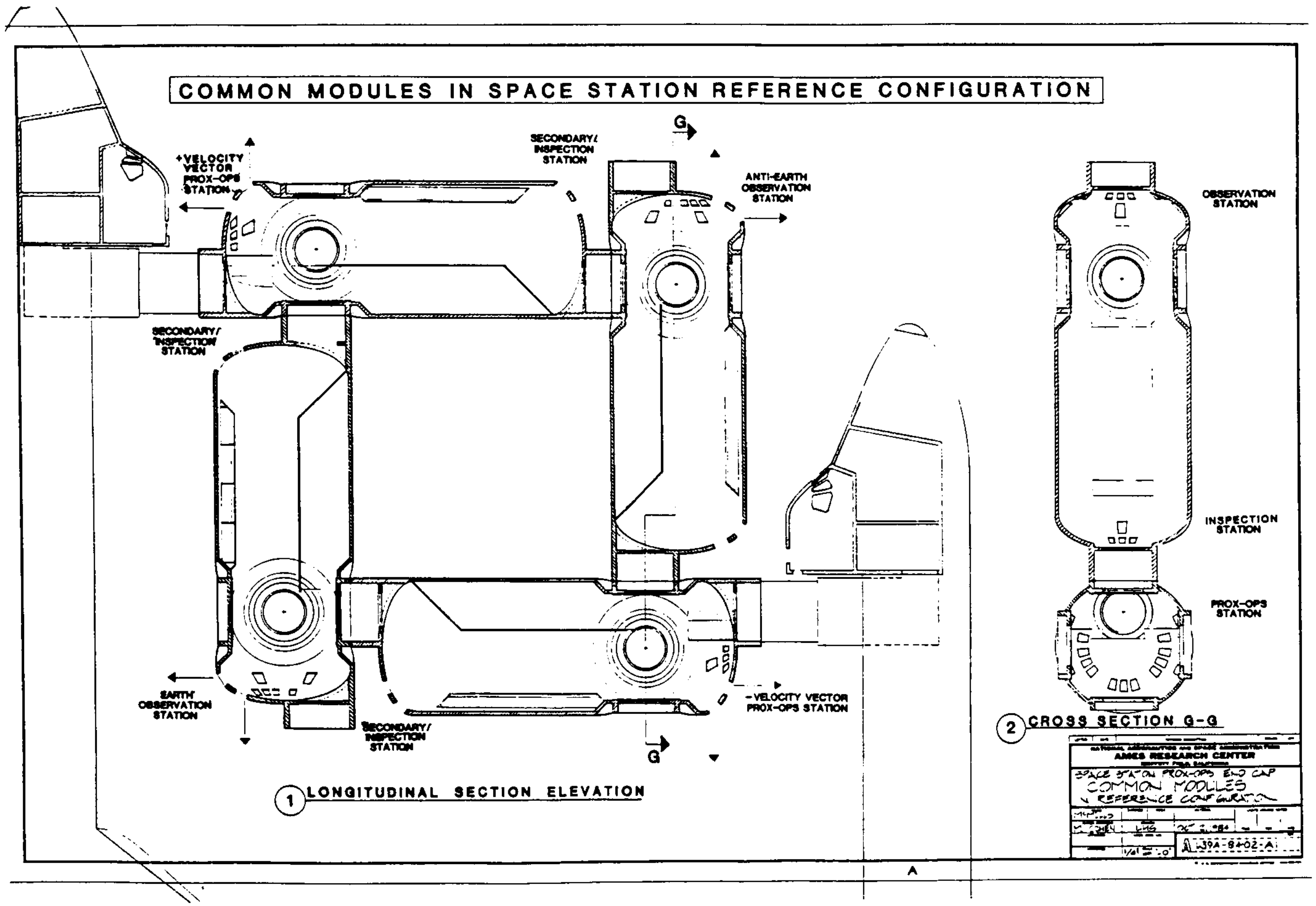


Figure 80.- Interpretation of original Space Station reference configuration using common modules with ellipsoidal end caps having off-center ports, so that wide-angle view windows occur on outside corners of module assembly pattern.

ORIGINAL PAGE IS
OF POOR QUALITY

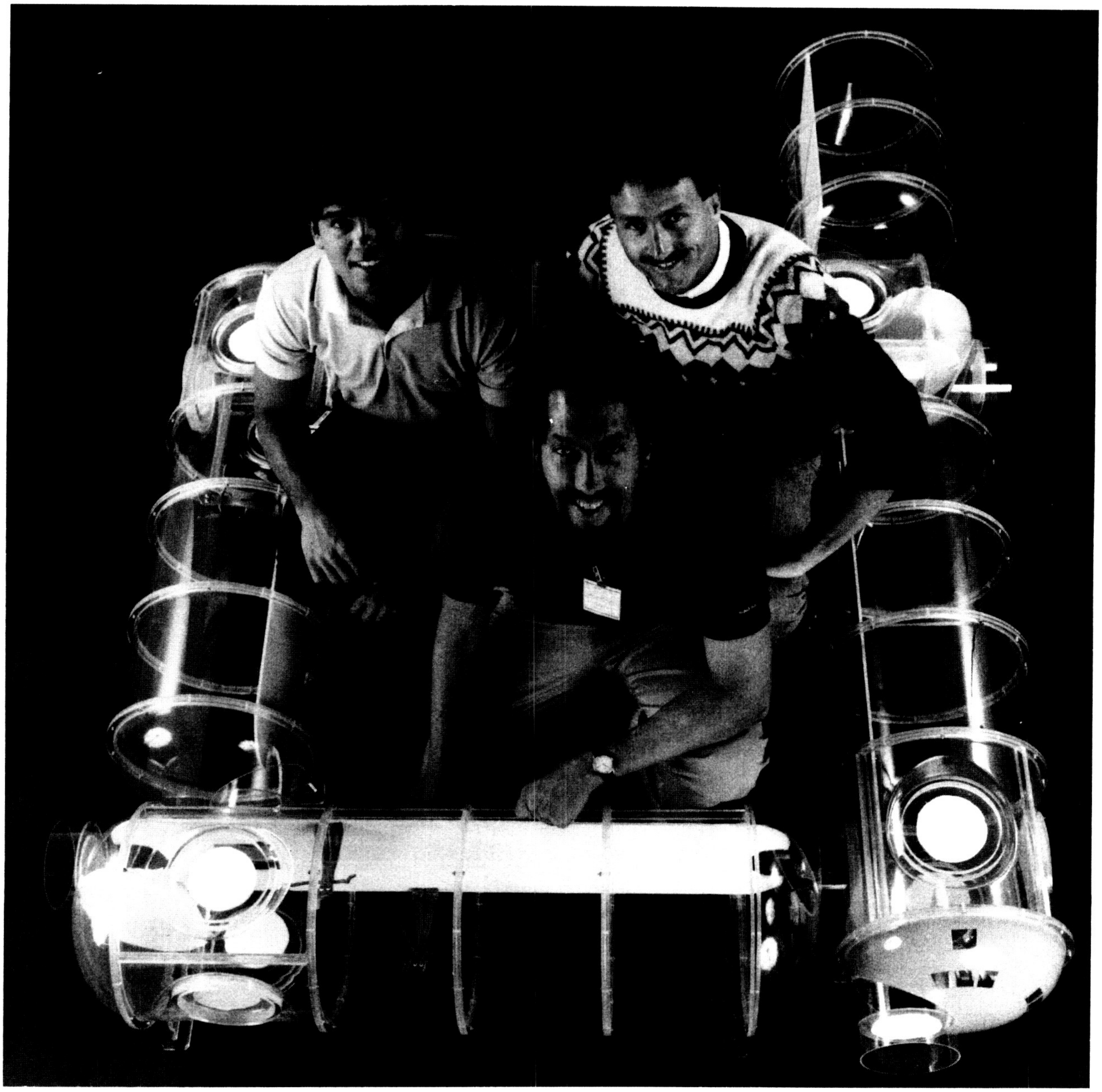


Figure 81.- Marc M. Cohen, Andrew McMills, and Wade Schauer with Space Station module orientation simulator.

C-2

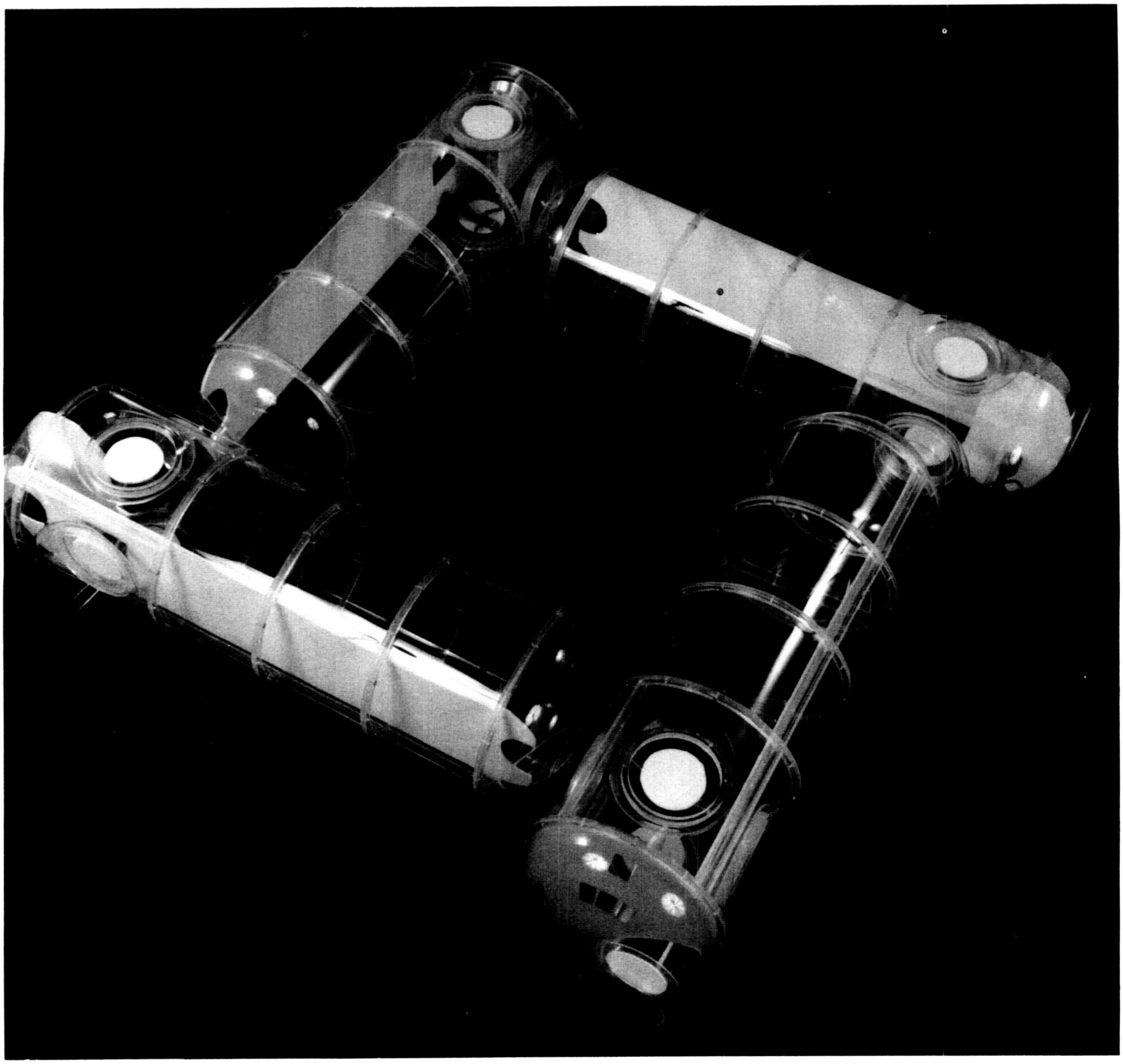


Figure 82.- First orientation of module assembly pattern with floors around the outside perimeter.

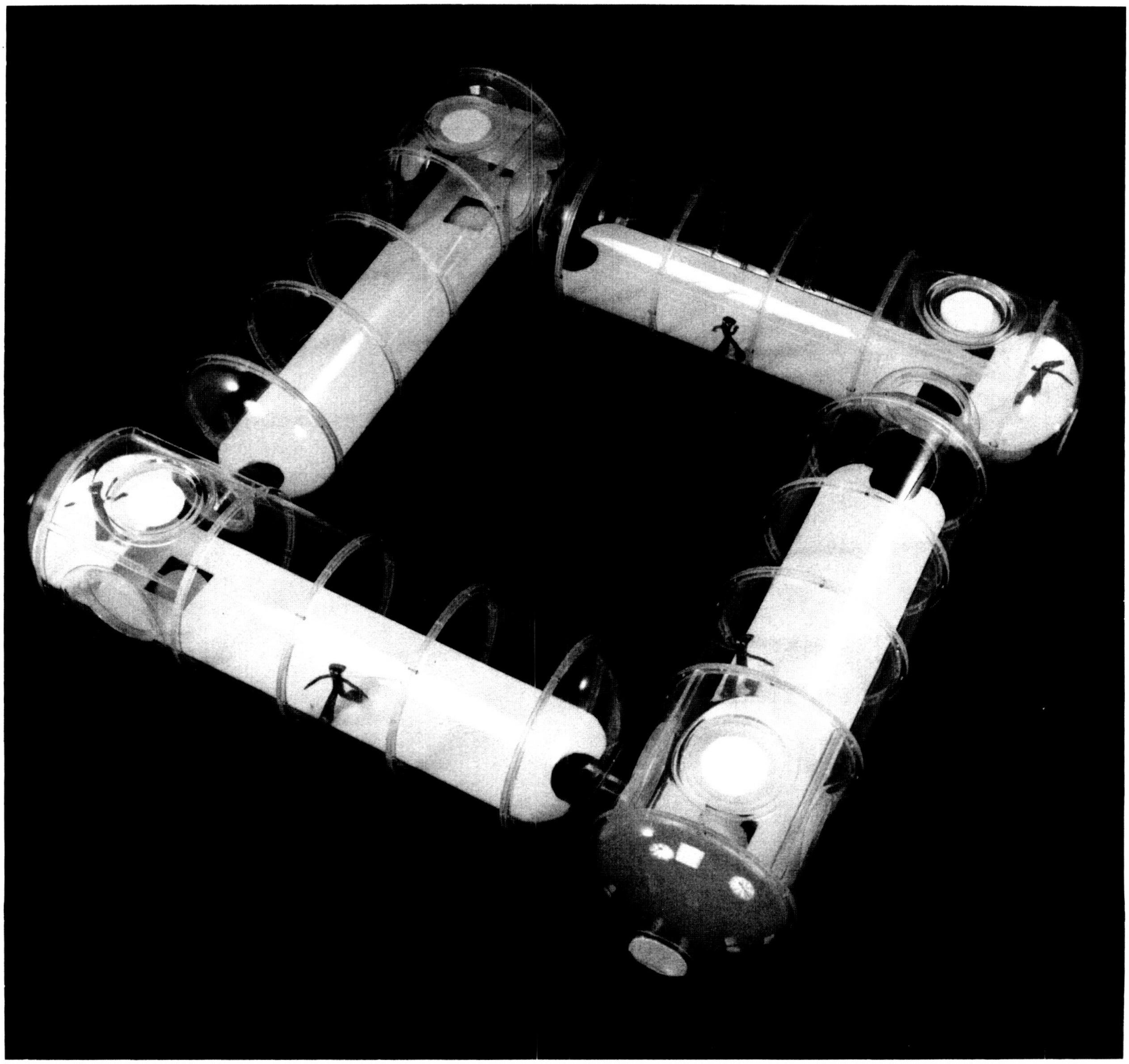


Figure 83.- Second orientation of module assembly pattern with floors rotated 90° from first orientation, so that all floors are co-planar.

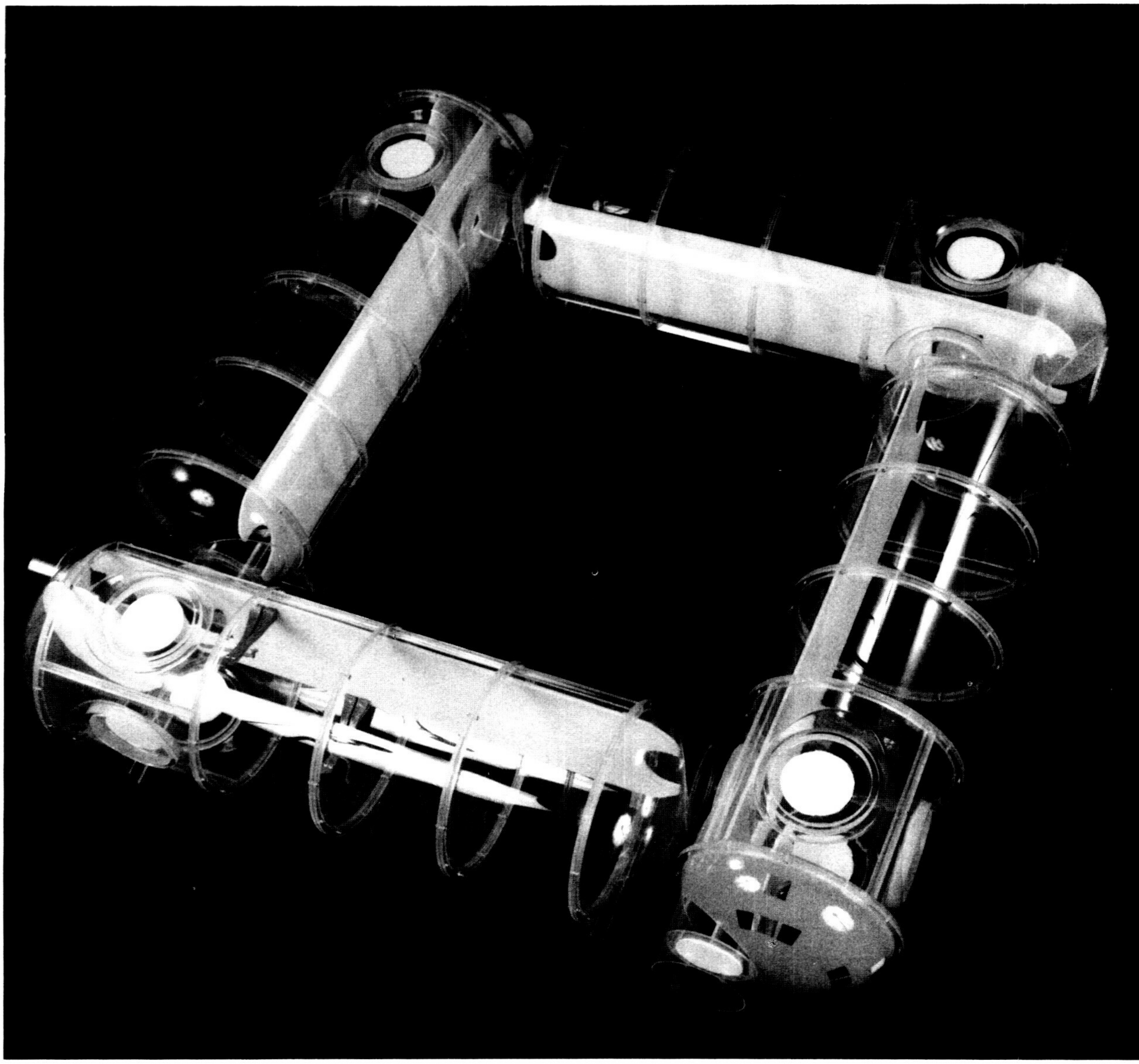


Figure 84.- Third orientation of module connection assembly with floors rotated 90° from second orientation, so that floors form an inner racetrack around inside perimeter.

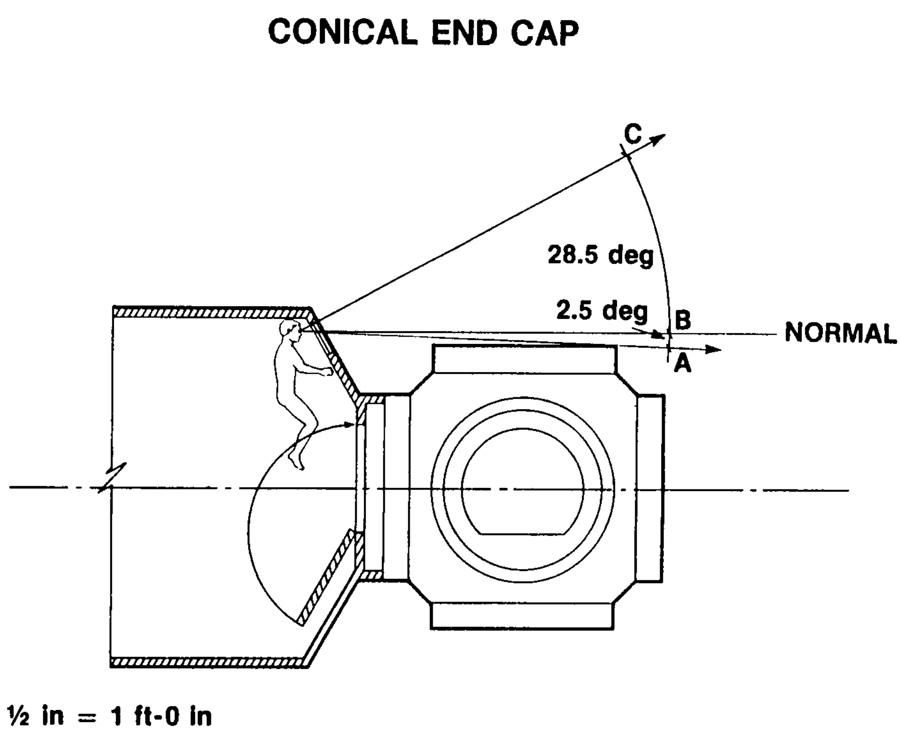


Figure 85.- Conical end cap with on-center port showing vision occluded by berthing node.

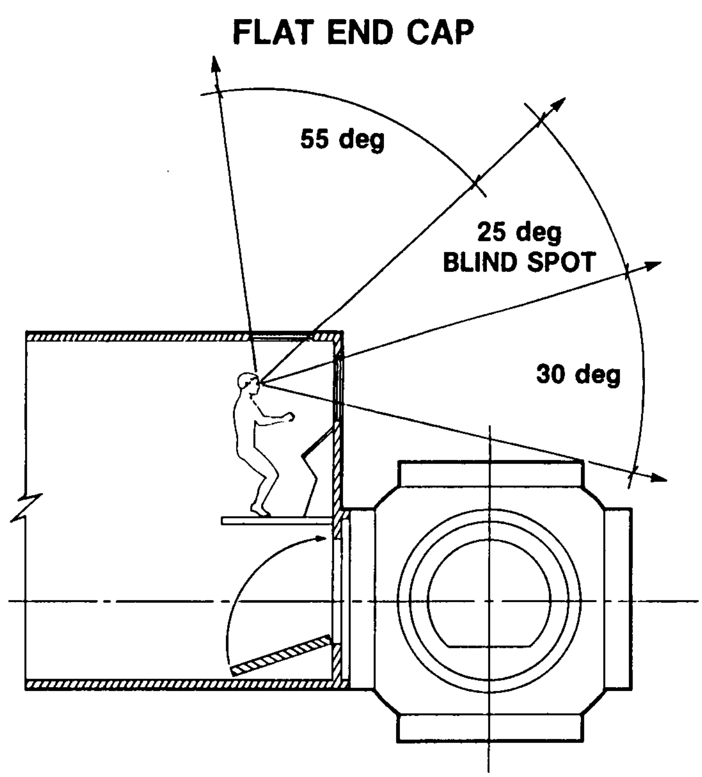


Figure 86.- Flat end cap with off-center port showing range of unoccluded vision.

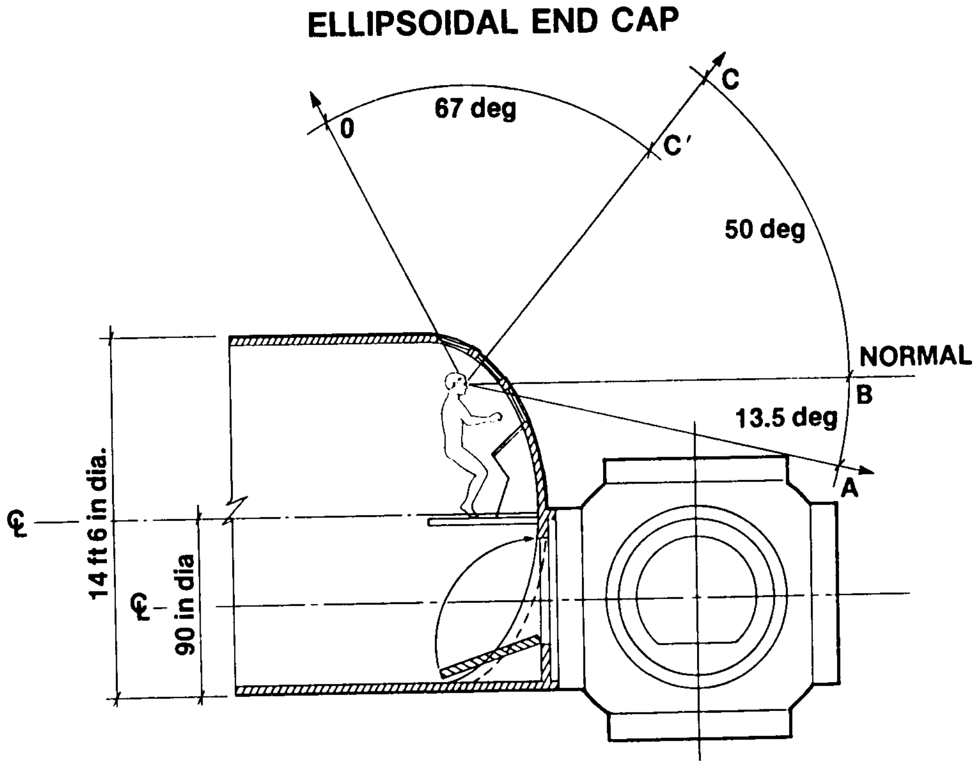


Figure 87.- Ellipsoidal end cap with off-center port showing range of unoccluded vision.

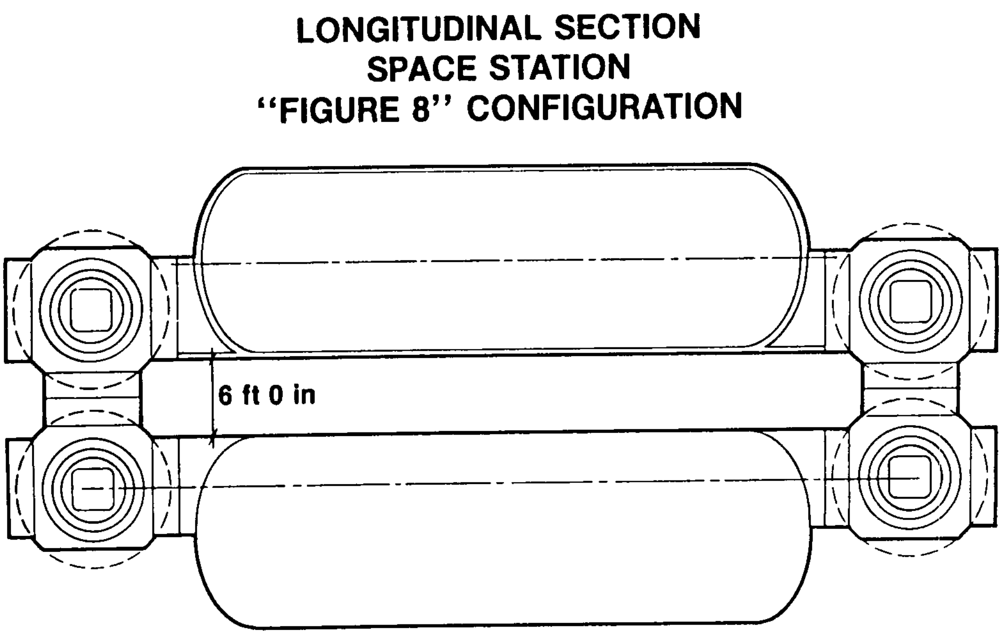


Figure 88.- Two module and four spherical node subassembly of figure 8 configuration showing off-center ports in ellipsoidal end caps "back to back."

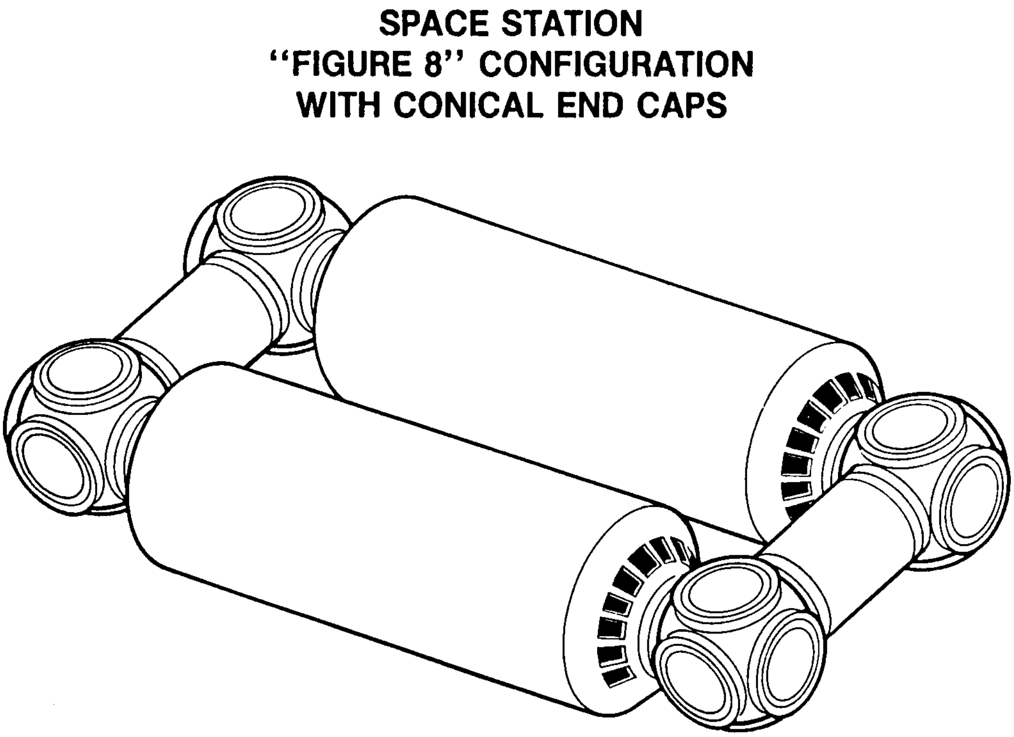


Figure 89.- Actual "figure 8" subassembly with conical end caps and berthing nodes on center.

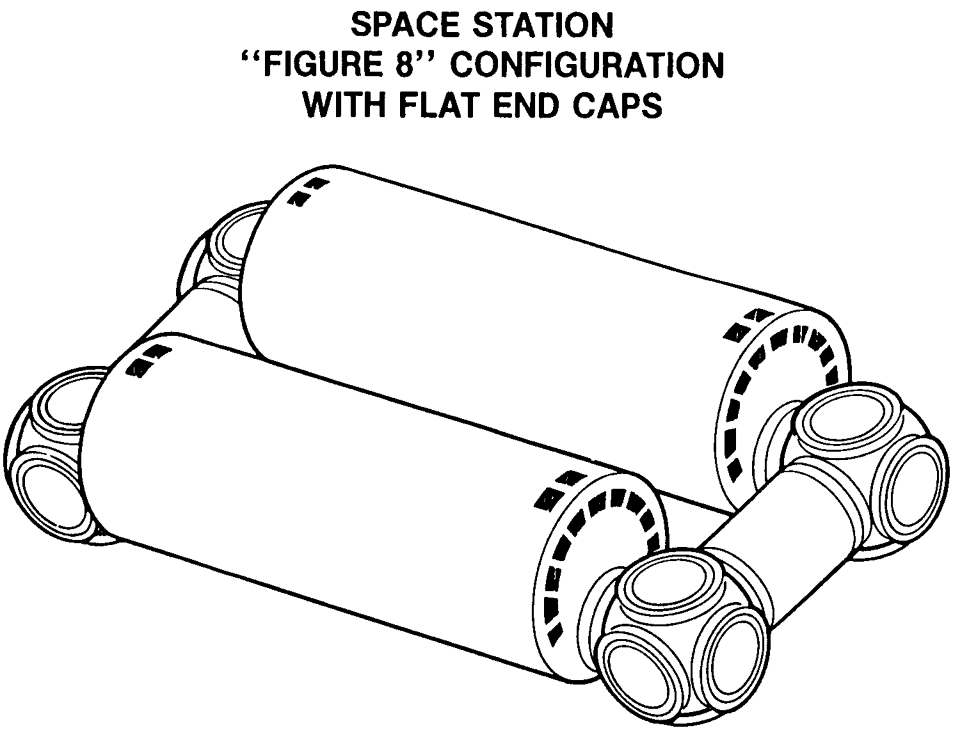


Figure 90.- "Figure 8" subassembly with flat end caps and off-center ports.

SPACE STATION
"FIGURE 8" CONFIGURATION
WITH ELLIPSOIDAL END CAPS IN PARALLEL

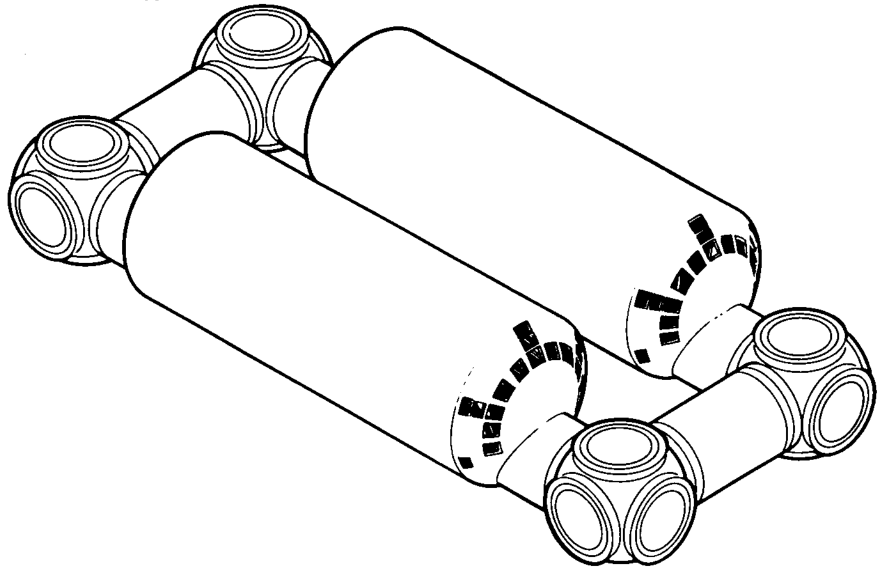


Figure 91.- "Figure 8" subassembly with ellipsoidal end caps with off-center ports, and floors co-planar.

SPACE STATION
"FIGURE 8" CONFIGURATION
WITH ELLIPSOIDAL END CAPS
"BACK TO BACK"

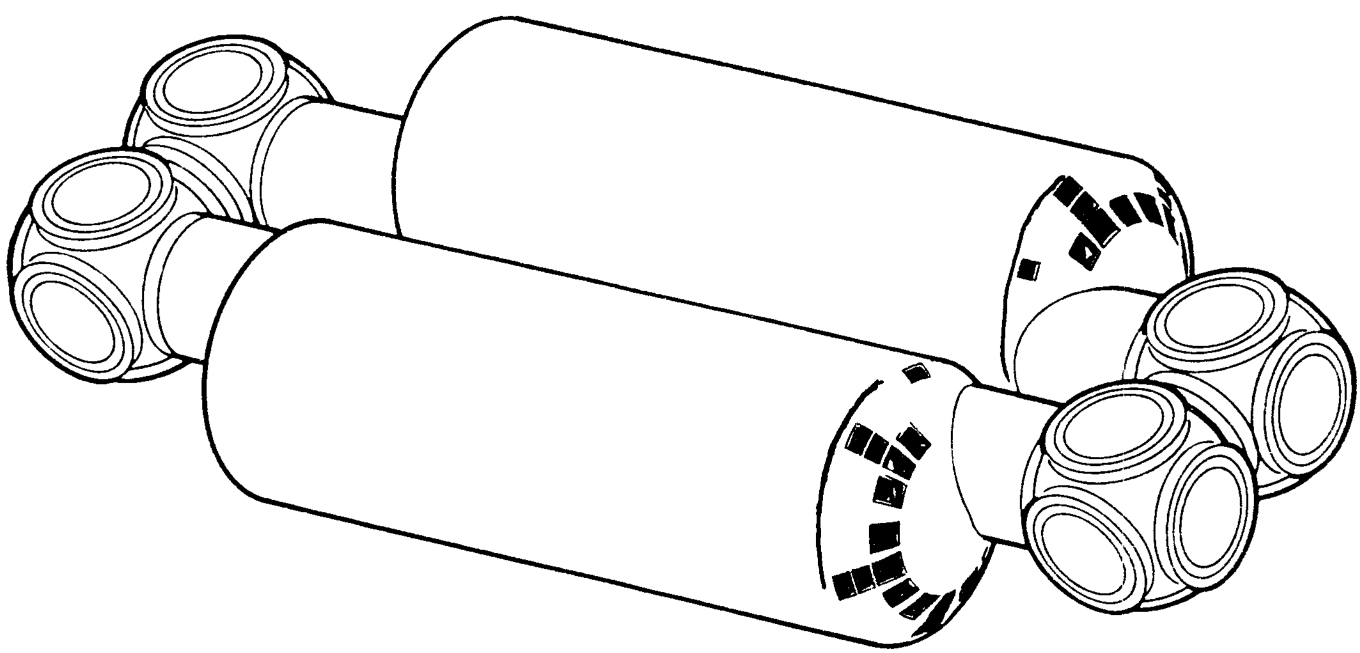


Figure 92.- Modified "figure 8" Space Station subassembly, with ellipsoidal end caps, off-center ports and modules turned "back to back" so that window wide-angle viewing occurs on the outside corners.

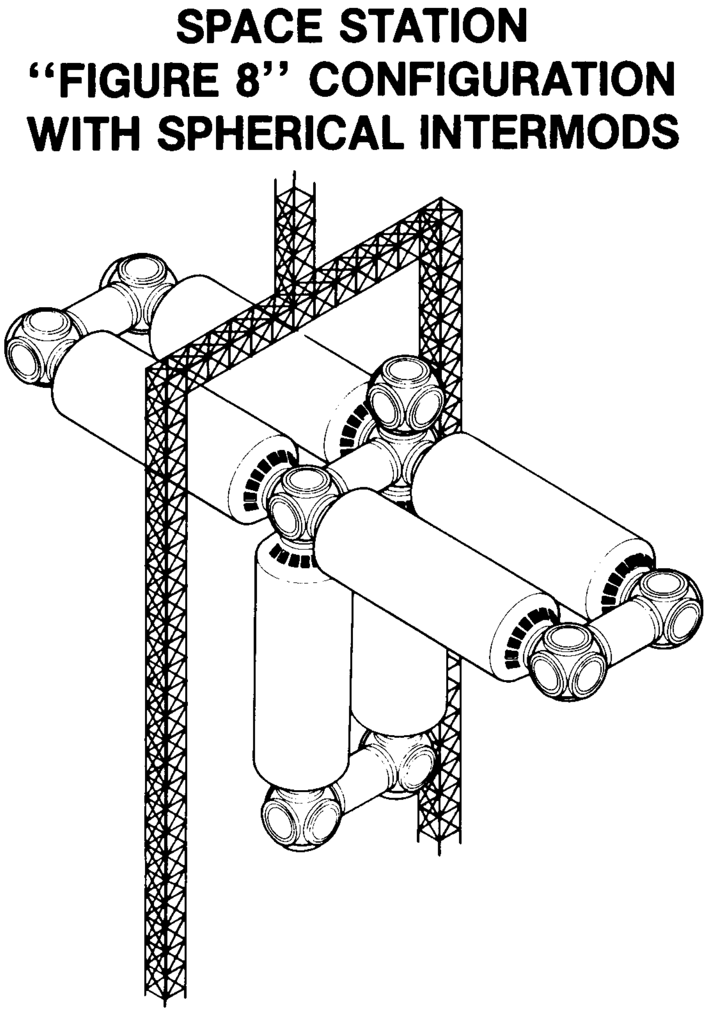


Figure 93.- "Figure 8" module connection pattern, growth possibility but with V-bar and R-bar viewing totally obscured.

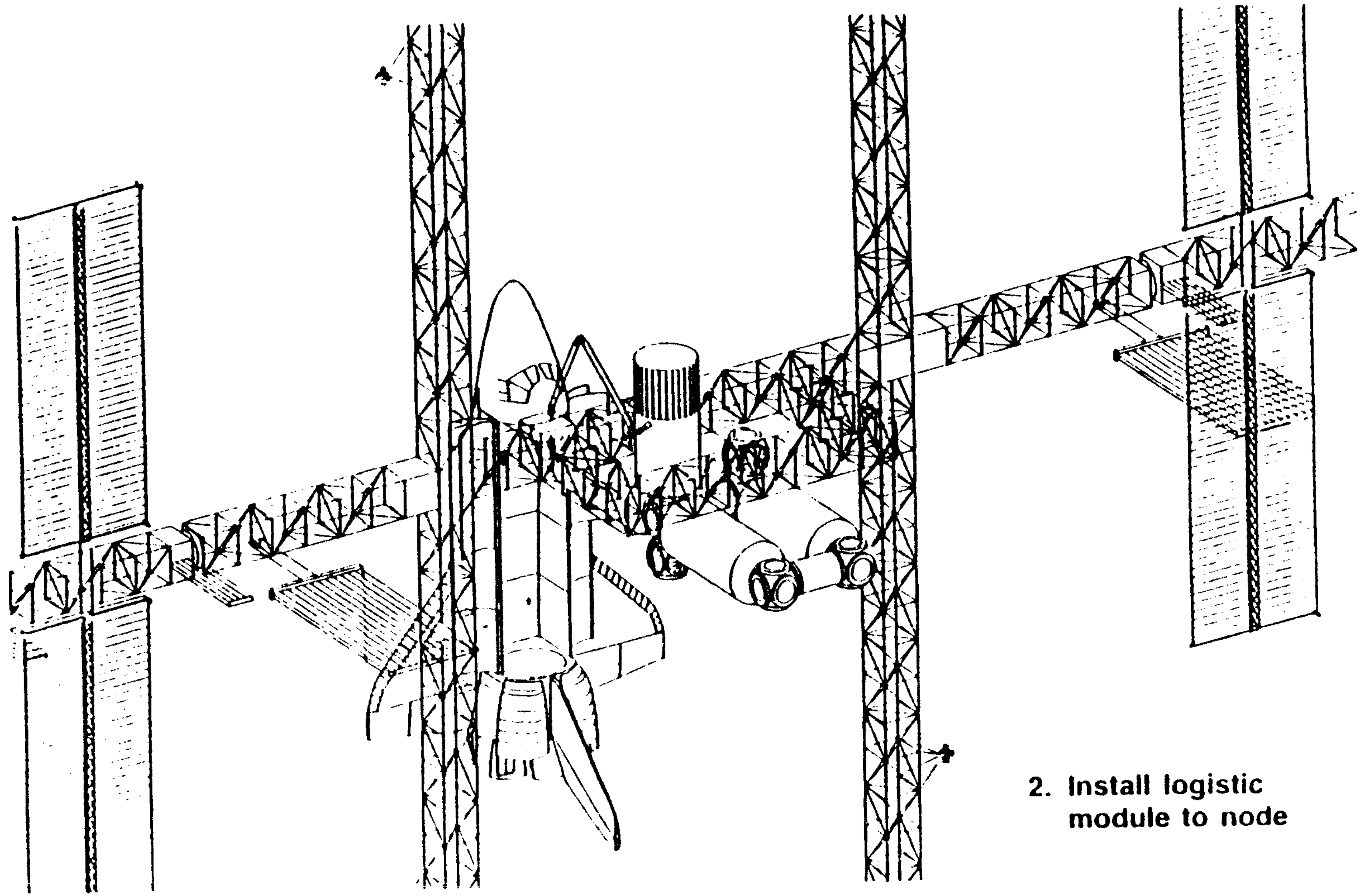


Figure 94.- Dual-keel truss assembly with "figure 8" module assembly.

SPACE STATION
"FIGURE 8" CONFIGURATION
WITH SPHERICAL INTERMODS
"BACK TO BACK"

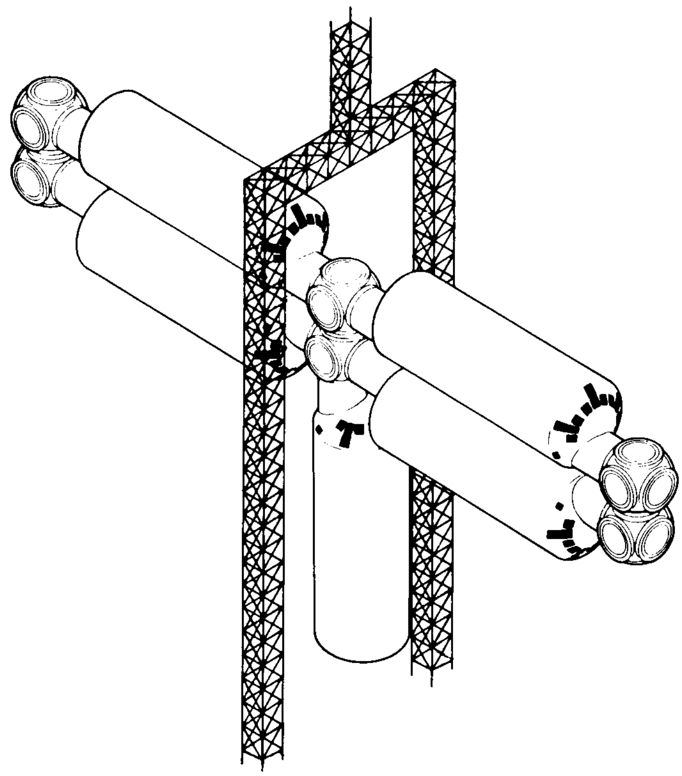


Figure 95.- Modified figure 8 module assembly with wide-angle viewing window work stations at outside corners, with full V-bar, R-bar and side-viewing capability.

WORKSHOP MODULE WITH BERTHING HUB
AS SUBSTITUTE FOR "MULTIPLE DOCKING ADAPTER"
BASED ON TRI-TET SHELL GEOMETRY

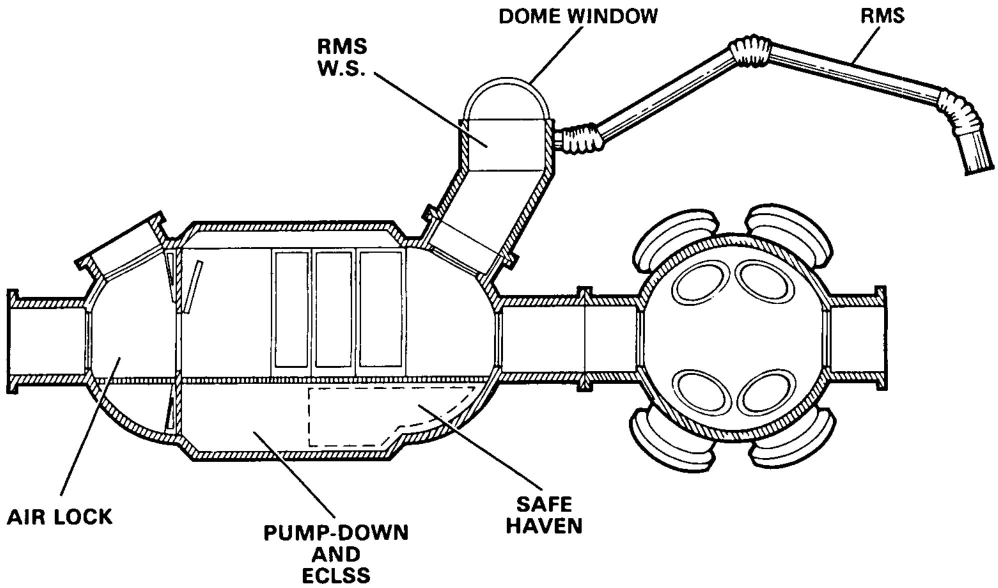


Figure 96.- Some key features from the triangular-tetrahedral Space Station study.

ORIGINAL PAGE IS
OF POOR QUALITY

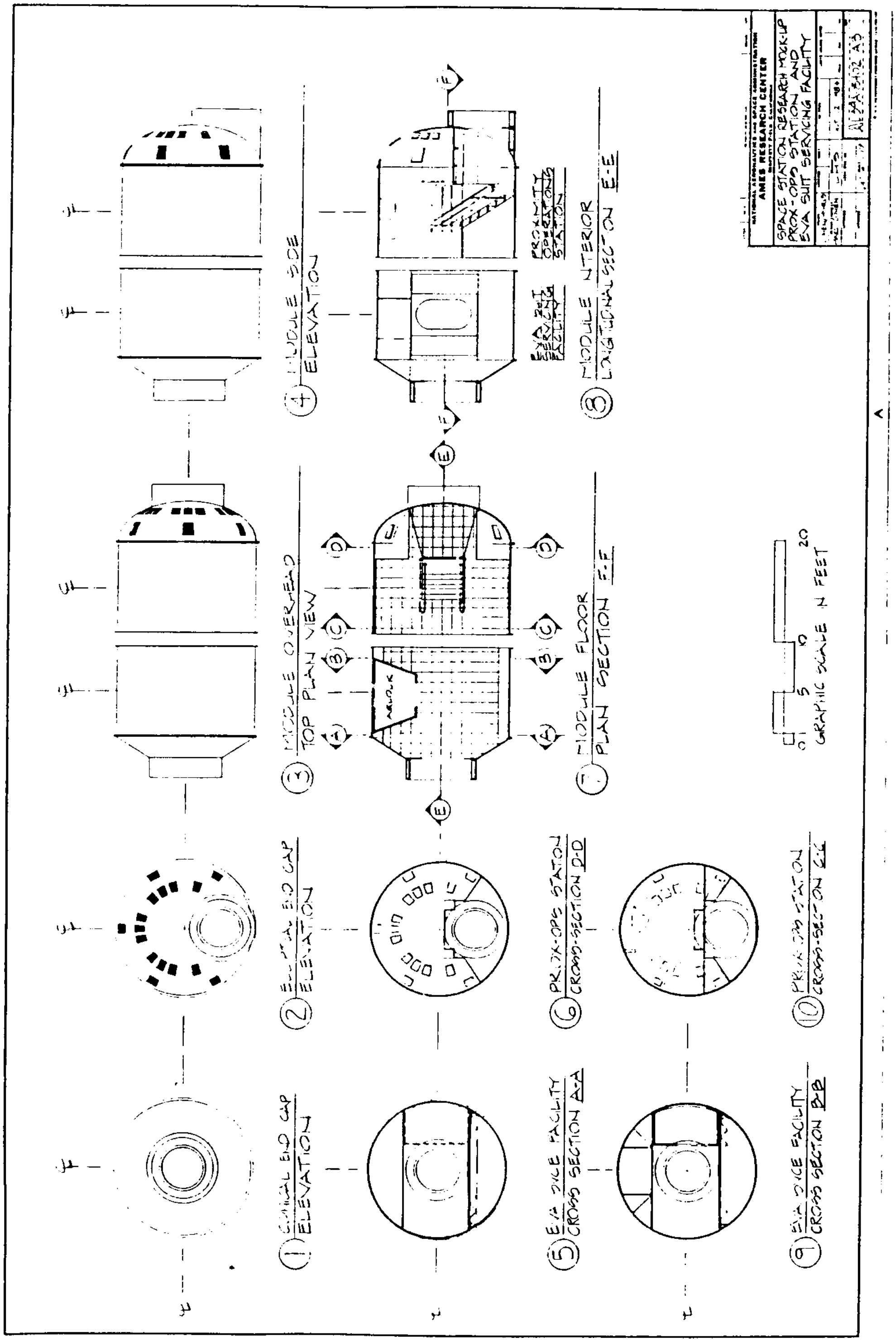


Figure 97.- Schematic design of Space Station proximity operations simulator mockup.

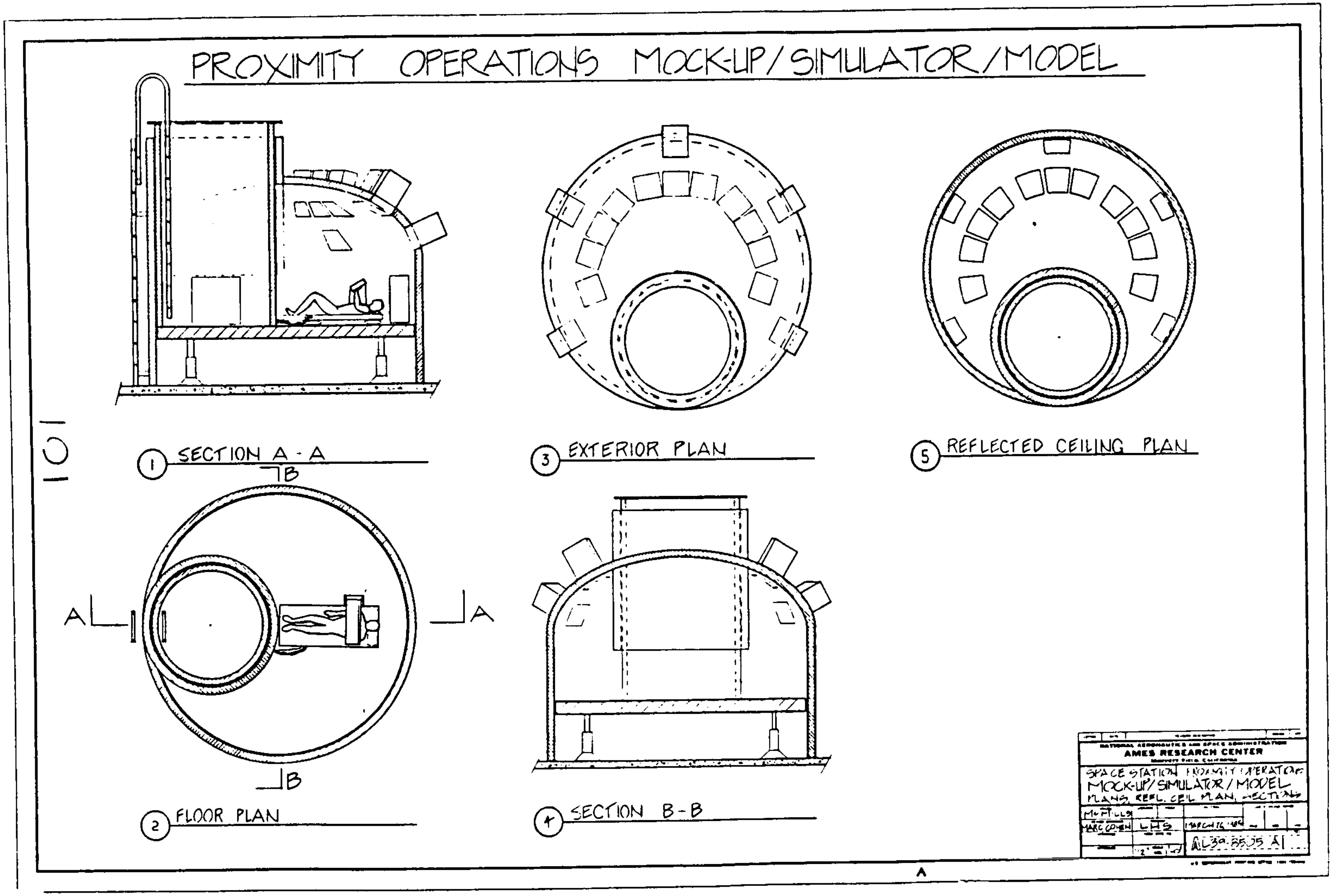


Figure 98.- Proximity operations mockup/simulator/model.

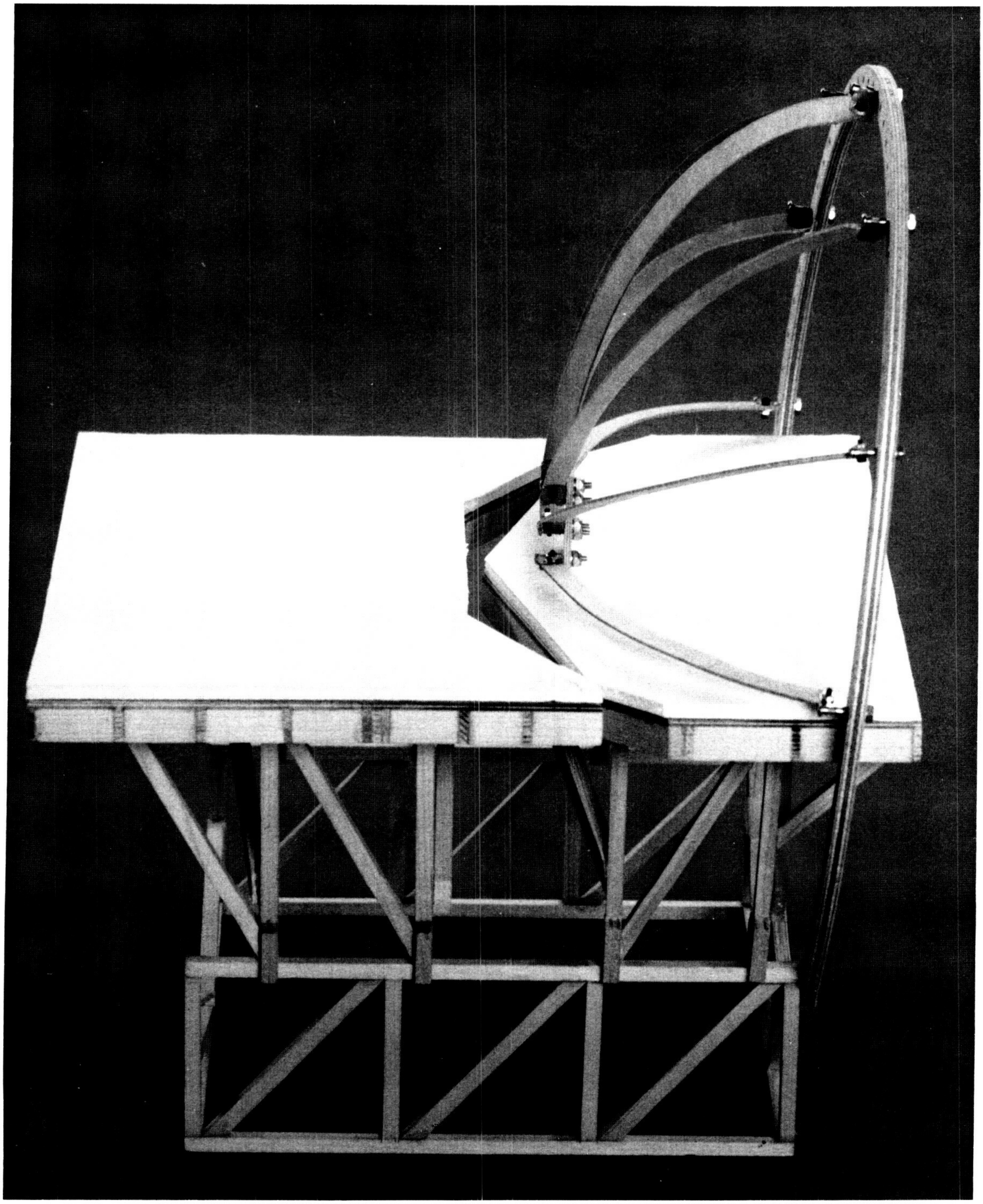


Figure 99.- Side view of palletized prox-ops mockup concept model, showing ellipsoidal "half-dome" and two removable pallets.

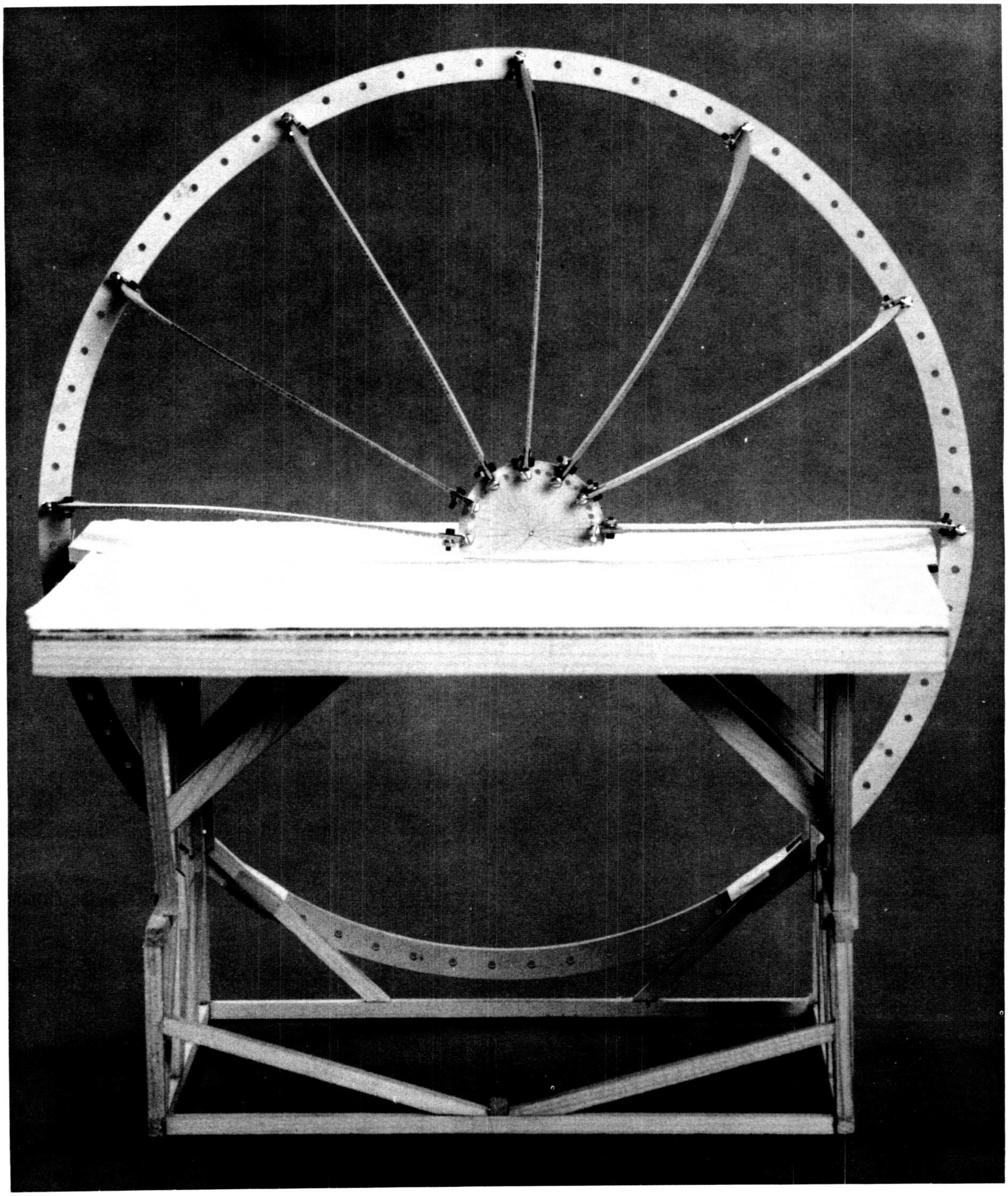


Figure 100.- Front view of palletized prox-ops mockup concept showing rib connections to outer ring and central front connecting plate.

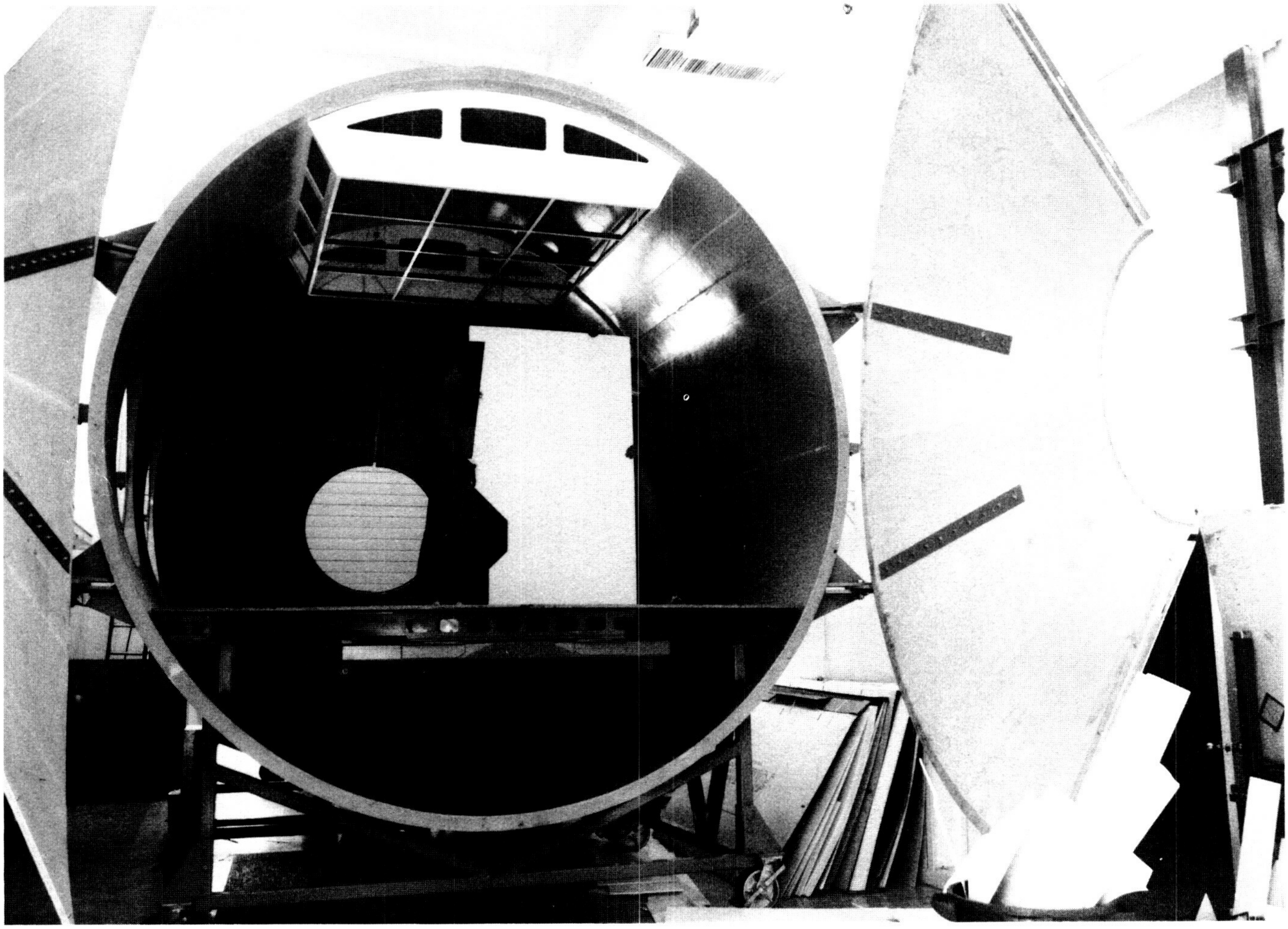


Figure 101.- View of cylindrical mockup shell interior, with hinged end-cap doors open, ceiling unit framing and floor pallets in place. Students Rick Young and Calvin Smith hold a mockup template.

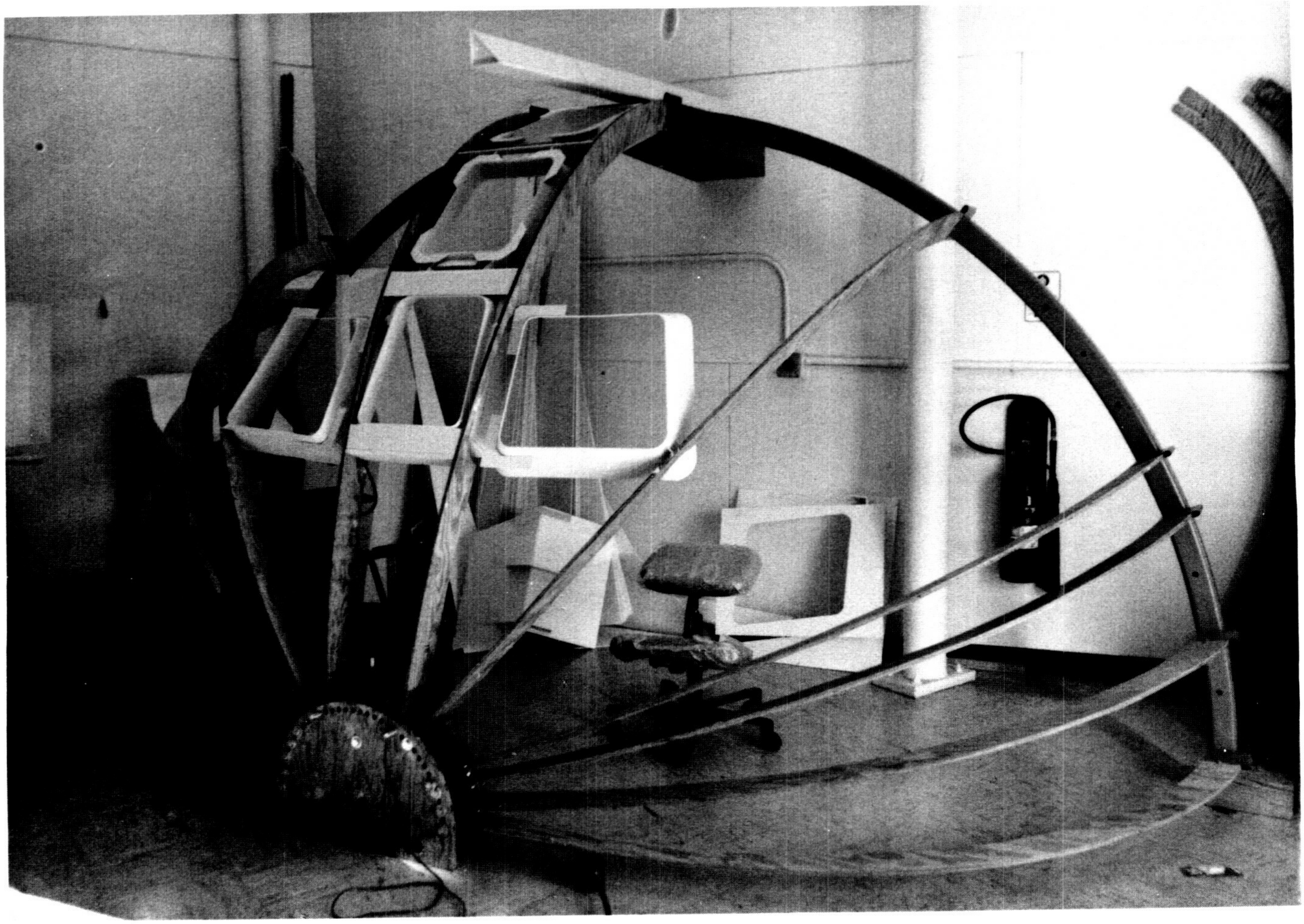


Figure 102.- Full-scale configurable half-dome with movable elliptical ribs for experimenting with window geometries.

ORIGINAL PAGE IS
OF POOR QUALITY

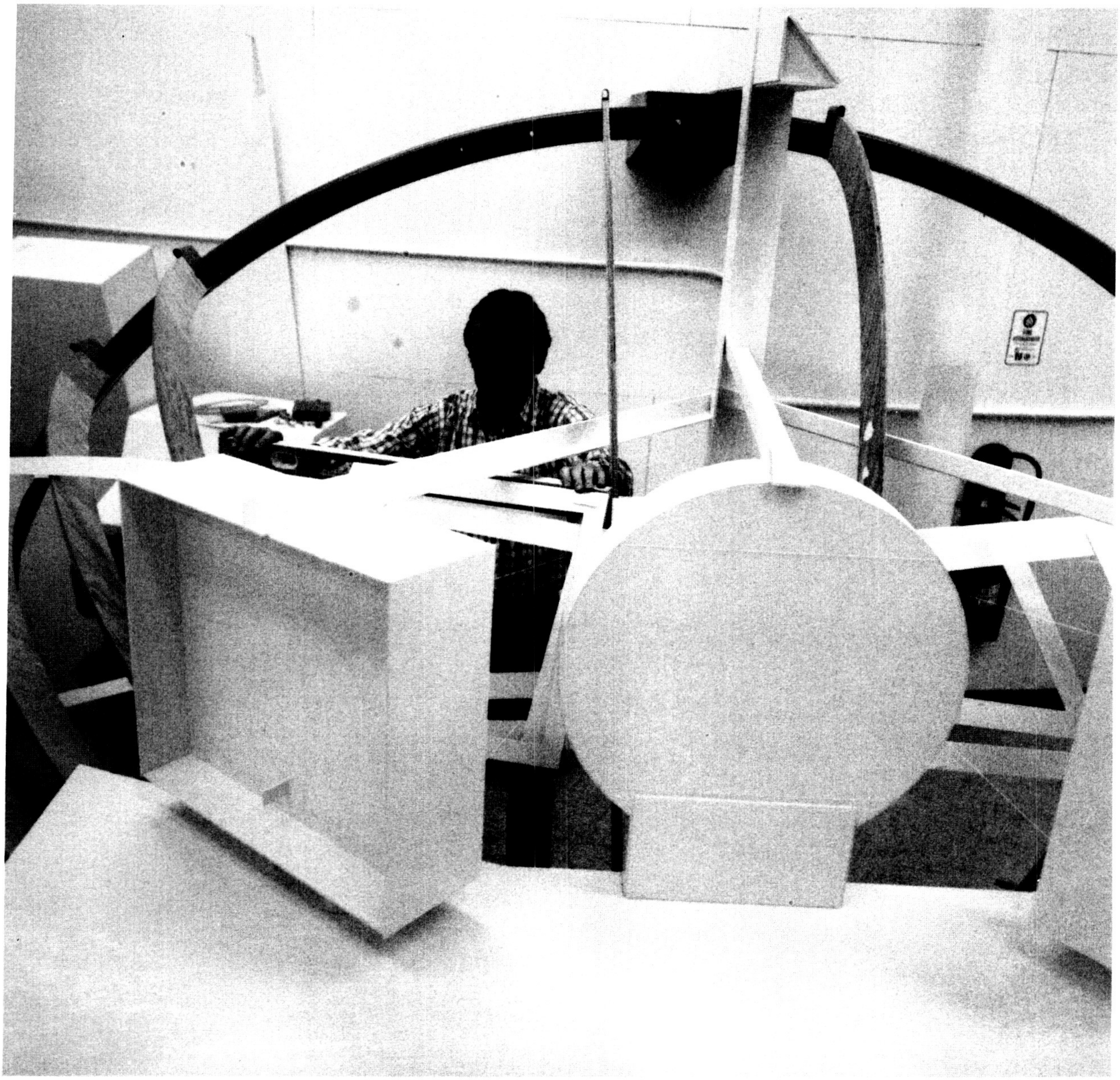


Figure 103.- Phil Culbertson Jr., Informatics General Corp., measures the level of window geometries. Mockups of columnating lenses are in the foreground.

Figure 104.- Inverted trapezoidal window framing in ellipsoidal half dome to counteract keystoning effect of computer display monitors through columnating lenses.

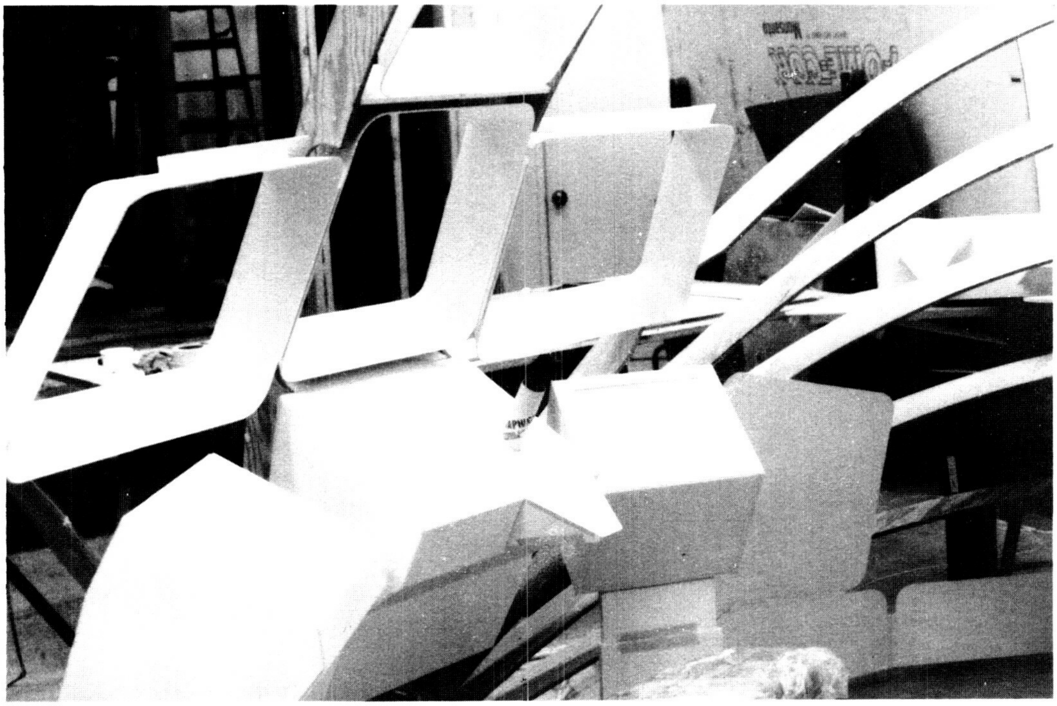


Figure 105.- View of control console mock-up.

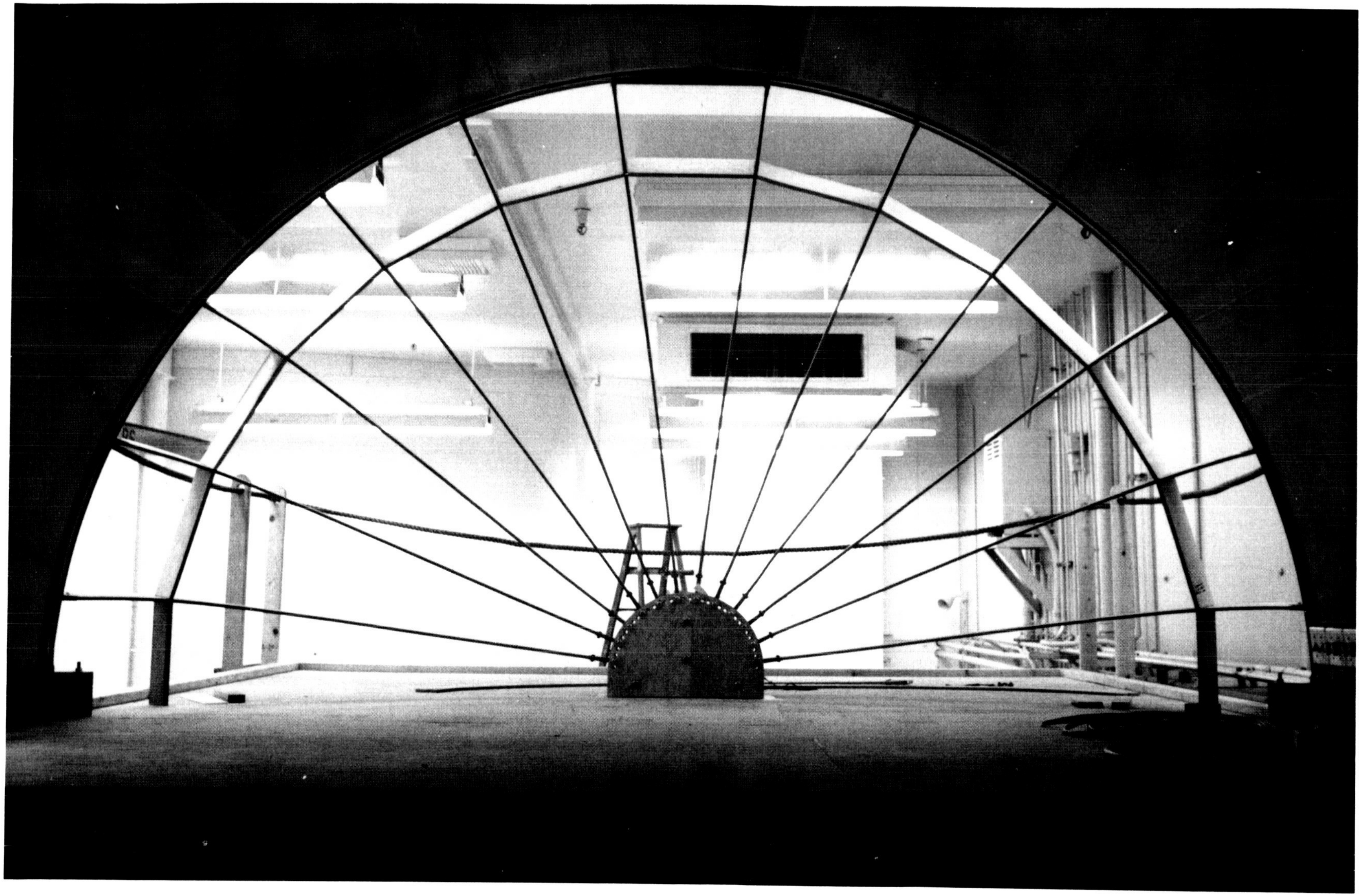


Figure 106.- Half-dome mounted to cylindrical mockup, on top of BDB, view from inside module shell.

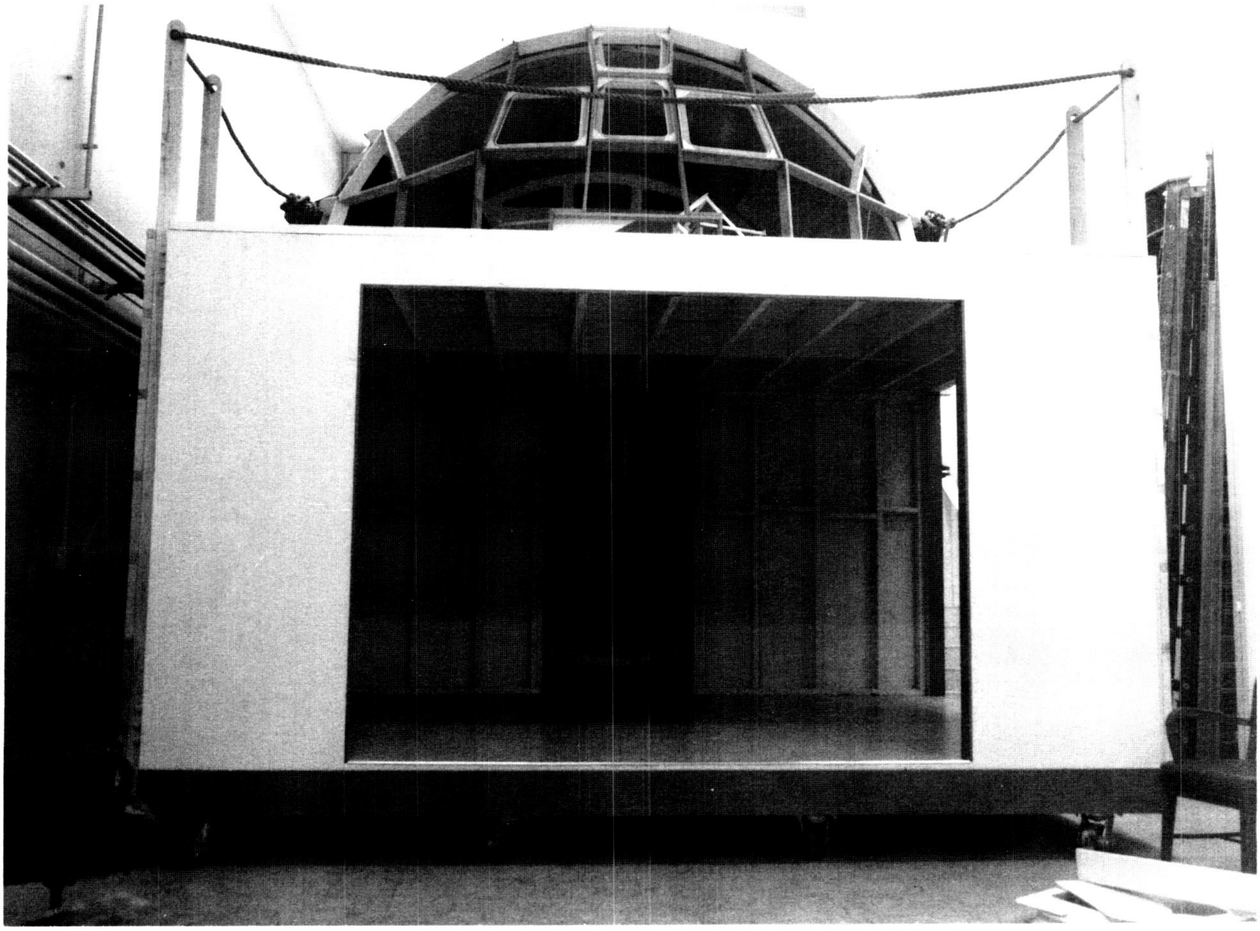


Figure 107.- "BDB" mockup support structure, front view showing computer area below and ellipsoidal half-dome above.

N88-19884

SPACE STATION ARCHITECTURAL ELEMENTS MODEL STUDY

SPACE STATION HUMAN FACTORS RESEARCH REVIEW

BY

Thomas C. Taylor
Taylor and Associates, Inc.
P.O. Box 1547
Wrightwood, CA 92397
Phone 619-249-6882

Eyoub Khan
Conceptual Design Group
18002 Skypark Circle
Irvine, CA 92714

John Spencer and Carlos Rocha
Design Science
7033 Sunset Blvd, Suite 310
Los Angeles, CA 90028

Ethan Wilson Cliffton, AIA
3435 Army Street, Studio 332
San Francisco, CA 94110

ABSTRACT

The objective of the study is to explore and analyze the interaction of major utilities distribution, generic workstation, and spatial composition of the module interior. The study is approximately half complete with seven different interior models fabricated at a scale of 1" equal 1' - 0". The final output will be a Final Report using the "Inquiry by Design" approach and suggesting an Evaluation Criteria for interior human factors module design.

Taylor and Associates, Inc. study manager is Thomas C. Taylor and previous work includes three years experience in the Alaskan Construction camps. These camps provide a rough analog to the Space Station which includes the severe environment, utility design problems, logistics considerations and the effect of interior human factors design on the workers involved. Other work includes Orbital Assembly Studies, Human Factors Interior Design, Aft Cargo Carrier and entrepreneurial activities such as SPACEHAB.

THE SPACEHAB Module is a 1,000 cubic foot pressurized Middeck Augmentation Module for the STS. It is financed by private funding and expects to sign a M.O.U. with NASA in the near future.

The Flat End Cap research from the 1984 NASA contract led indirectly to the design of the Flat End Caps used on the SPACEHAB Module and the interior design models used similar techniques to the previous NASA Contract. The SPACEHAB Module can provide up to 100 additional Middeck lockers and still have 70% of the interior volume to devote to other manned activities. The potential for the development and orbital testing of Space Station "Lead In" interior hardware, science experiments and commercial process development exists with the SPACEHAB Module and could start six to eight years before the hardware is tranferred to the station. The SPACEHAB organization intends to focus on low cost repeated access to space through a module costing approximately $5 million to lease and 6 about months to integrate.

Two other ideas from the first study were chosen to be expanded and explored in the second contract. The ideas include a Triangular Central Beam and a Workstation for orbital modules. These have been developed into seven scaled models by the three subcontractors listed. The approach has been "Inquiry by Design" which requires an interior design free of the conventions of the one gravity environment. This search has led to a central beam to be used as a testbed. Then the approach develops theoretical interior designs on which to test the variables. The interior configurations test the theoretical human factors variables through the seven designs and explores the Human Factors, commercial and functional issues. The result will be a series of Oppositions/Gradients and produce components of Human Productivity, namely operations, design and human performance.

A variety of issues can be expressed as Oppositions and Gradients. They include Packing Densities vs. circulation, Efficiency of Packing vs. Standardization, Flexibility vs. Diversity, and most importantly the Composition of Interior Volume as Space for Living as a PLACE vs. Residual "Negative" Volume. It is this "SPACE FOR PRODUCTIVE LIVING" we found to be critical in the very commercial and competitive environment of the Alaskan Construction Camps.

The result of the study is expected to be a series of observations and a preliminary evaluation criteria which focuses on the Productive Living Environment for a module in orbit.

Several other aspects have been explored in the study but not covered in depth in the presentation. Utilities for example are a critical design driver. A series of utility rules of thumb are developed to expand on the Alaskan experience and adapt it to the microgravity environment. There is no reason to make the same mistake twice. The workstation for an orbital module can have an impact on both the station operations and surface commercial customers. This is an area where private funding combined with NASA research budgets can create an entrepreneurial thrust similar to the SPACEHAB Module.

Three subcontractors have contributed to the NASA study this year.

Eyoub Khan is the principal force behind the Conceptual Design Group, an Irvine, CA architectural design and planning firm, and created three of the models and most of the renderings for the study. The interior design concepts created include the Hexagonal Beam - Large, Square Beam and H Beam models.

John Spencer is the head of Design Science, a Los Angeles firm specializing on interior human factors design. Previous work includes human factors interiors for an Undersea Lab and Antarctic design projects. John is assisted by Carlos Rocha, and the firm created the Triangular Beam on Center and off Center model. Also created were the Hexagonal - small and the Workstation models.

Ethan Wilson Cliffton, AIA, is an architect in San Francisco and brings to the project a depth of technical knowledge gained in more than ten years experience on complex surface science related projects. These include a major research complex at Lawrence Berkeley Labs. The complex consists of a building to house the world's most powerful Atomic Resolution Microscope, a connecting ARM Support Laboratory and the Surface Science and Catalysis Laboratory. His work also includes a large telescope facility in Hawaii and projects for Cetus and Hewlett-Packard. Ethan created the Center Cluster Beam concept.

INTRODUCTION

- BACKGROUND
- LAST YEARS CONTRACT
- SPACEHAB MODULE
- OBJECTIVES
- APPROACH
- HUMAN FACTORS/HUMAN PRODUCTIVITY VARIABLES
- ISSUES
- CENTRAL BEAM TEST DESIGN
- WORKSTATION TEST DESIGN
- OBSERVATIONS

BACKGROUND

TAI WORK IN SEVERE AND ISOLATED ENVIRONMENTS, ALASKAN CONST CAMPS, UNDERSEA LABS, ANTARCTICA, ETC.

FIRST NASA-AMES SPACE STATION STUDY

- CONCEPTS FOR

  CENTRAL BEAM

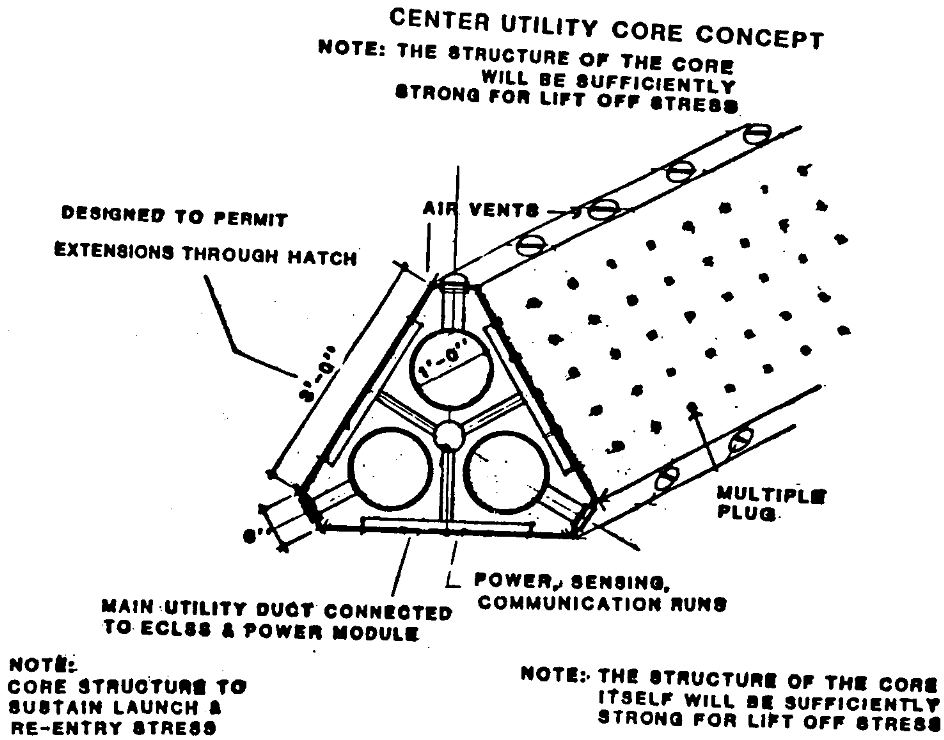
  WORK POD

  FLAT END CAP

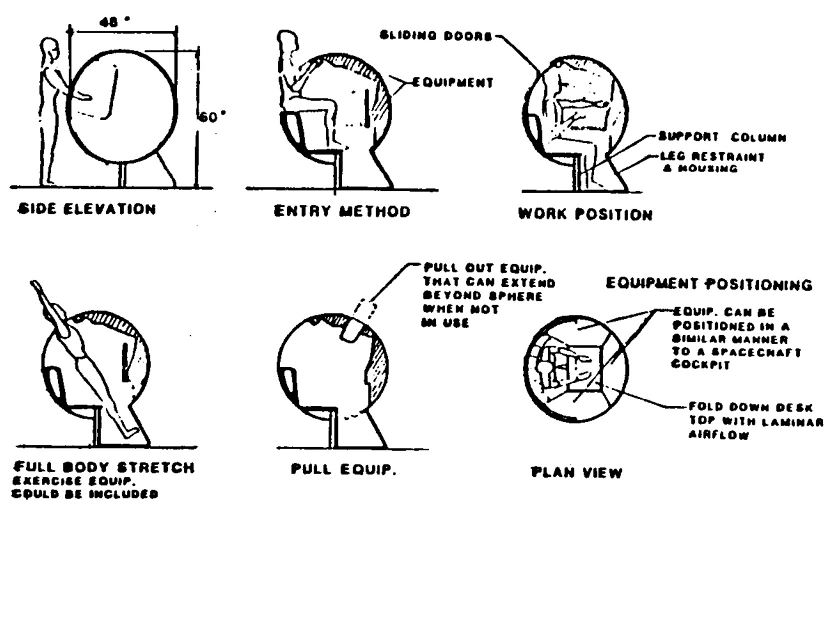
  HUMAN FACTORS FOR FLEXIBLE WORK SPACE

SPACEHAB INITIATIVE - PRIVATELY FINANCED COMMERCIAL VENTURE

GENERIC RESEARCH OF THE FIRST STUDY LED TO THE FLAT END CAP AND WORK POD WHICH EVOLVED INTO THE DEVELOPMENT OF THE SPACEHAB DESIGN



Triangular Central Beam



OBJECTIVE / OUTPUT

OBJECTIVE:

TO EXPLORE AND ANALYZE THE INTERACTION

OF

MAJOR UTILITIES DISTRIBUTION

GENERIC WORKSTATION

SPATIAL COMPOSITION

OF MODULE INTERIOR

OUTPUT: INQUIRY BY DESIGN DERIVED EVALUATION CRITERIA

RESULTS OF THE FIRST STUDY

1. INTERNAL UTILITIES DISTRIBUTION IS A MAJOR DESIGN DRIVER.
2. WORK STATIONS HAVE CRITICAL RELATION TO UTILITY DISTRIBUTION AND COULD BECOME THE INTERFACE TO SPACE STATION FOR SOCIETY THROUGH COMMERCIAL DEVELOPMENT OF THE ENGINEERING WORKSTATION.
3. TOGETHER UTILITIES AND EQUIPMENT INTERACE WITH SPATIAL COMPOSITION.
4. THE FLAT END CAP CAN PROVIDE AN ALTERNATIVE TO THE CONICAL END CAP FOR EFFECTIVE UTILIZATION OF THE STS.
5. THE MODIFICATION AND TECHNICAL UPDATING OF THE MODULE ON ORBIT IS A CRITICAL DESIGN DRIVER.

APPROACH BASICALLY "INQUIRY BY DESIGN"

1. THE STUDY OF WORKSTATION, UTILITIES AND HUMAN FACTORS REQUIRES THAT TEST DESIGNS START WITH AN INTERIOR CONFIGURATION FREE OF ONE GRAVITY CONVENTIONS SUCH AS UP-DOWN, FLOOR/CEILING.

   (BUT DOES NOT PRECLUDE EVOLUTION OF CONVENTIONAL FORMS FROM RESEARCH DESIGNS.)

2. SEARCH OF POSSIBILITIES LED TO SELECTION OF CENTRAL BEAM APPROACH AS MOST FREE OF ARCHITECTURAL CONVENTIONS – TO BE USED AS A 'TEST BED' FOR INQUIRY BY DESIGN.

3. DEVELOP THEORETICAL APPROACHES TO INTERIOR CONFIGURATIONS TO EXPLAIN INTERACTION OF BEAM, WORK POD DERIVATIVE, LOGISTICS SUBMODULES AND SPATIAL COMPOSITION.

4. DEVELOP INTERIOR CONFIGURATIONS TO TEST THEORETICAL VARIABLES:

   - 6 BEAM CONFIGURATIONS, GROUPED IN THREE PAIRS.

   - HUMAN FACTORS/ COMMERCIAL/ FUNCTIONAL

APPROACH BASICALLY "INQUIRY BY DESIGN"

5. THRASH/ WRING OUT HUMAN FACTORS ISSUES AS OPPOSITIONS/GRADIENT AND AS COMPONENTS OF HUMAN PRODUCTIVITY —— OPERATION/DESIGN/ HUMAN PERFORMANCE.

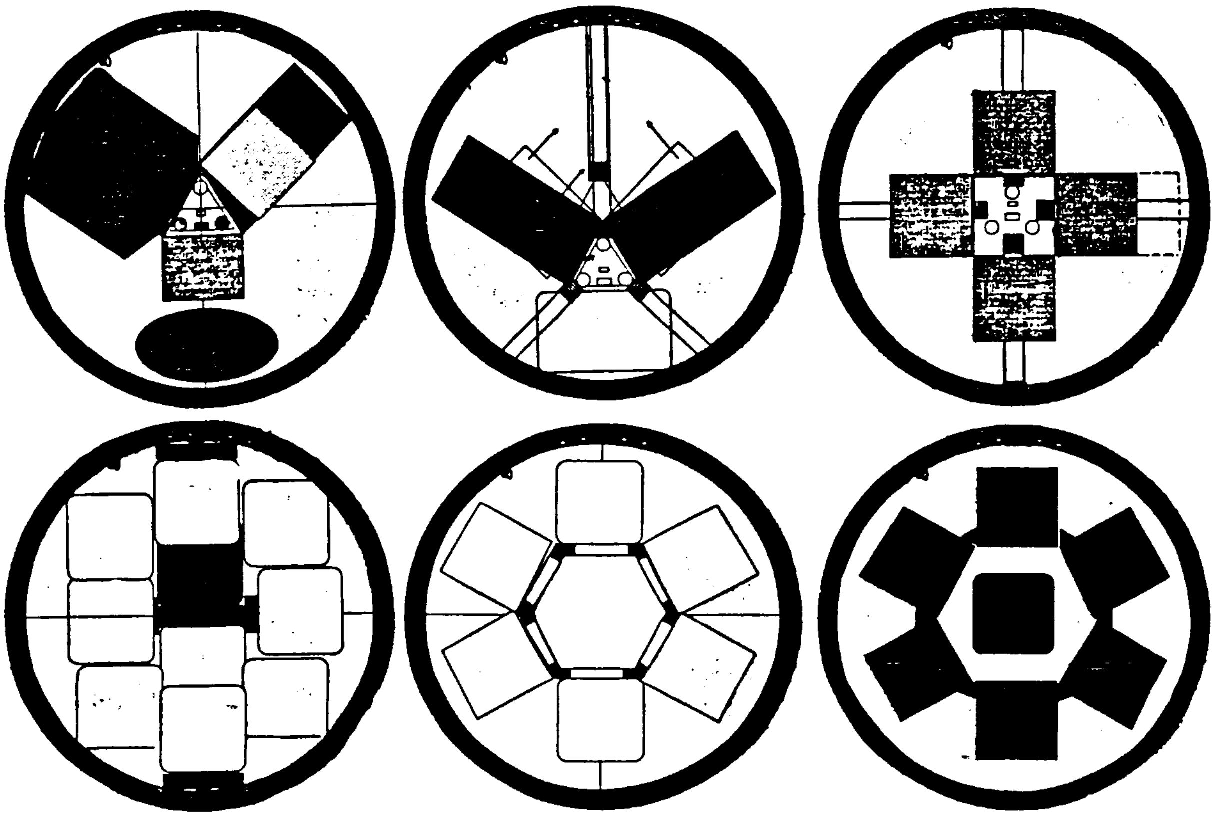
6. OBSERVATIONS

7. FINDINGS

8. RECOMMENDATIONS

   EVALUATION CRITERIA

CENTRAL BEAM TEST DESIGNS



ISSUES: OPPOSITIONS OR GRADIENTS

COMPOSITION OF INTERIOR VOLUME AS A LIVING VOLUME VS RESIDUAL 'NEGATIVE' VOLUME

PACKING DENSITIES VS CIRCULATION

PACKING DENSITIES VS PERCEIVED SPACIOUSNESS

SYMMETRY VS ASYMMETRY

EFFICIENCY OF PACKING / STANDARDIZATION VS FLEXIBILITY / DIVERSITY

STANDARDIZATION OF UTILITY INTERFACES VS DIVERSITY OF ACCOMMODATION REQUIREMENTS

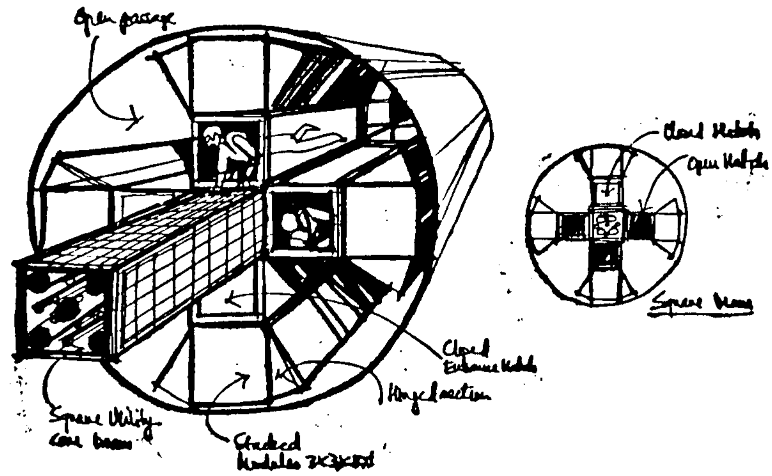
STANDARDIZATION OF STRUCTURAL INTERFACES VS DIVERSITY OF MODULAR PACKAGING

CENTRAL BEAM TEST DESIGNS

SQUARE BEAM ON CENTER

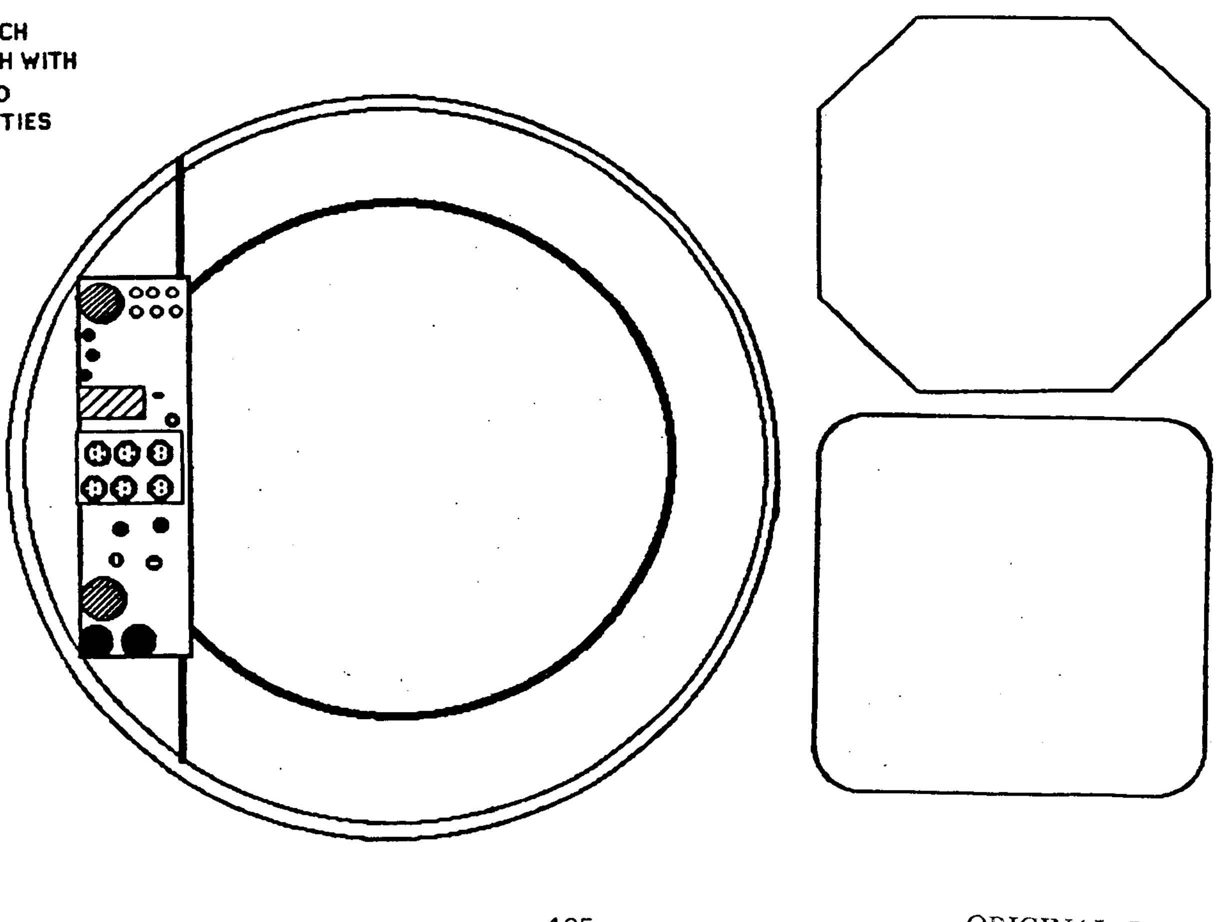
PERMITS TWO AXIS SYMMETRY

MOST PERFECTLY SPACE FILLING BEAM ALLOWS ALIGNMENT OPPOSITE SIDES

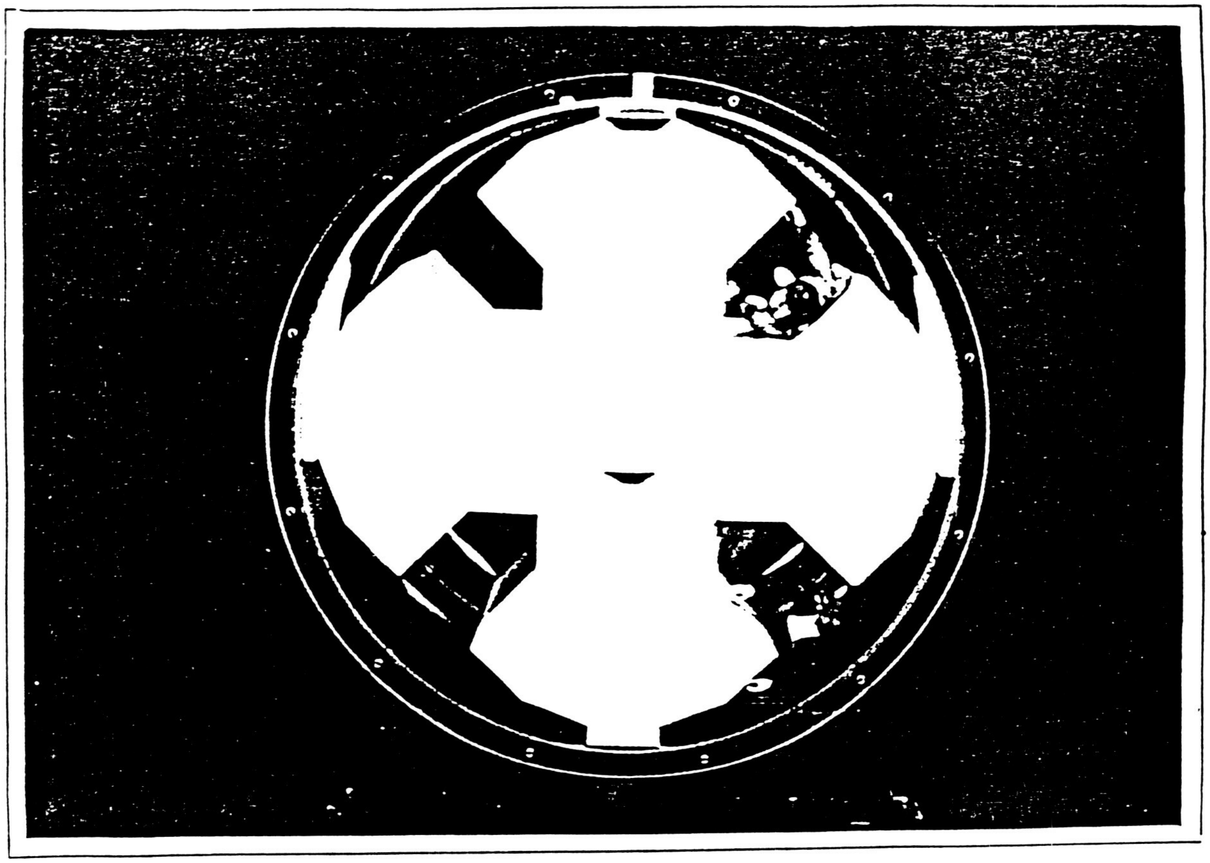


Hatch Assumption

50 INCH HATCH WITH BOXED UTILITIES



ORIGINAL PAGE IS OF POOR QUALITY



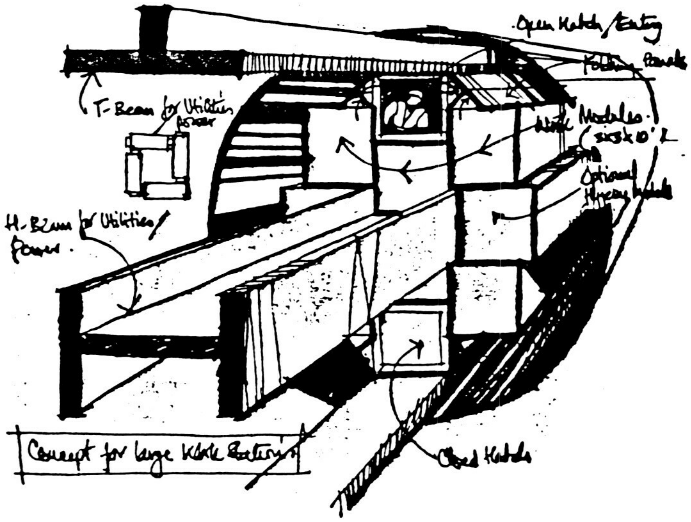
SQUARE BEAM WITH EXPANDED SUBMODULES

CENTRAL BEAM TEST DESIGNS

H BEAM - ON CENTER

LEAVE ONE SUBMODULE OUT TO PERMIT PASSAGE

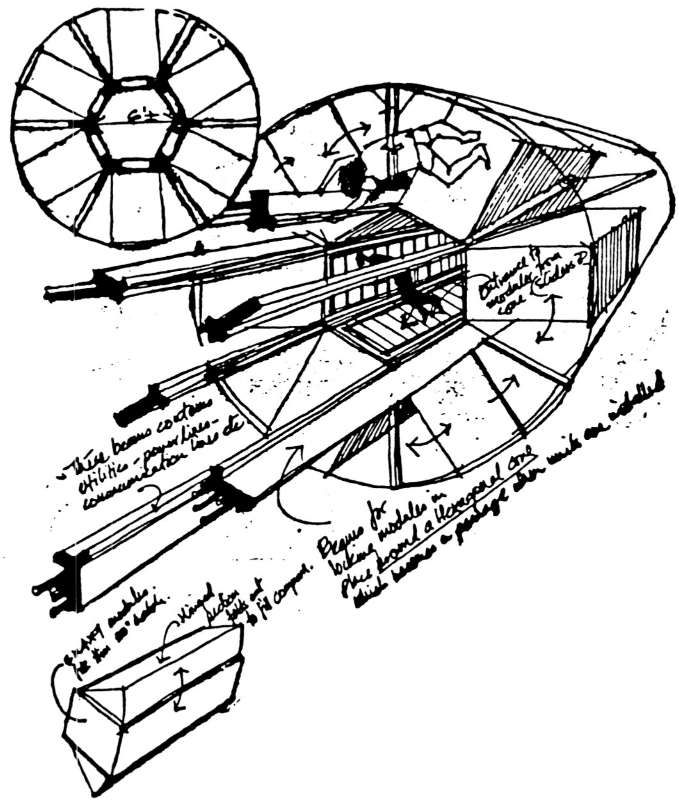
DISTRIBUTED UTILITY LOOPS



ORIGINAL PAGE IS OF POOR QUALITY

CENTRAL BEAM TEST DESIGNS

HEXAGONAL BEAM - LARGE



GOOD EFFICIENCY FACTORS

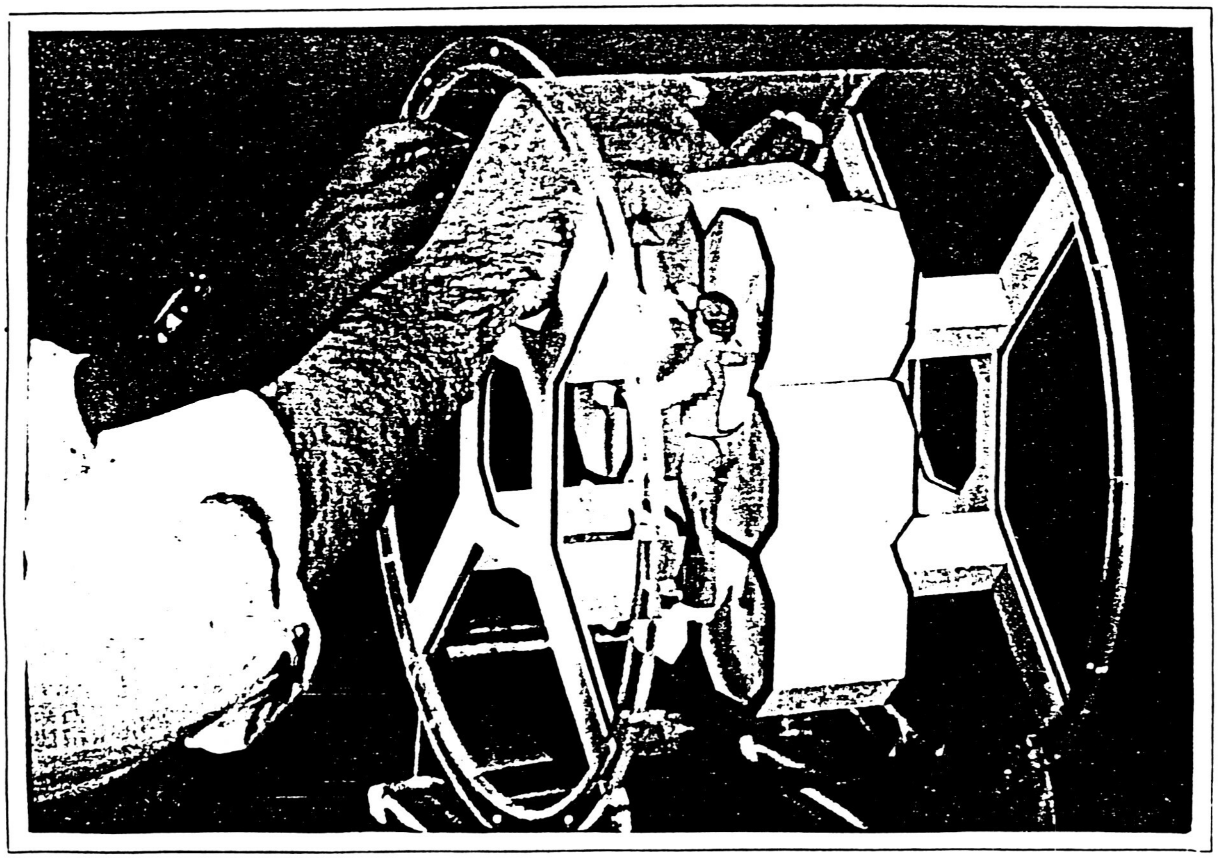
HIGHEST PACKING DENSITY

CENTRAL BEAM TEST DESIGNS

HEXAGONAL BEAM - SMALL WITH CENTER PASSAGE

GOOD LOGISTICS IMPLICATIONS

GOOD CIRCULATION AND ACCESS TO ALL CHANGE OUT UNITS



HEXAGONAL BEAM - SMALL

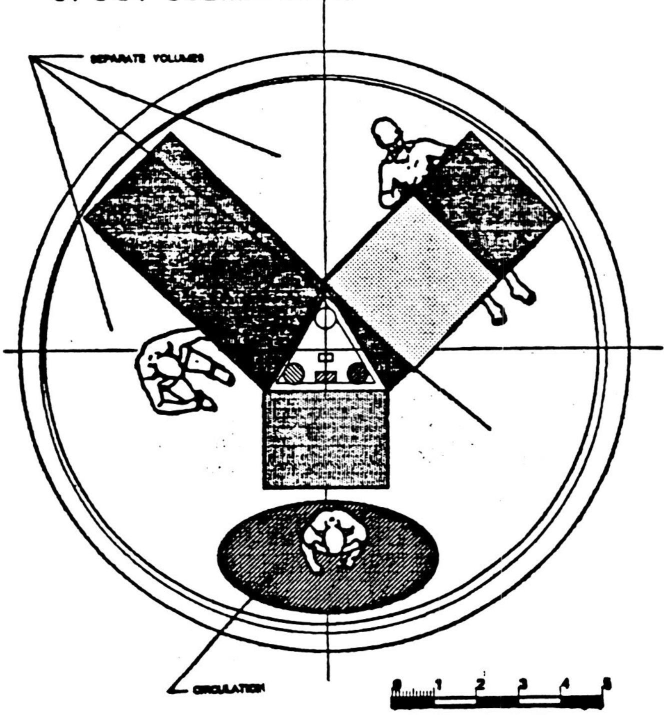
CENTRAL BEAM TEST DESIGNS

TRIANGULAR BEAM
ON CENTER

SYMMETRIC CORE W/ 120 DEGREE BRACE AT THIRD POINTS

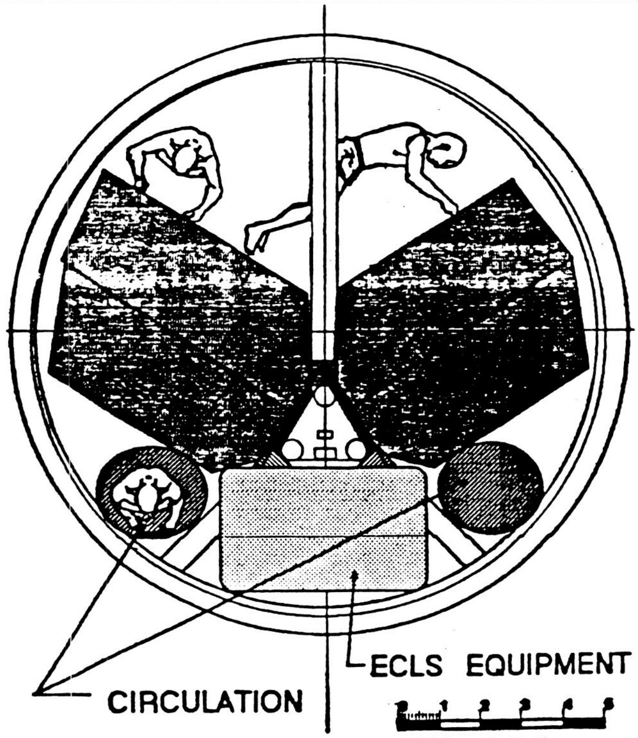
RELATES WELL TO CIRCLE

SUFFICIENT VOLUME FOR UTILITIES



CENTRAL BEAM TEST DESIGNS

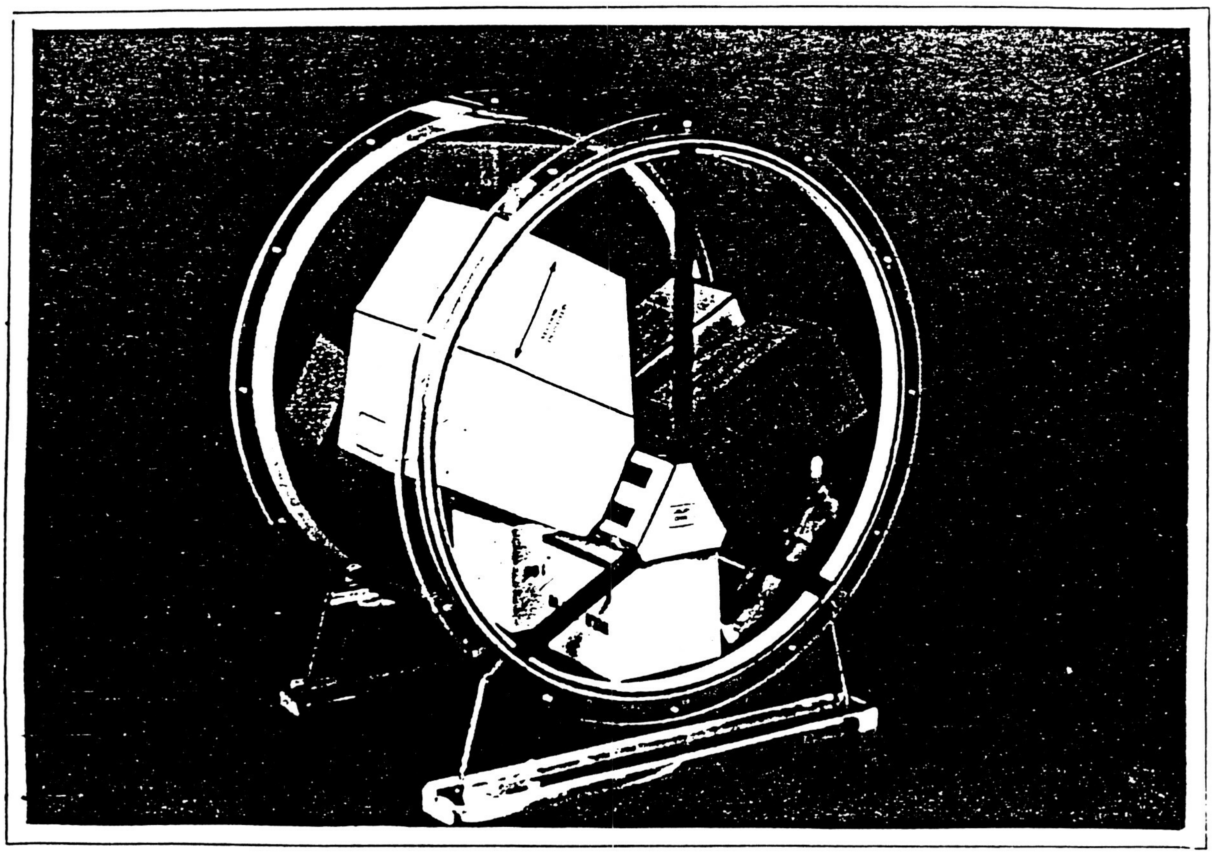
TRIANGULAR BEAM OFF CENTER



MOVING CORE OFF CENTER YIELDS GREATER CROSS SECTIONAL AREA AND DIVERSITY OF FUNCTIONAL ALLOCATIONS

PERMITS USE OF EXPANDABLE SUBMODULES EFFECTIVELY

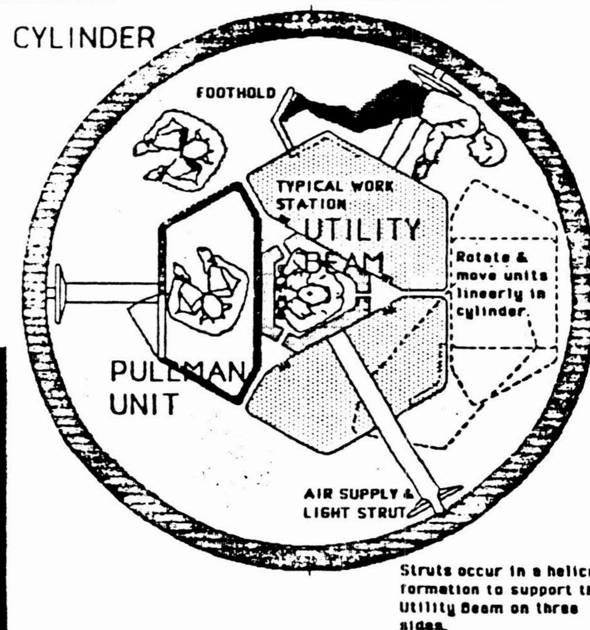
SUFFICIENT VOLUME FOR UTILITIES



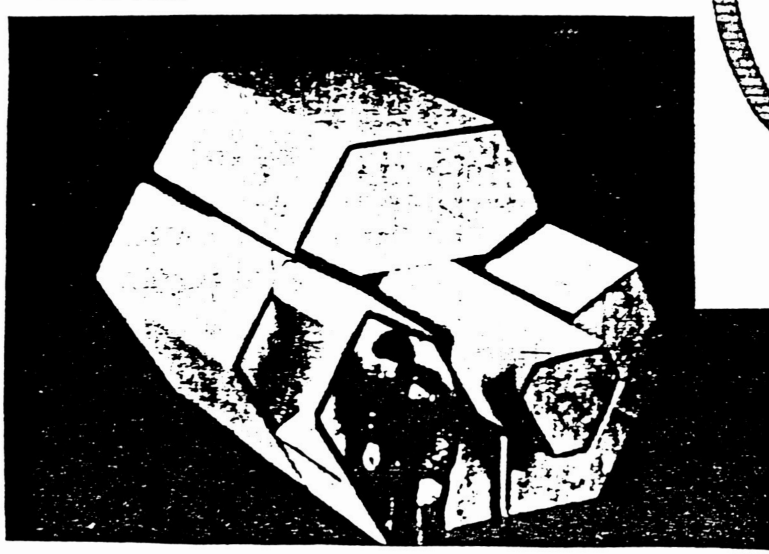
TRIANGULAR BEAM - OFF CENTER

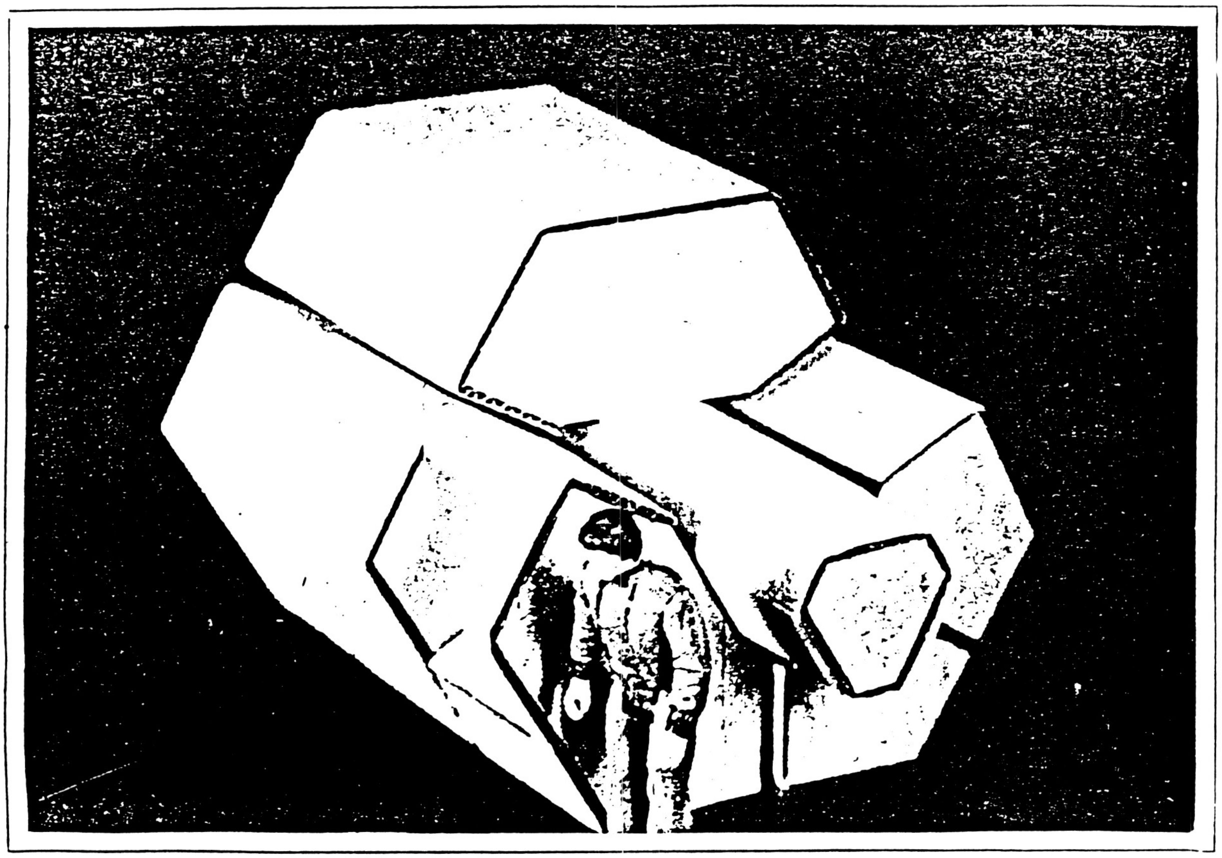
CENTRAL BEAM TEST DESIGNS

CENTER CLUSTER BEAM WITH EXTERNAL CIRCULATION



MOVEMENT OF CHANGE OUT UNITS IS NEAR THE INNER SURFACE OF THE MODULE



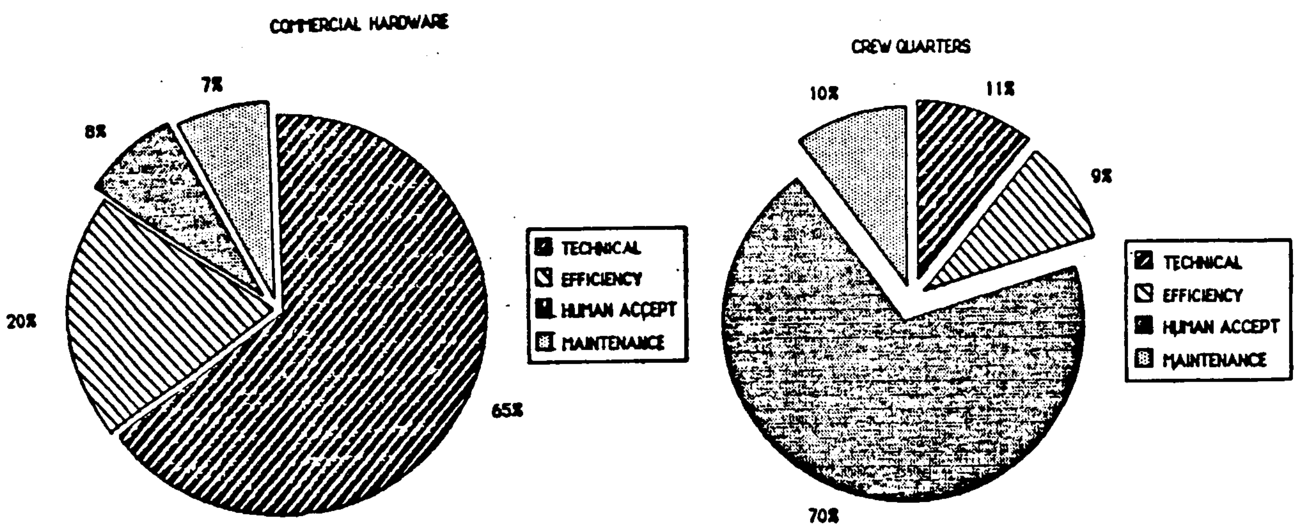


CENTER CLUSTER BEAM

COMPARISONS - VOLUME AND PACKING DENSITY

BEAM	UNEXPANDED VOLUME	EXPANDED VOLUME	PASSAGE WAYS	NEGATIVE VOLUME	%	COMMENTS PACKING DENSITY
SQUARE BEAM	36	89	22.5	26.2	19	65 %
H BEAM	58.5	82.5	9	44.4	32	62 %
HEX LARGE	54	89.2	22.7	15.1	11	73 %
HEX SMALL	TBD					
TRI-ON CENTER	49.5	82.5	50	4.1	3	61 %
TRI-OFF CENTER	54	86.5	37	12.5	9	65 %
CLUSTER BEAM	TBD					
SPACE-LAB	46.9	64	41	21.5	15	56 %

Recommended Evaluation Factor Examples



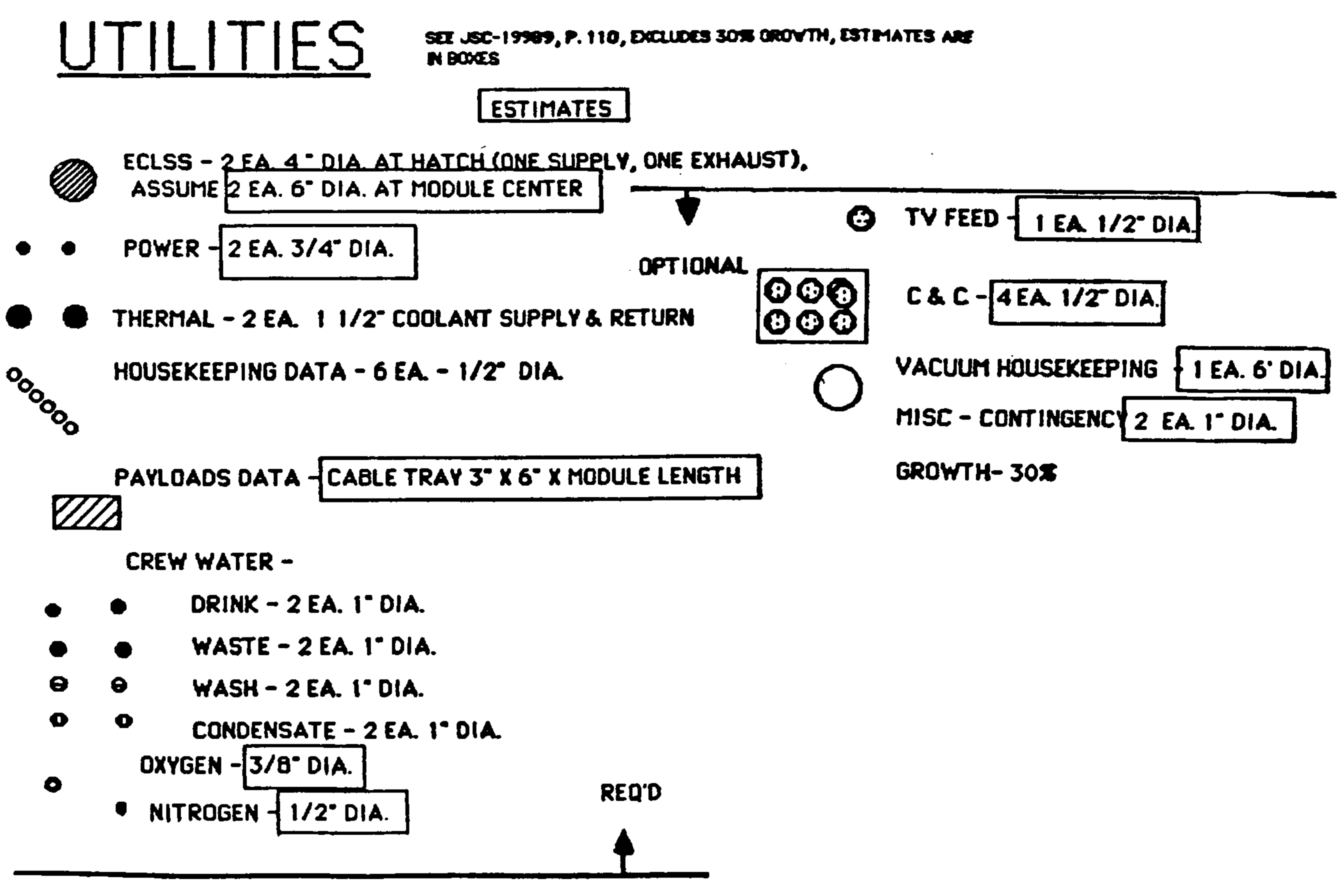
EVALUATION FACTOR

EXAMPLES OF WEIGHTED COMPONENTS

ORIGINAL PAGE IS
OF POOR QUALITY

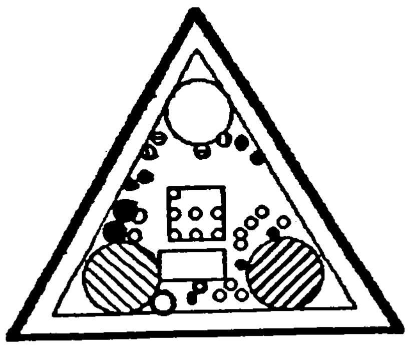
ORIGINAL PAGE IS
OF POOR QUALITY

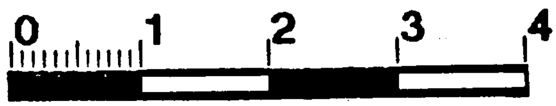
Assumed Utilities



UTILITY PLANNING

TRIANGULAR CENTRAL BEAM





SCALE 1" = 1' - 0"

7.3 CF ECLSS
35.3 CF OPTICAL, ETC.
17.6 CF INTERNAL UTIL.
10.8 CF HAB

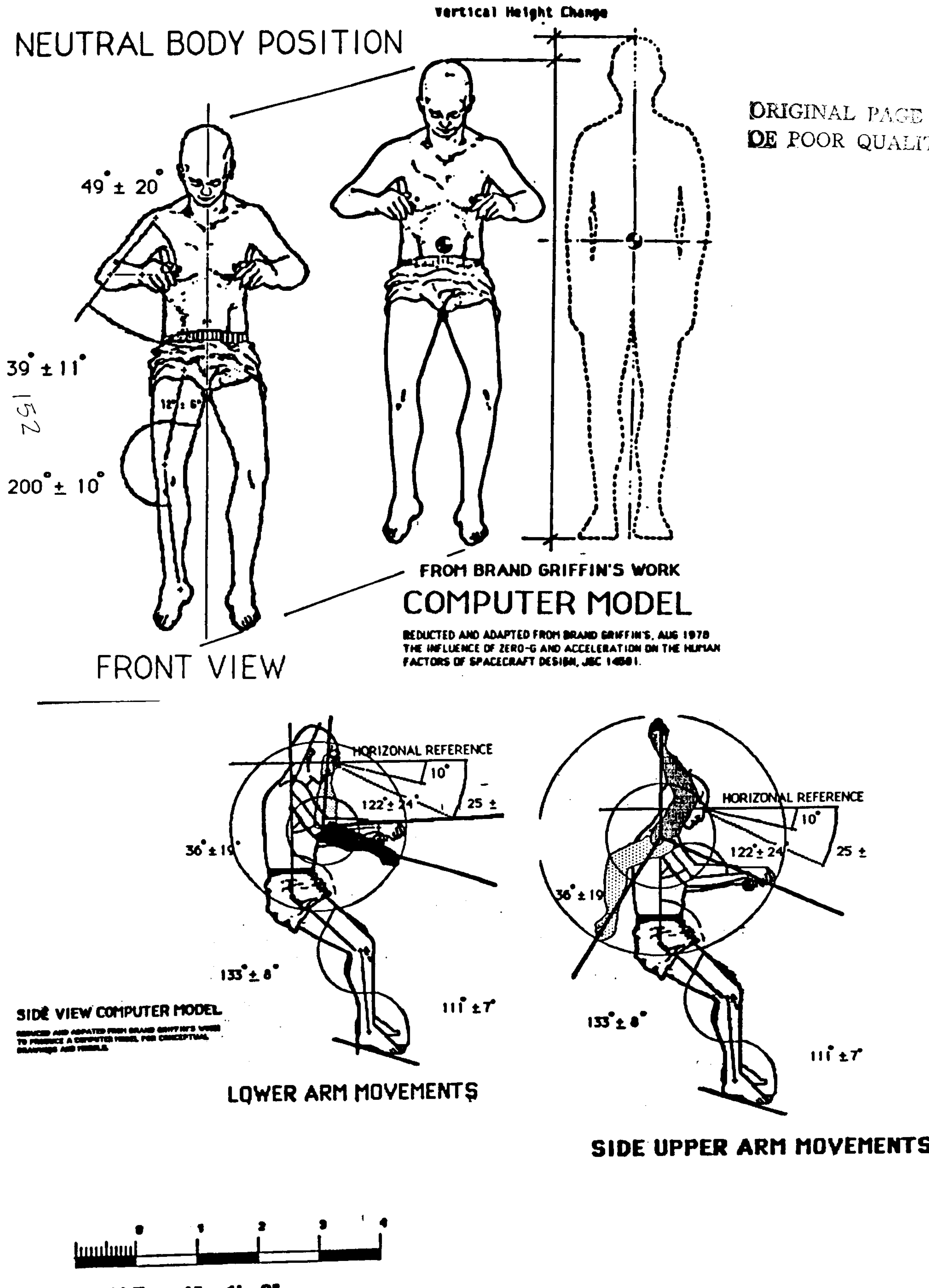
71.0 CF REQUIRED

INTERNAL VOLUME

VOLUME W/O 1" 1/2" STRUCTURE

= 2.85 CF X 27' = 77 CF

PLUS TRANSITIONS AND HATCH PASS THROUGHS



NEUTRAL BODY POSITION
Vertical Height Change
49° ± 20°
39° ± 11°
12° ± 6°
200° ± 10°
FRONT VIEW
FROM BRAND GRIFFIN'S WORK
COMPUTER MODEL
REDUCTED AND ADAPTED FROM BRAND GRIFFIN'S, AUG 1978
THE INFLUENCE OF ZERO-G AND ACCELERATION ON THE HUMAN
FACTORS OF SPACECRAFT DESIGN, JSC 14581.
HORIZONAL REFERENCE
10°
122° ± 24°
25 ±
36° ± 19°
133° ± 8°
111° ± 7°
SIDE VIEW COMPUTER MODEL
LOWER ARM MOVEMENTS
HORIZONAL REFERENCE
10°
122° ± 24
25 ±
36° ± 19
133° ± 8°
111° ± 7°
SIDE UPPER ARM MOVEMENTS
0
1
2
3
4
SCALE 1" = 1' - 0"

152

N88-19885

SPACE STATION ARCHITECTURAL ELEMENTS MODEL STUDY

No. 31799

Order No. A-21776 (MAF)

MICHAEL KALIL

AERO-SPACE HUMAN FACTORS DIVISION
NASA AMES RESEARCH CENTER
MOFFETT FIELD, CA 94035

SPACE STATION HUMAN FACTORS RESEARCH REVIEW

December 3 to December 6, 1985

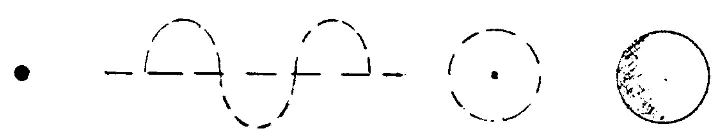
Ames Research Center
NASA Contract A 21776 (MAF)

Space Station Architectural Elements Model Study

Introduction:
It is our premise that the primary issue in the creation of architecture is how the relationship of Individual and Place to architecture is understood.

There is a unity and order common in nature and in man which we continually respond to in the creation of our man-made environments. Certain proportions used again and again indicate the inter-relatedness of all things -- whether created by nature, or apparent in the most ageless creations of man. So far in the effort to create a space station suitable for human habitation the materials and hardware necessary have been developed by technological research. Now we must pay attention to the appropriate spaces which will allow us to house ourselves with dignity within the vast reaches of our universe.

The recognition of unity as the foundation to our preliminary design drawings is best expressed in the following illustration:



"Unity", the basic vibratory element of matter (a) produces an oscillatory motion which, when observed, generates a wave (b). The wave is classically the foundation of a circular form (c). A spherical body (d) is generated by the rotation of this circular form, returning one's perception to unity.

Proportional Powers:
There is a power of certain proportions analogous to musical and root harmonies that has been known since ancient times. Certain proportions create harmony and unite parts of a whole. In other words, space and form are harmonious when their internal relationships are such that a whole is created.

Ames Research Center
NASA Contract A 21776 (MAF)

Space Station Architectural Elements Model Study

There are proportions, patterns and an order which will unfold when unity is used as an ordering principle. Unity has three powers in this project:

PLACE:	Position of Space Station in the Universe
ARCHITECTURAL SHELL:	The preferred diameter of the cylinder
INDIVIDUAL:	The center point in the window of the eye

Attention must be given to unity, order, and the harmony of elements which support the creation of space for the individual to dwell with meaning.

Background:
In the first stages of this project the need was seen to examine the proposition that harmonious proportions are the key element in a well-ordered and easily comprehended environment. The use of the word "proportion" here describes the manner in which shape and form and dimensions relate to the whole. Ratios describe the relationship between two or more dimensions. They, ratios, are non-dimensional numerical values representing relationships between dimensioned quantities. There is a reciprocal relationship between two unequal parts of a whole. The small part stands in the same proportion to the large part as the large part stands to the whole. The different parts of the whole are united yet each maintain their own identity while blending into a greater whole.

In reviewing the history of the existence of proportional relationships, one must consider the role of natural phenomenon in the overall sense of harmony. Natural evolutionary processes first established dimensional ratios which, when analyzed mathematically, surface the "Golden Section" as the prevalent value found. We can also see many values in nature falling within a rather narrow band of this proportion. This phenomenon is too glaring and consistent to be ignored. Mathematically, this ratio has the value of 1.618 and can be found in crustations, plants, insects, shells, pine cones, the human face and in a myriad of other forms. Some are resolved within spiral configurations and others are found in the relationships of linear dimensions. Each is related to the growth pattern of the organism. Our proclivity to use and preference for the ratios in the range of the Golden Section then goes deeper than the fact that consciously, a given shape or form is pleasant to the eye. Our continued exposure to this proportional ratio in nature for eons has provided us with almost genetic preferences for this range of ratios.

Since very early times in history, man has used systems of proportionality, stemming from nature, as a method of installing order in his creations. Enduring man-made works can be analyzed and understood by examining their proportional systems. For centuries shaman, artisans, and architects of many civilizations have exhibited a preference for specific ratios. As examples of this order we can look at many civilizations and their specific expressions such as Stonehenge, the Parthenon, Chartres, the Garden of Ryoan-Ji, etc. which all use the Golden Section as unity. It is evident that those human creations, which we define as enduring, express a truth and a relationship to the basic pattern-forming process of nature.

Schematic Studies:
The investigation of a proportional base for the design of the habitation module establishes the diameter as "Unity". The development of geometric forms, as the support system to the shape of space, unfolds from "Unity" creating and balancing

dimensions of the module for specific user needs. Ratios for consideration were derived from figures which represent values of 1.414, 1.618, and 1.73. These values are derived from geometric figures based on $\sqrt{2}$, the Golden Section, and $\sqrt{3}$. Elements of construction based on these ratios are made and tested for balance and harmony. This is an on-going process in order that the best ratios for the design be found and that small differences in perception and harmony are resolved. For this reason, a strict numerical ratio has not been established; however, the range of values has been narrowed to that which best fits the needed pattern. There the Properties and Behavior of the Individual and the architectural shell unite to form opportunities for selection with respect to the interior arrangements of the habitation module.

Conclusion:
The Space Station, as with all architecture, must unite the Properties and Behavior of Individual and Place, using proportions from both to make whole the understanding of ourselves at this moment in evolution. Harmonious proportions in any environment are similar to the acceptance and enjoyment of the harmony of many well-tuned musical instruments. A well-tuned or well-ordered environmnet tends to have "invisible" proportions. They produce order but do not intrude on the perception and cognitive mapping of the environment.

Systems of proportion are not ends in themselves but are a means to select a series of "Spaces" which relate one to another in dimensionally specific terms. These internal relationships create a whole when the forms are harmonious. This harmonic relationship is of intrinsic value for individuals to be physically and psychologically in balance with their universe.

Ames Research Center
NASA Contract A 21766 (MAF)

Space Station Architectural Elements Model Study

"Whenever a human being truly dwells, he sets up a region of meaning that is charged with different levels of sensibility. A healthy environment allows the person to move through different spaces, sense their qualitative differences, and grasp a unifying pattern."[1]

[1] Joseph Grange, "Radiant Lessons for the Failed Landscape of Desire:, Places 2, no. 2 (Spring 1985): 18-23.

N88-19886

SPACE STATION GROUP ACTIVITIES HABITABILITY MODULE STUDY : A SYNOPSIS

DAVID NIXON AND TERRY GLASSMAN
INSTITUTE FOR FUTURE STUDIES, SCI-ARC

OBJECTIVES

The purpose of the study is to explore and analyse architectural design issues involved in the Group Activities Habitability Module identified in the Space Station Reference Configuration (ref. 1) as Habitability Module 1 and hereinafter referred to as HM1. The principal features of HM1 are the galley, wardroom and health maintenance (exercise) facilities, of which the wardroom is the most significant in terms of size and operation. Various design strategies for the interior of HM1 are proposed in scale model form. Each strategy demonstrates an approach that addresses certain design issues or requirements and how they impinge on the interior of the Common Module. The results will be combined in a set of preliminary illustrated design guidelines and recommendations for the interior of HM1.

SCHEDULE

The study is divided into a research phase and a design phase. The research phase, which commenced in June 1985 and completed in August 1985, identified a set of architectural design program requirements and a set of preliminary habitability design guidelines for HM1. The design phase, which commenced in September1985 and will complete in December 1985, comprises the study of a series of schematic approaches to the interior configuration of HM1 with appropriate evaluations and recommendations.

RESEARCH PHASE: ARCHITECTURAL DESIGN PROGRAM

The Architectural Design Program developed during the research phase identified a range of accommodation and facilities required within HM1 in terms of broad design characteristics and outline design requirements. The range of accomodation and facilities are designated in terms of ten activity types which are summarized as follows:

1 Meetings and Teleconferences
2 Planning and Training
3 Relaxation and Entertainment
4 Eating and Drinking
5 Food Preparation and Cooking
6 Exercises and Games
7 Housekeeping and Hygiene
8 Space Station Operations
9 Meditation and Study
10 Shift and Crew Handovers

RESEARCH PHASE: PRELIMINARY HABITABILITY DESIGN GUIDELINES

The Preliminary Habitability Design Guidelines developed during the research phase comprise background advisory guidelines necessary to support the design phases of the study. They include information on crew activity routines, crew activity proximities, crew activity ergonomic envelopes and crew activity group volumes.

Crew Activity Routines

A study of crew activity routines provides a necessary reference framework for establishing the types and sequence of crew activities likely to occur in HM1. Original criteria on crew make-up and scheduling were taken from Space Station Definition and Preliminary Design (ref. 2). 24-hour routine activity timetables are used to compare crew routines with crew numbers, groupings and shifts. Key activities occuring in HM1 are identified as a flow sequence with the number of sequence cycles in a 24-hour period governed by the number of crew shifts involved. A single sequence cycle includes activities occuring consecutively in time and activities occuring in parallel. A single cycle occuring twice in 24-hours for a two shift crew contains the following activities summarized in chronological order:

A Lunch
B Training
C Station Specialist Operations
D Planning + Exercise and Recreation (parallel)
E Breakfast + Shift Handover and Unscheduled Time (parallel)
F Dinner
G Station Specialist Operations + Exercise and Recreation (parallel)

Crew Activity Proximities

A study of crew activity proximities is used to identify crew activity spatial and organizational interrelationships and key activity adjacency criteria using significant Space Station habitability recommendations (ref. 3), and extended spaceflight human requirements (ref. 4). A matrix is used to interrelate each activity type on a 5-point scale of spatial compatability showing which activities can be combined or adjacent, and which activities need partial or complete separation. The matrix is summarized in a simple bubble diagram which outlines significant activity proximities and separations as well as typical crewmember daily circulation routes. The proximity studies indicate that the key crew activities in HM1 can be wholly or partly combined into five spatial or compartmental groups, of which the first is volumetrically and socially the most significant. The five groups are:

- Meetings and Teleconferences, Eating and Drinking, Planning, Relaxation and Entertainment
- Meditation and Study
- Food Preparation and Cooking
- Exercises and Games
- Space Station Operations

Crew Activity Ergonomic Envelopes

A set of scale diagrams is used to identify a preliminary range of ergonomic geometries for individual crewmember activities using established anthropometric criteria (ref. 5) and background workstation design studies (ref. 6). The diagrams examine the interfaces between a single figure and different ergonomic envelopes for a range of activities common to HM1. Each interface is illustrated as three different geometries describing a minimum feasible, a maximum feasible and a median approach to the envelope involved. Anthropometric neutral body postures for the 5% female and 95% male percentile groups are applied to the envelopes in plan, front and side view. Related reach envelopes and sightlines are indicated. The following five activities drawn from the activities identified in the Architectural Design Program are examined using this technique:

- Meetings
- Planning and Training
- Eating and Drinking
- Food Preparation and Cooking
- Space Station Operations

As an example, Figures 1 is the composite diagram for Planning and Training.

Figure 1 overlays the separate diagrams for minimum and maximum feasible envelopes (shown in Figure 1 as dashed and dotted outlines respectively), and illustrates the median envelope between the two. The median envelope is determined by optimizing worksurface and viewing surface areas within acceptable arm reach and sightlines of 5% female and 95% male percentile groups while remaining compact in overall physical form. The worksurface area comprises keyboard, checklist display, notebook, object restraint and ancillary control zone of 0.33 sq.m., and viewing surface area comprising twin monitor, tapedeck, a/v control, reference manual display and instrumentation zone of 0.66 sq.m. The shape and size of the median envelope is considered to be close to a recommended reference envelope for Planning and Training workstation activities.

Crew Activity Group Volumes

The set of scale diagrams developed as Crew Activity Ergonomic Envelopes is used to develop a set of scale diagrams which examine preliminary complex spatial envelopes for each major group activity in HM1. Using the median individual activity envelopes as building-blocks, the diagrams identify alternative volumetric geometries generated by the number of crew involved in each group activity. The volume shapes and sizes are determined by the combined stationary crew envelopes, associated physical movement patterns and activity sightline requirements. The following five activities drawn from activities identified in the Architectural Design Program are examined using this technique:

- Meetings
- Teleconferences
- Planning and Training
- Eating and Drinking
- Food Preparation and Cooking

As an example, Figure 2 shows alternative crew group volumes for Planning and Training.

The diagrams are based on the median individual activity envelope for Planning and Training illustrated in Figure 1. Six alternative arrangements are identified for two adjacent Planning and Training workstations. In order of sequence they are: (A) face-to-face direct, (B) face-to-face angled out 90°, (C) side-to-side direct, (D) face-to-face offset, (E) side-to-side angled out 90°, (F) back- to-back. Each diagram also shows an adjacent crew circulation route requirement.

SCHEMATIC DESIGN PHASE: BASIC METHOD

The schematic design phase (in progress at the time of writing) involves the development of a series of outline design concepts for the interior configuration of HM1 in scale-model and explanatory drawing form . Each design concept expresses an alternative design approach based on individual interpretations of how the programmatic requirements identified in the Research Phase can be resolved within the shape and size constraints of the Common Module interior.

SCHEMATIC DESIGN PHASE: INDIVIDUAL CONCEPTS

Ten outline design concepts for the interior configuration of HM1 have been selected as test concepts with substantially different design objectives. At a schematic design level, the value of choosing and pursuing widely and deliberately different concepts is twofold:

- Wide-ranging interpretations of a common design problem at an early stage can sometimes herald or highlight innovatory design concepts which potentially can develop superior operational potential to more traditional or conventional counterparts.
- The process of developing and documenting such innovatory design concepts at a schematic level broadly identifies their field of feasibility and gives an early indication of the nature and extent of their realistic application before commitment to design development.

The ten alternative design concepts, not in any ranked order, are summarized as follows:

1 Flexible, freeform envelope highly responsive to fluctuating crew activity requirements using air-activated transformation / rigidization of interior linings.

2 Dedicated architectural organization and circulation with sequence of fixed compartments and adaptable elements determined by established activity requirements.

3 Highly adaptable operation with frequent or cyclical crew-generated compartment changes using modular and articulated partition and lining elements/equipment.

4 Twin, partly-adaptable, interlocking compartment complexes containing circulation paths and crew activity enclosures with integral equipment and storage facilities.

5 Organizational identity responsive to community and privacy needs using combination of fixed and telescopic compartments and adaptable elements and equipment.

6 Transformable, modular, internal configuration achieving changes using articulated and linked pentahedral capsules with various equipment and storage functions.

7 Open, unrestricted volume with discrete multi-purpose element and equipment features adaptable and responsive to variable daily crew activity requirements.

8 Evolutionary design approach responsive to future compartmental or equipmental adaptation generated by changing habitability operational requirements.

9 Definitive architectural character with regularly-spaced tubes acting as multi-purpose consoles for range of equipment and storage applications.

10 Clear anthropometric expression of linked and cellular compartments using series of anthropometric activity volumes as major design generators.

SCHEMATIC DESIGN PHASE: ANALYSIS AND EVALUATION

The analysis and evaluation of the outline design concepts for the interior configuration of HM1 will be carried out in matrix form. Matrix techniques will be used to analyse the ten individual design concepts outlined above, and expressed in scale-model and explanatory drawing form, with a range of ten key design factors applicable to all module types. The analysis results will be evaluated by taking each key design factor and identifying different methods of architectural interpretation using the ten outline concepts as examples. The ten key design factors to be used in this exercise are:

A Basic Configuration
B Communal Organization
C Spatial Perception
D Compartmental Modification
E Internal Circulation
F Anthropometric Conformation
G Ergonomic Operation
H Sound Propagation
J Materials Application
K Life-Cycle Utilization

The results of the analysis and evaluation process will be summarized as a series of observations which will have three main aims:

- To compare the broad advantages and disadvantages of the design concepts.
- To rank the design concepts in order of feasibility of overall resolution of the greatest number of design factors examined together.
- To identify the individual design concepts which exhibit the greatest potential for optimizing each individual design factor examined in turn.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations based on the combined results of the Research Phase and the Schematic Phase will be contained in the Final Report.

SOME PRELIMINARY CONCLUSIONS

- THE LONG-TERM OPERATIONAL EFFICIENCY OF THE SPACE STATION MAY REQUIRE A FUTURE CAPABILITY FOR SUBSTANTIAL, BUT SIMPLE, ON-ORBIT MODULE INTERIOR MODIFICATION OR RECONFIGURATION (PERHAPS WITHOUT DE-COMMISSIONING). THE IMPLICATIONS OF THIS SHOULD BE IDENTIFIED AT THE PRELIMINARY DESIGN STAGE IF THIS CAPABILITY IS TO BE EFFICIENTLY AND ECONOMICALLY INCORPORATED.
- A POTENTIAL REDUCTION OF THE I.O.C. MODULE CLUSTER FROM FIVE TO THREE (IF MADE NECESSARY BY BUDGET CONSTRAINTS) WOULD PROBABLY REQUIRE SOME MULTI-PURPOSE OR SPATIALLY-ADAPTABLE HABITABILITY MODULE FACILITIES. THIS, IN TURN, COULD SIGNIFICANTLY INCREASE THE DESIGN COMPLEXITY OF CONFIGURATION ELEMENTS AND EQUIPMENT. THIS FACT MAY NEED TO BE TAKEN INTO ACCOUNT NOW.

- FUTURE INCREASED FREQUENCY OF TRANSIENT CREW CIRCULATION THROUGH HABITABILITY MODULES PRODUCED BY ADDITIONAL MODULES, EXPANDED CREW COMPLEMENT , CREW HANDOVERS OR EMERGENCY PROCEDURES MAY INCREASE THE RISK OF UNFORSEEN OBSTRUCTIONS OR 'BOTTLENECKS' IN HABITABILITY MODULES. THIS POSSIBILITY SHOULD BE TAKEN INTO CONSIDERATION IN EVALUATING CIRCULATION ROUTES THROUGH I.O.C. MODULES.

- A 'LIBRARY' OR SHARED QUIET AREA FOR ONE OR TWO CREWMEMBERS MAY BE AN IMPORTANT INGREDIENT IN MITIGATING THE POTENTIAL SOCIAL POLARIZATION THAT MAY ARISE IF THE ONLY OFF-DUTY CHOICE IS BETWEEN A PRIVATE SLEEPING COMPARTMENT OR THE COMMUNAL WARDROOM. A 'LIBRARY' CAN PROBABLY BE ACCOMMODATED IN HM1 WITHOUT ANY DIFFICULTY OR PENALTY IF IT IS TREATED AS AN INTERMITTENT-USE FACILITY.

- THE DECISION TO CHOOSE A 2-SHIFT OR 3-SHIFT DAILY CYCLE WILL SIGNIFICANTLY IMPACT THE DESIGN CONFIGURATION AND OPERATIONAL EFFICIENCY OF HM1. IN VIEW OF THE LARGELY UNKNOWN OPERATIONAL CHARACTERISTICS OF THE SPACE STATION AT THIS TIME, IT WOULD BE WISE TO ENSURE THAT ALL DESIGNS ARE EQUALLY APPROPRIATE TO BOTH SHIFTS.

REFERENCES

1. National Aeronautics and Space Administration: Space Station Reference Configuration Description, Systems Engineering and Integration, Space Station Program Office, Johnson Space Center, JSC-19989, August 1984.

2. National Aeronautics and Space Administration: Space Station Definition and Preliminary Design, Request for Proposal, September 15 1984.

3. Stuster, J. W.: Space Station Habitability Recommendations based on a Systematic Comparative Analysis of Analogous Conditions, Anacapa Sciences Inc., Ames Research Center, NAS2-11690, December 1974.

4. Connors, M. M.; and Harrison, A. A.; and Akins, F. R.: Living Aloft - Human Requirements for Extended Spaceflight, Ames Research Center, NASA SP-483, 1985.

5. Griffin, B. N.: Design Guide - The Influence of Zero-g and Acceleration on the Human Factors of Spacecraft Design, Johnson Space Center, JSC-14581, August 1978.

6. Bond, R. L.; and Gundersen, R. T.: Zero-G Workstation Design, Johnson Space Center, JSC-09962, June 1976.

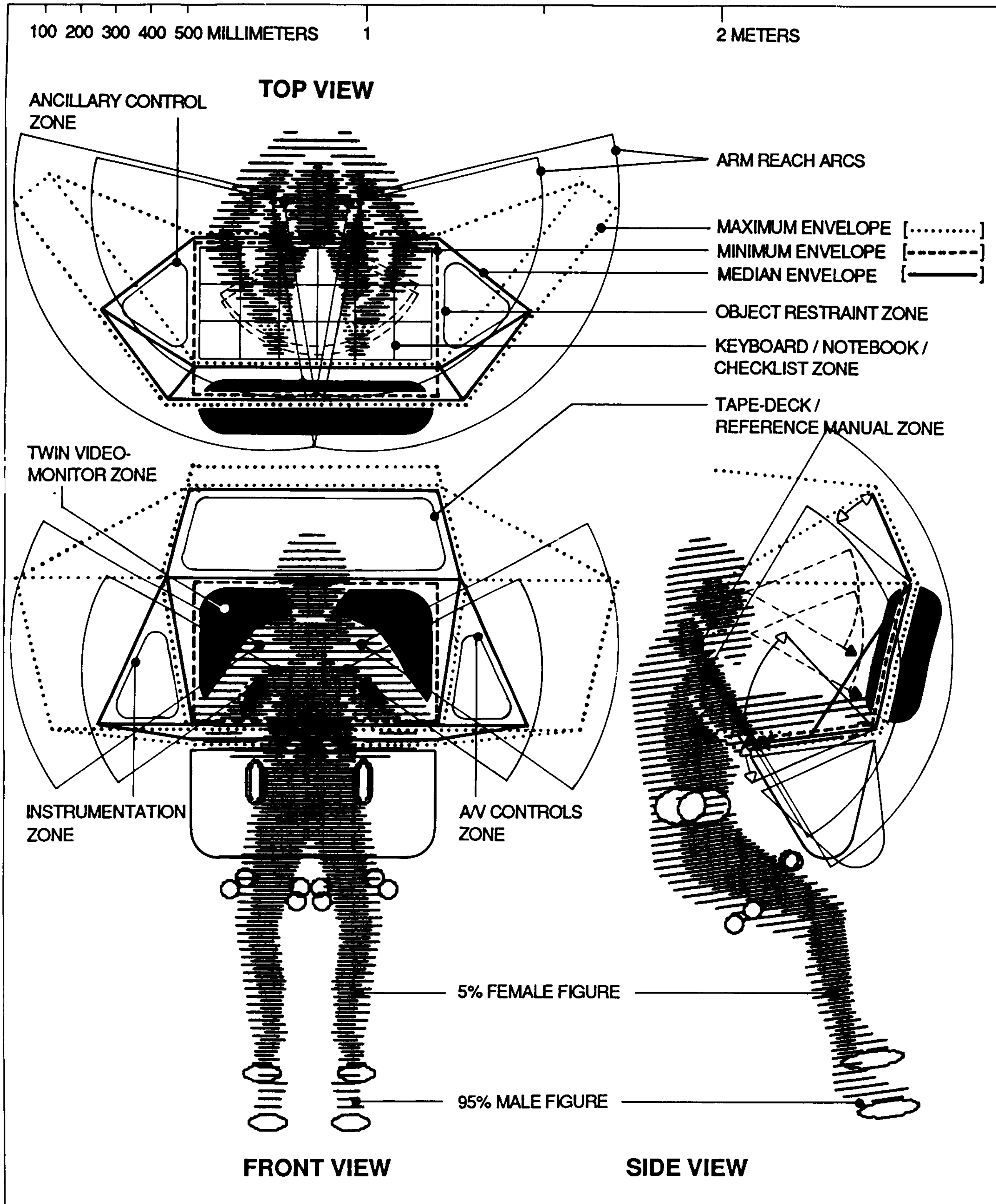


FIGURE 1 PLANNING AND TRAINING : ERGONOMIC ENVELOPES

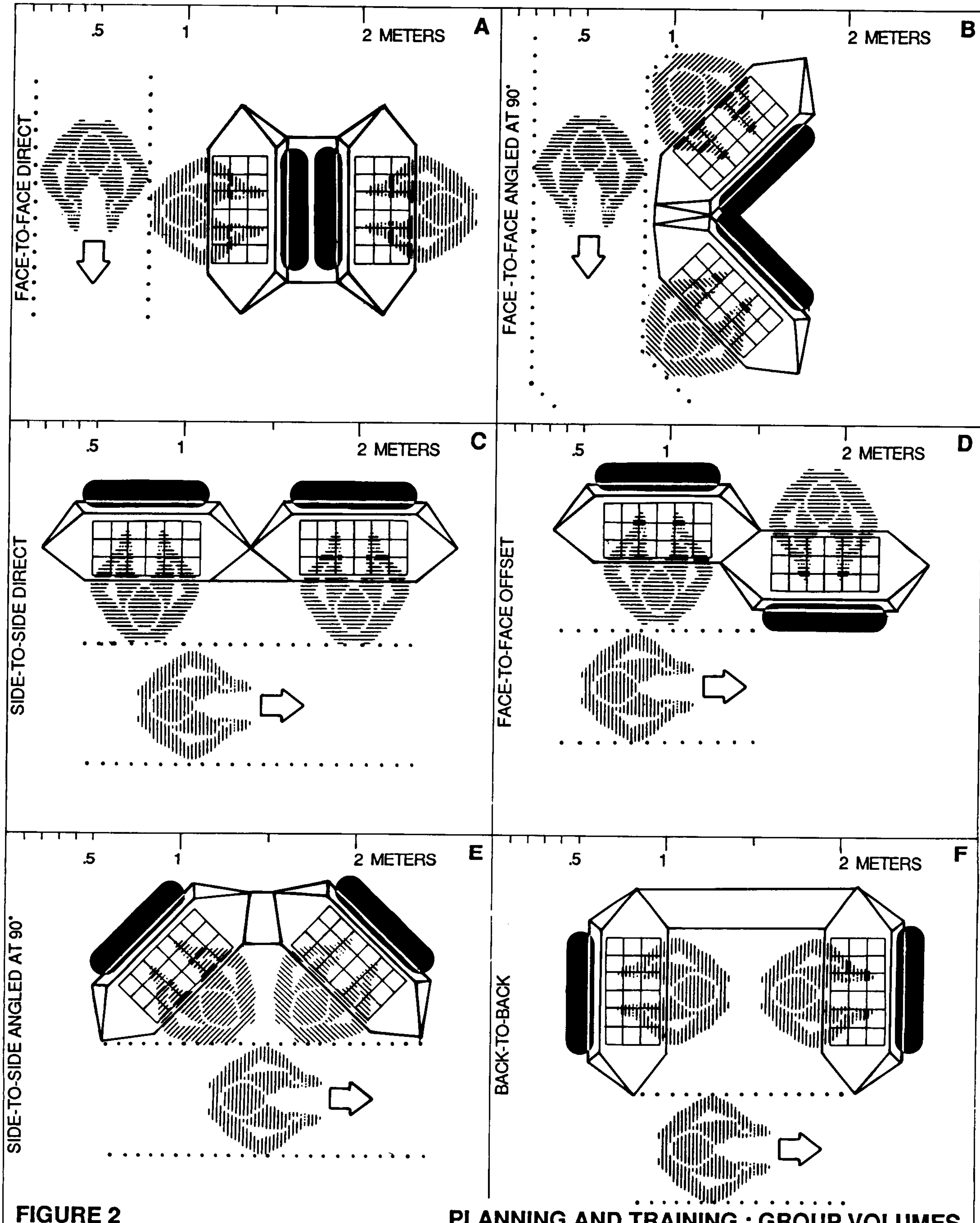


FIGURE 2 **PLANNING AND TRAINING : GROUP VOLUMES**

N88-19887

FULL SCALE ARCHITECTURAL SIMULATION TECHNIQUES FOR SPACE STATIONS

Colin W. Clipson
The Architecture and Planning Research Laboratory
The University of Michigan

Architectural Simulation

The Architecture and Planning Research Laboratory (APRL) has carried out a series of research studies that make use of full scale mock-ups of architectural environments. Operational scenarios and empathic training exercises are integrated with mock-up development to provide elaborate simulations of activities in different types of architectural and environmental conditions.

The laboratory uses approximately 5000 sq. ft. of indoor high-bay space, and large outdoor covered areas to build and evaluate mock-up facilities and environments. Ergonomic problems, equipment layout, and comparisons of internal spatial configurations are studied. Realistic operational scenarios are developed and studied in full scale mock-ups to evaluate user and equipment problems and to train potential users of new environments in simulated settings exposed to simulated events. This architectural and environmental simulation laboratory provides an ongoing site for the study of thermal, acoustical, and lighting problems integrated with the layout of work spaces and equipment. APRL has been particularly concerned with the study of new types of architectural environments, critical or dangerous procedures, and frequently repeated work spaces that benefit from studies of this type. Specialized ergonomic studies of individual work stations are studied in this way before design requirements for new facilities are formulated.

Gaming/Operational Simulation

The architectural mock-up of physical and environmental conditions is complemented by and integrated with gaming simulation studies. The simulation of operations and critical events are combined with the architectural mock-up for evaluation and training purposes. Certain common elements can be found in each of the gaming simulations applied. These include:

1. A scenario or simulated set of activities or events that are part of the time-space conditions to be studied.

2. Users playing roles that do or do not correspond to those they assume in real life.

3. An evaluation and monitoring procedure that accounts for what takes place in the simulation and the consequences of matching particular scenarios to particular spatial configurations and environmental conditions. The resulting simulations are recorded and fed-back to participants for reiteration of events, and the modification of the architectural setting for more appropriate ergonomic conditions. Thus the simulation device serves multiple purposes as a conceptual design tool, an evaluation device, and a training environment.

Empathic Modelling

An empathic model is frequently used in simulation studies to approximate sensory changes in the user of the mock-up environment caused by events and conditions of the scenario being used, or by the capabilities and limitations of the population being studied, e.g., age-related sensory loss.

Much of the use of empathic models at APRL has been for the purpose of providing "personal experience" to designers and researchers, in imageable terms, of what it must be like to experience sensory loss or degradation in some environmental conditions. The empathic model is made up of an assortment of appliances that simulate visual, auditory and tactile sensitivity in persons of advancing age. While these simulations are relatively crude, they offer empathic experiences to persons involved in mock-up simulation that can be repeated for various controlled settings of space, light, sound, and so on. Empathic devices can be taken out of the mock-up environment to experience changing conditions in the real world setting, thus developing early appreciation for new problems before a new environment is built.

Computer Aided Simulation

APRL has developed a powerful set of computer aided building design software tools which support all APRL research efforts in software research and development; the Computer Laboratory is a central component of all APRL simulation efforts.

Monitoring And Evaluation

The visual studies component of the laboratory provides specialized equipment and space for the simulation, recording, and analysis of mock-ups. It is equipped to produce live and taped video images, photographic images, and various types of image reproduction. The visual studies area is equipped with two motorized lighting grids, 16 feet by 16 feet with lighting tracks and dimmers, each with individual controls. The ceiling and attached grids may be elevated from 3 to 25 feet.

The Spectrum of Simulation

The combination of architectural mock-ups and gaming scenarios attempt to represent potential real world conditions. The means of simulation can best be visualized as a spectrum from real world to mathematical analysis. The real world contains all the detail and complexity, while the mathematical simulation is the most abstract. For architectural simulation it is possible to use the real world (though this often proves to be costly and impractical, and for many of the environments to be studied that real world does not yet exist). Rather, it is desirable to move tentatively along the spectrum from reality to abstraction (fig.1) settling on a degree of simulation that best suits the problem context at hand.

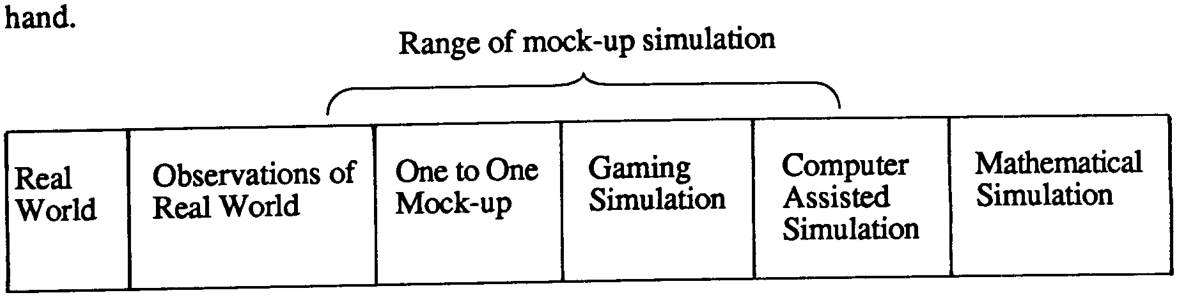


Figure 1. Spectrum of Simulation

Generating User Requirements

The simulation environment provides the research site for a three level approach to determining user requirements and matching them with supportive architectural environments. This approach combines the study of activity systems with their major systems support (such as life support and communications) and with key environmental conditions in the mock-up, e.g., acoustical, luminous, thermal factors.

Activity systems: The analysis consists of identifying activities to be carried out in the architectural system and deriving user requirements to achieve system objectives.

Associated support systems: This analysis takes as its focus the various systems of artifacts required in the activity processes. Included are monitoring, life support, and communication systems. Since redundancy is inherent in this approach, greater stress is placed on requirements not easily accessible through the activity based approach, e.g., back-up system of monitoring and control.

	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Implications Adaptive Range
Vision															
Hearing															
Touch															
Smell															
Psychomotor															
Kinesthetic															
Reaction Time															
Memory: Short Term / Long Term															
Task Performance															
Habits															
Preferences/Attitudes															
Activities	Sleeping		Personal Hygiene		Cooking & Food Prep.		Eating & Drinking		Housework		Leisure & Socializing		Movement & Communication		
Allocation of Function	User	Env.	User	Env.	User	Env.	User	Env.	User	Env.	User	Env.	User	Env.	

Figure 2. Interactive User Considerations

ORIGINAL PAGE IS
OF POOR QUALITY

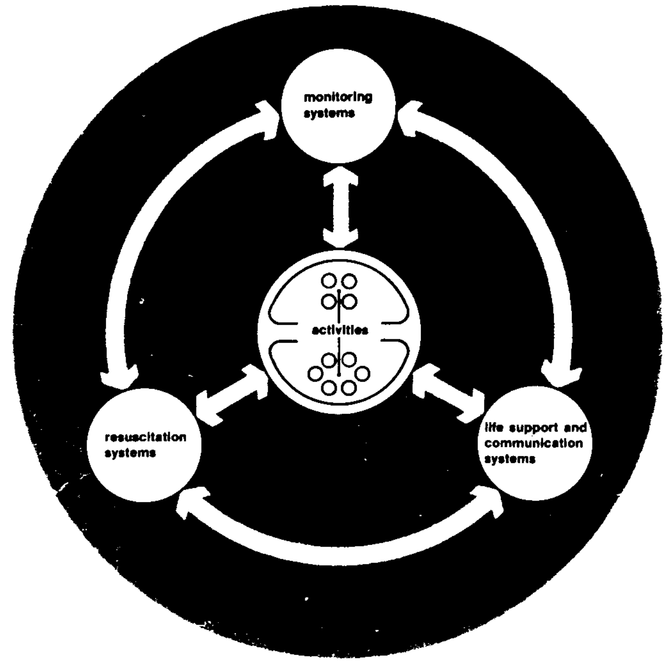


Figure 3. Model for User Requirement Development

Environmental systems: This analysis provides a third approach towards understanding the user needs of the system, as the three major human sensory aspects of the environment are investigated to yield suitable requirements to support and supplement those previously generated.

Simulating Routine and Emergency Events in a Mock-Up Unit

The following section briefly describes a set of simulation studies carried out by Clipson and Wehrer as part of a comprehensive study of health care facilities. The simulations combined full scale mock-ups, elaborate scenarios for everyday and emergency events, role playing by experienced users, and analogue computer simulations (of normal and abnormal physiological conditions of patients) that drove the scenarios. Remote controlled video and motorized photography were used to monitor and evaluate the simulations.

The main purpose of developing the mock-up unit was to provide a realistic, operational environment for the simulation of routine and emergency care procedures, and to provide a physical environment which would be easily modified to provide a wide range of physical configurations and make possible the collection of data critically needed for making decisions on the delivery of intensive cardiac care.

After some initial pilot observation projects in existing Cardiac Care Units (CCU's), the following problems became apparent, which could only be overcome by developing a simulated environment: 1) Setting up observations and equipment in the close confines of the CCU is very obtrusive and could be detrimental to the patient and to the operation of the unit. 2) Witnessing cardiac emergencies in real situations and resuscitative procedures is unpredictable and very time consuming. 3) The use of closed circuit TV installed in patient rooms is considered to be an intrusion on the privacy of the patient and staff at so critical a time. 4) It is often impractical and undesirable to experiment with changes in operational routines, staff roles, and space use in the day-to-day operation of the cardiac care unit.

The Mock-Up Structure: The structure is made up of a set of easily erected, easily changed wall panels constructed from 1" x 4" pine frame, with 4' x 8' homosote face panels painted in typical hospital colors. Using simple drilling jigs and assembly jigs, 17 wall panels were constructed, along with life support service panels for electrical supply, oxygen, air, and suction. Five of the 17 wall panels were built with removable window areas which could easily be interchanged for viewing in and out of the mock-up. The wall panel frames were pre-drilled to permit edge-to-edge bolting in three places. Shelving track attached to 1" x 4" strips was sandwiched between each panel frame to permit adjustable shelving and storage units wherever required.

The structure is stabilized overhead with 2" x 6" beams running from wall to wall at each 4' module, with external diagonal bracing. The overhead beams are used for hanging lighting, video cameras and microphones, and curtains. The initial structure was completely erected and furnished by a 4-man team in two hours. Adjustments and re-arrangements of the apparatus take only a few minutes.

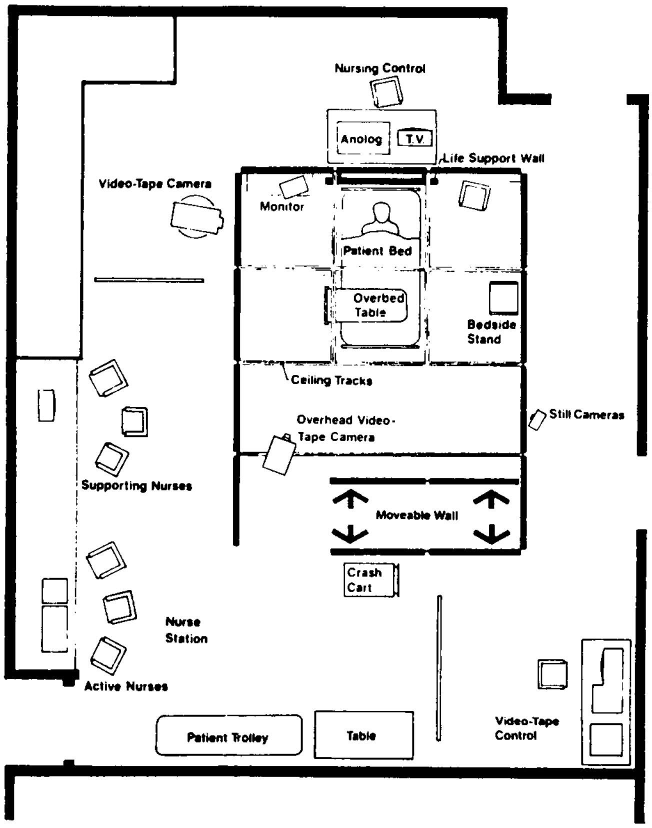


Figure 4. Plan of Mock-Up Facility

Equipment: A key piece of equipment in the simulation activity is Resusci Anne, a lifelike "manikin" which can be electronically programmed to develop a range of arrhythmias and life threatening states, for example, ventricular tachycardia, ventricular fibrillation, and cardiac arrest. The manikin patient's EKG output is displayed on cardiac monitoring equipment at the bedside and at a mock-up training station adjacent to the patient bed area. Resusci Anne is also equipped with a special thorax skin so that cardiopulmonary resuscitation can be performed. In addition, nursing personnel can actually defibrillate or countershock arrhythmias by proper use of DC defibrillator electrodes on the manikin's bare chest.

In a sequence of each training session on patient delivery and admitting, the manikin is replaced by a live patient, a volunteer adult subject prebriefed in a patient role, and delivered to the unit on a standard hospital cart. Patient handling, movement to the bed, and preparation for care can be more realistically simulated this way than by the use of the manikin, which has none of the handling characteristics of the actual patient.

Patient surveillance equipment consists of a bedside EKG monitor and, at the nurses' station, an EKG monitor with rate meter, alarms, and printout capability. The unit is equipped with an emergency crash cart which carries a defibrillator and other life support equipment and medications.

In addition, the entire activity in the mock-up is recorded on video tape from video camera equipment situated over the unit for vertical scanning, and around the floor of the unit for eye level viewing. Both cameras have 300mm close-up capability for close details of care techniques, and the cameras are synchronized and controlled from a video control center adjacent to the mock-up. Simultaneously, the visual output is displayed on TV screens for the benefit of instructors, observers, and other groups outside the mock-up area. "Instant replay" can be used for discussion and critique seminars after the training seminar is completed. From this video record, the design team has been able to extract data on specific care routines for ergonomic analysis and design development.

A 35 minute video tape of edited excerpts of the simulations has been prepared for teaching purposes in nurse training programs. In addition, 35mm cameras have been used to record selected sequences of the space use and details of equipment location at the beginning and conclusion of each training session.

Procedures: The simulation activity consists of a limited number of coronary events enacted in different physical settings. Nurses from the University Hospital training programs are divided into work teams, six nurses to a team. Prior to work in the mock-up, the trainee nurses have undergone either classroom training and demonstration in cardiac intensive care or, in the case of advanced training, nurses have actually worked in CCU's.

After briefing on the purpose of the mock-up, during which nurses familiarize themselves with the mock-up unit and its equipment, each team of nurses is exposed to 40 minutes working in the mock-up, where they must deal with routine care procedures and cardiac emergencies pre-programmed into Resusci Anne. At the beginning of a training session, the six-nurse team is divided into two groups. Three nurses play an "active role" for 40 minutes, working directly with the patient and making decisions on courses of action. The other three nurses play a "supportive role," observing the events on a closed circuit TV and helping only when specifically called on by the three active nurses. Whenever it is necessary, the nurse attending the patient makes his or her own decision about pressing the alarm button, calling for assistance from other nurses in the team, asking for additional equipment not in the room, and taking any other course of action that is necessary. At the end of 40 minutes, there is a five minute break while the active and supportive nurses switch roles.

At the beginning of the training period, the nurses are provided with the patient's case notes so that, as each simulation period starts, the nurses can familiarize themselves with the patient's condition much like at a change of shift in a hospital. The active nurses then begin to watch the patient's progress on the monitor at the nursing station and patient bedside. Throughout the training period, the instructors record trainee progress on a series of checklists.

In a second series of simulations, teams comprised of a cardiologist, anesthesiologist, inhalation therapist, and CCU nurses and technicians ran through a series of cardiac emergencies utilizing both fixed and portable emergency equipment. As in the simulations using nursing teams, the room configurations were adjusted to provide a range of room dimensions and equipment locations.

Space use: The patient bed and the configuration of equipment and room furniture are re-arranged to simulate typical and novel patient bed spaces to be studied by the facility design team. These configurations represent changes in room size, bed position, room entrance position, relationship of entrance to the bed, storage location and volume, location of equipment and services, partitions and curtains between beds, and transportable equipment. The efforts of the simulation team are directed toward presenting a variety of layouts which range from the minimum bed area and clearances for patient delivery, up to more spacious units, where more flexible arrangements of the support equipment and bed can be observed. Because of the provision of flexible wall modules, shelving and service modules (which house electrical outlets, nurse paging system, clock, and inhalation equipment), it is possible to make many changes in the unit in a matter of minutes, thus observing, in the next sequence, any effects due to changes made.

The range of room shapes and room arrangements were chosen to explore the use of a) typical hospital room layouts, and b) recent innovations in the design and position of the life support service walls.

Experiences in the mock-up: Even with limited use, it has been convincingly demonstrated to the project research team that simulating cardiac events in the mock-up

Schedule of CCU Simulation Project

Training Session for 18 Nurses
Coronary Events: a = ventricular fibrillation
b = cardiac arrest
c = patient transfer

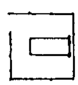
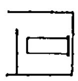
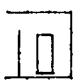
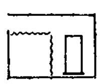
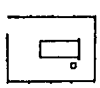
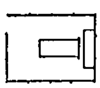
Training Groups	Coronary Event	Space Configuration	Event Time	Total Time
First Day 6 Nurses: 3 active 3 supportive	Team 1: active Team 2: supportive a b c II II II	1 	40 min.	1 1/2 hr
		Room Change	10 min.	
	Team 2: active Team 1: supportive a b c II II II	2 	40 min.	
Second Day 6 Nurses: 3 active 3 supportive	Team 1: active Team 2: supportive a b c II II II	3 	40 min.	1 1/2 hr
		Room Change	10 min.	
	Team 2: active Team 1: supportive a b c II II II	4 	40 min.	
Third Day 6 Nurses: 3 active 3 supportive	Team 1: active Team 2: supportive a b c II II II	5 	40 min.	1 1/2 hr
		Room Change	10 min.	
	Team 2: active Team 1: supportive a b c II II II	6 	40 min.	

Figure 5. Space-Activity Interaction

CCU Simulation: Sequence A — Ventricular Fibrillation

1. Normal Sinus Rhythm — 2 Minutes

Nurses Station -
3 nurses at scope reading chart
3 support nurses watching T.V. monitor

2. 4 Premature Ventricular Contractions per minute (Repeat Once) — 2 Minutes

Nurse	1	2	3	4	5	6
Obtain write out tracing (30 sec.)						
Prepare Lidocaine bolus (1 min.)						
Administer Lidocaine bolus into I.V. tubing (1.5 min.)						
Add Lidocaine to I.V. bottle (2 min.)						
Reassures patient (1 min.)						
Returns to nursing station (1 min.)						

3. Ventricular Fibrillation — 3 Minutes

Checks scope at alarm (30 sec.)						
Identifies arrhythmia (30 sec.)						
Enter room and check patient (30 sec.)						
CPR						
Clears Airway						
Inserts airway						
Bags Patient						
Initiates chest compressions						
Calls supportive nurses						
Calls a code						
Brings crash cart						
Defibrillator						
Plugs in						
Turns on power						
Sets watts seconds						
Applies paddles						
Safety check and gives warning						
Discharges defibrillator						
Prepares sodium bicarbonate and gives I.V.						
Checks patient (responsive)						

4. Sinus Bradycardia (Rate 40) — 2 Minutes

Recognizes sinus bradycardia						
Draws up Atropine						
Administers Atropine I.V.						

5. Normal Sinus Rhythm — 2 Minutes

Checks Scope						
Recognizes EKG pattern						
Observes patient						
Reassures patient						

Sequence Completed

Figure 6. Operational Simulation Routines

does provide a reasonable facsimile of actual events. By preparing and carrying through a carefully prepared scenario for each cardiac activity, a high degree of realism is achieved in the delivery of care to the stricken patient, as well as in the appearance of the environment in which the activities take place.

Experienced CCU nurses receiving advanced training procedures reported in post-simulation discussions how quickly their awareness of the simulation features of the activity faded and that they were completely engrossed in the problems of nursing procedures.

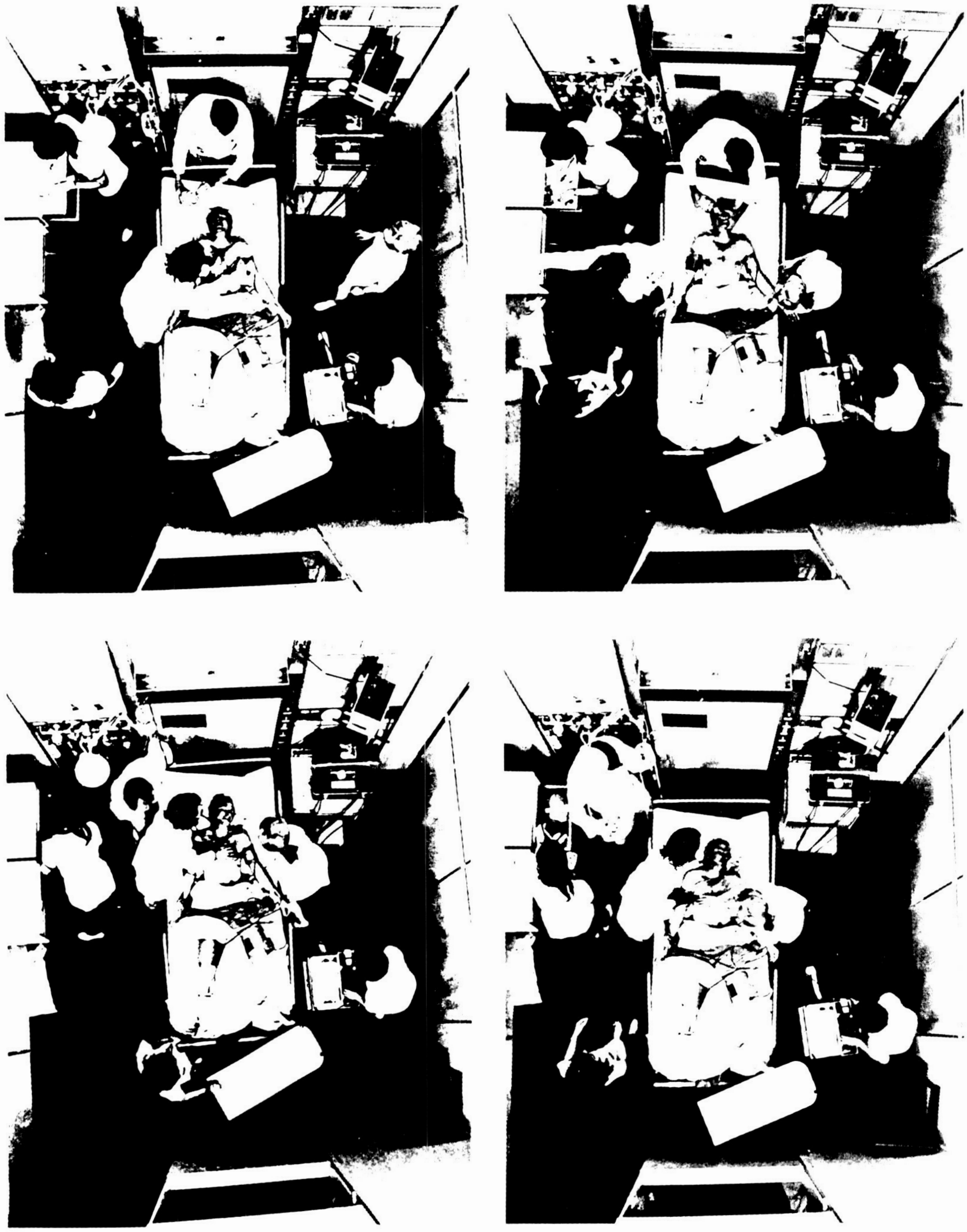


Figure 7. Emergency Simulation in the Mock-Up

References

Armstrong, R.; Hobson, M.: Introduction to Gaming/Simulation Techniques. University of Birmingham: England, 1975.

Borkin, H.; et al.: Computer-Aided Building Design. Pioneers of CAD in Architecture, Alfred M. Kemper (Ed.). Hurland/Swenson Publishers: Pacifica, CA, April 1985.

Brandle, K.; Boehm, R.F.: Evaluation of Air-Flow Windows: Final Report, LBID-560. Lawrence Berkeley Laboratory: Berkeley, California, May 1981.

Clipson, C.; Wehrer J.: Planning for Cardiac Care. Health Administration Press: Ann Arbor, 1973.

Clipson, C.: Techniques for Identifying the Needs of Specialized Facilities. Architectural Applications of Design and Technology Research. The American Institute of Architects: Los Angeles, 1985.

Duke, Richard D.: Gaming: The Future's Language. Sage: Beverly Hills, CA, 1974.

Feldt, Allan G.: CLUG: The Community Land Use Game. MacMillan Co.: New York, 1972.

Geisler, M.A.; Haythorn, W.W.; Steger, W.A.: "Simulation and the Logistics Systems Laboratory," Naval Research Logistics Quarterly, Vol.10, No.1, March 1963.

Meister, D.; Rabideau, G.F.: Human Factors Evaluation in System Development. New York, 1975.

Pastalan, L.A.: "The Empathic Model: A Methodological Bridge Between Research and Design," The Journal of Architectural Education, Vol XXXI, No. 1, 1977.

N88-19888

SOCIAL FACTORS IN SPACE STATION INTERIORS

by

Galen Cranz, Alice Eichold, Klaus Hottes
Kevin Jones, Linda Weinstein

Dept. of Architecture, U.C. Berkeley

Introduction

This presentation comes from the work done in a seminar on "Social Factors in Architecture" in the Department of Architecture at the University of California at Berkeley. We focused on the different theoretical perspectives which have been brought to the design of the chair. Ergonomics, production and materials, maintenance and storage, high style, historical precedent and cultural appropriateness all have their advocates as the highest priorities for chair design. We became fascinated with the problem of designing chairs for zero-gravity. Since the chair is a gravity-resisting device, it has no purpose in zero-gravity. Yet we observed chairs in Skylab and saw chairs in drawings for future interior space modules. When we asked ourselves why chairs were being implemented in outer space, the social history of the chair, which we had been studying, became relevant in a new way. The chair is a cultural artifact and institution in Western civilization, which has unquestioned value there and seems natural, almost a biological necessity. In outer space it amounts to cultural baggage.

These insights about the chair have served us as a paradigm for thinking about design processes. Accordingly, we spent time thinking about the design process for unprecedented situations, comparing and contrasting design from analogy with design for uniqueness. At the same time we confirmed the importance of two recurrent architectural variables, flexibility and perceptual order.

Social History of the Chair

The chair has an interesting history as an object which reveals that its real significance is as an institution. It originated some 5000 years ago in Egypt as a device for reinforcing the superior status of royalty and was copied by others as a means of dignifying themselves. Before then, people squatted, sat cross-legged, or used a variety of other postures as they do to this date in much of the Third World. Chair-sitting has become one of the distinguishing characteristics of Western civilization (Hewes 1957). Jesus did not sit, but reclined to eat at the Last Supper, as was customary at that time and in that region. (Rudofsky 1980). The Greek chair responded slightly more to anatomy than the Egyptian, with its slanted and curved back rest. Chairs disappeared during the Dark Ages and slowly re-emerged with the church hierarchy, confirming their direct relation to cultural history. Eventually in Northern Europe the domestic chair evolved from the Medieval storage chest. Only during the Renaissance did the chair come into its own as a three-dimensional object, free of the walls and room edges. Eighteenth century designers refined the prototypes, trying to balance physiology (seat-back angle, height and support of thigh versus sitbones) with the aesthetic goals of unifying the piece sculpturally (uniting arm and back transitions, leg and seat front connections, composing the back, etc.). Comfort and padding became synonymous during the 18th century when chairs were upholstered. In the 19th and 20th centuries designers started to experiment with new forms based on extending the limits of materials: laminating and bending wood, pouring plastic into molds, expressing the tensions between steel and leather. Comfort in any sense became secondary.

Throughout these transformations, one legacy has been enduring: people sit to work. Millenia of experience and the richness of other cultures were overlooked in making the assumption that the chair was required, but the basic idea has never been seriously challenged in the West (exceptions are Gideon, 1948; Rudofsky, 1980; Caplan, 1982). We sit and lean on backrests. The result is that our torsos weaken, and we come to <u>need</u> the backrests. So we rely on them, and thereby need them all the more, ad infinitum in a vicious cycle. We have never seriously studied those other cultures which practice what Rudofsky calls "autonomous seating."

Consequently, when faced with a zero-gravity environment, cultural blinders kept the Skylab designers from doubting the value of the chair at the ATM work station. Chairs were drawn into the sketches and plans of work stations and built. In reality, the astronauts' experience proved that work could better be done in a "standing," neutral body posture -- that posture so remarkably close to what F. M. Alexander called the position of "mechanical advantage" which is also used in martial arts and tennis as the ready-for-anything-whatever-comes-next position.

Chair-sitting is primarily a cultural institution. We have to be trained to use chairs, but soon chair-sitting seems only natural. All children in all cultures squat comfortably, but lose that ability in the West through sustained chair-sitting. Chair-sitting produces inherent instability and leaning back against a back rest causes the body to slide forward to the point where it's slouched in a C; the chairsitter then sits up at the edge of the chair, only to tire (because of underused, hence weakened, torsos) and then slides back to lean on the back rest, which eventually pushes the sit bones forward, and so forth in an unstable cycle.

The chair is so much a cultural given that Westerners could not recognize its liabilities and think their way free of it; those anticipating travel to space could do no better even though they were presumably trying to design free of any considerations save technical, anatomical and ergonomic.

The Design Process

The example of the chair has alerted us to the possibility of rethinking the most basic assumptions about designing for life in space. Building on prior experience may be faulty, hence analogous situations can be of limited or even doubtful value.

The design process typically begins with a review of what is known about a subject. For example, having received a restaurant commission, an architect goes to the library to learn about the range of building types for different types of food services. If the architect has established his or her practice around restaurant design, he or she may rely on personal experience, but in either case past experience is being drawn upon, whether codified and published by others, simply remembered, or some combination of both. Ideally, the building is programmed, built, and then evaluated as to the accuracy of the designer's hypotheses about how the physical design would best fulfill the program for that type of restaurant. This evaluation would then be available for the next restaurant the firm designs and, ideally, published so that others could benefit from this experience. Ultimately, a cycle of program - design - build - evaluate - program unfolds.

In contrast to this ideal procedure, we wonder what happens to the design process when designers face a largely unprecedented situation like space stations. Analogies to similar situations of isolation, danger and confinement only provide information. Ignoring analogous situations altogether would be foolish, but drawing on them without regard for the uniqueness of the situation has led to inappropriate designs, like chairs at work stations. We propose to explore the tension between analogies and uniqueness in design process. Is it possible to anticipate all those factors which will affect the design of zero-gravity environments or must the program proceed on a trial-and-error basis, building its own post-occupancy evaluation literature? If one does not want the expense of trial and error or cannot wait for the records to accumulate, the procedure of systematic doubt offers an option which we will describe below.

The Question of Analogies: Or What Can 20-20 Hindsight Teach Us About Solving Design Problems?

Numerous studies of situations analogous to space stations are available. For example, in 1984 Anacapa Sciences, Inc. did a systematic comparative analysis of 13 analogs including (in descending order of relatedness): Skylab 4, Sealab II, Tektite I, Tektite II, submarines, Antarctic research stations, commercial oil field diving, long-distance yacht racing, commercial fishing vessels, research vessels (coastal), Ra Expedition, supertankers and offshore oil platforms. For each situation, they investigated how habitability affects crew productivity using 14 behavioral issues: 1. sleep, 2. clothing, 3. exercise, 4. medical support, 5. personal hygiene, 6. food preparation, 7. group interaction, 8. habitat aesthetics, 9.

outside communications, 10. recreational opportunities, 11. privacy and personal space, 12. waste disposal and management, 13. onboard training, simulation, and task preparation, and 14. behavioral and physiological requirements associated with a microgravity environment.

By this process a number of known criteria were developed for long term human adaptation to crowded interiors in hostile environments. The criteria are both physical and psychological. However useful they are, though, a second look is in order. Data gathering is not enough. For example, the incidence of insomnia increases during stressful times, precisely when rest is most crucial. Solutions to insomnia, about which very little is actually known, range from the use of drugs to increased privacy. These partial solutions are probably ancient, but the problem persists. Since more people will be spending more time in space stations, the number of cases of insomnia will certainly increase. New solutions are needed, calling on our powers of direct observation, imagination and intuition.

Soviet space station analogs are also revealing. As analogs they offer a lot of information but their greater value may be as a cross-cultural comparison which can help us question our cultural and technological assumptions. The Soviets anticipate year-round large population stations and interchangeable modules for living, working, scientific experiments. They put a great deal of emphasis on the need for comfort and amenities. They also emphasize the relationship between psychological factors and physiological functioning, as measured in tests of, for example, fatigue. Excessive leisure is as fatiguing as excessive work; a balance needs to be achieved. The Soviets reported that under conditions of prolonged isolation, subjects occupied themselves during periods when no work was scheduled: they sang, recited poetry, read, painted, engaged in creative writing and crafts.

Cosmonauts show a leisure preference for creative and communal pleasures as contrasted with Americans who seem to prefer reading, listening to recorded music and viewing earth. Does this imply that the cosmonauts may feel less isolated from earth than the astronauts? Perhaps astronauts would enjoy interactive video games with Earth, such as chess. They might enjoy making things together, such as home movies. Humor should have an explicit role as a human need in outer space in terms of leisure design or crew selection. It is known to be therapeutic.

On the whole, the Soviets take an integrative approach. They claim that "Cosmonauts should be involved in the design. They should participate in: mockup activity, layout, development of systems in the testing laboratories and on the launch pad, participate in technical meetings to resolve problems, and help in writing and rewriting the flight plan and flight documentation."[1]

The work stations aboard Skylab offer a glaring example of what not to do. They were not designed to accommodate Neutral Body Posture in zero-gravity. How on earth did that happen? Just that, it happened on earth. No one imagined what the problems of Neutral Body Posture sight angles at consoles designed for chairs would really be because they were busy applying analogous scientific data and not extrapolating sensory data imaginatively.

That a chair was inserted at the Skylab workstation reinforces the postural research of Christopher Hewes which concludes that cultural influences are more important than anatomy in determining how we sit and stand. That the astronauts tried to use it and gave up in discomfort indicates that culture can give way to circumstances.

Neutral body posture is natural when performing at a console in zero gravity. This posture has been accommodated in the latest workstation designs following the trial-and-error rather than any anticipatory design method. We are left to wonder what other features of space capsule interiors might be re-examined. Here are some possibilities:

1. The design of small things, such as drawers and doors of cabinets, should be interchangeable or modifiable.
2. Flexibility should also apply to objects like instrument placement for the psychological value of change (the simple satisfaction of rearranging the furniture) as well as for utilitarian reasons.
3. Early space stations might be designed for a select astronaut size. Small people might be the most efficient as they are as jockeys for horse racing. As more data is collected and understood, a wider range of astronaut sizes could be included.
4. Astronauts have indicated that they do not need local reference orientation; after the first few days of adaptation, they find that wherever their feet point feels like down, therefore the familiar floor is not needed and it should not be used as a frame of reference. Using it conventionally may preclude more desirable, more imaginative uses of walls and ceilings for spatial variety and utility.
5. Has a preference for symmetry vs. asymmetry been established for either functional or aesthetic reasons or both?

6. Is the table the most logical place to eat and work on things in zero-gravity?
7. Would bicycle seats on flexible and vertically adjustable stems (perhaps with knee activated leg restraints) function well in lieu of chairs?
8. Do people need to relate across body axes, such as the vertical axis through the body and the horizontal axis between the eyes or can people's bodies be tilted to one another and still work well together?
9. What are ways that humor can make a group more cohesive? How can the design of the interior accommodate or reflect this?
10. What possibilities for training exercises (such as ocean sailing) might prepare crews for media publicity as well as encourage group cohesiveness under stress?
11. In what ways are anthropometric measures important in a microgravity environment?
12. Many of these concerns might best be addressed by astronauts themselves, and their experience integrated into the design process following the architect-client relationship. The program would then emerge from an analysis of the user's needs and constraints. Once developed, the client and designer would agree to follow the program. Thereafter, design assumptions may be made and challenged. For example, having agreed on the need for two square feet for a task, the assigned area could be square, rectangular, or round and each shape could be challenged.

What can we learn from analogies? We know we can learn some things not to repeat, but can we avoid unprecedented mistakes in the first place? How can a designer do that? Certainly, not all mistakes can be avoided or should be avoided given what we learn from them, but how can a designer avoid getting off on the wrong foot and establishing precedents that may be difficult to change? We propose using intuition and imagination coupled with experience in applying what is already known and then challenging the results. Once made, an assumption should always be challenged.

A designer may apply known criteria to an old solution that has been tried before, using a great deal of intuition and imagination or very little. And a designer may apply known criteria towards a new solution utilizing a great deal of intuition and imagination or very little. One or another or all solutions may prove to be appropriate. How is one to know? Doubting may be the best means of challenging assumptions; self-doubt could be the best safety net.

Professor Horst Rittel at U.C. Berkeley, an international authority in design methods, has developed the principle of systematic doubt. A problem is stated and then every word is systematically negated in turn. The systematic reversal of different components of the "reality" in the original statement offers different opportunities for intervention, questions which might be overlooked otherwise. One example of how our seminar applied his method to the design of space station interiors is the following assumption and its reversals:

ASSUMPTION: The unprecedented conditions of long term living, i.e. work and leisure, in zero-g requires unprecedented interior design solutions in lieu of chairs -- such as restraining devices which may be flexible or rigid. We then challenged each part of that assumption.

1. There are no unprecedented conditions:

-- there are precedents such as Skylab and restraint was not a big issue;

-- there are no all female or mixed crew precedents;

-- 90 days is not long term;

-- 90 days in zero-g is long term; human factors come into play.

2. Living in zero-g on a space station does not include work and leisure:

-- it is not living; it is confinement;

-- it is not living; it is all work, all mission; the same is true for submariners and fire fighters;

-- it is leisure, just as life on a camping trip is leisure when one is always working;

-- it is not working; astronauts are having the time of their lives; lots of people would give anything for a space flight;

-- it is working, whether enjoyed or not; astronauts have enormous responsibility all of the time;

-- everyone is responsible for each other's lives, all of the time, just like mothers of infants;

-- everyone needs time off, time to not be responsible; it might be a good idea to give everyone time off from emergency responsibility; although they may not take it should an emergency arise, it might help them to enjoy leisure more.

3. In zero-g there are no unprecedented interior design solutions:

-- we build on things we know; there are no unprecedented solutions;

-- it is theoretically possible to have unprecedented solutions;

-- there is no totally innovative solution; nothing comes from out of the blue.

4. In lieu of chairs, restraining devices need not be rigid or flexible:

-- restraint is needed for certain tasks: to supply resistance, to aid manual dexterity, to facilitate sleeping;

-- restraint could be comforting if not physically needed;

-- restraint could be uncomfortable, yet needed;

-- there are both physiological and psychological reasons for needing and not needing restraining devices depending on the task;

-- rigid is preferred for working;

-- flexible restraints are best for sleeping;

-- flexible restraint implies that the user has a flexible radius and rigid implies a fixed radius.

Designing for Uniqueness: United Nations vs. Camp David

When designing for a unique or unprecedented situation this method surpasses reliance on analogy. Used alone, analogies may blind us at worst or at best provide insufficient information. The space station is a special environment, a unique one with potential for new social relations which can promote (or hinder) international cooperation. There is a range of other special environments for international negotiations, all the way from the urban formality of the United Nations to the rustic informality of Camp David. The United Nations General Assembly and Headquarters in New York is one of the most unique working environments to be designed during this century. As an organ specifically charged with the responsibility of maintaining, or better yet, attaining peace and conflict resolution at the international level, it functions as no other.

As one would expect, teams of the finest architects, engineers, planners and other professionals were selected to create the environment that would house the organs of the U.N. The representative architect of France, Le Corbusier, describes the responsibility of the designers of this most ambitious project: "It is truly worthwhile to seek and discover the elements by which this problem can be more closely examined."[2]

In the long run, though, the formal environment of the U.N. had to be supplemented by a network of less formal offices and meeting places in apartments and hotels. The formal sector overlooks the many different cultures that work there. The United Nations complex is one model of how to facilitate the communication, mutual respect, and sense of shared mission, and clear conflict resolution needed to attain and maintain world peace that need to take place under its roofs. The U.N. is not limited because of the environment alone, but any successes, as architectural historian Lewis Mumford puts it, "... will be in spite of, not because of the architecture ..."[3]

Site selection became moot for the U.N. designers when land was granted to them by the Rockefellers. Perhaps they "jumped the gun"; not having had to decide where to locate the buildings meant they did not have to align purpose with place. In any case, in setting about to create a program to design the "complex," the designers skipped over the issue of defining goals and went straight to specific and known analogous situations.

For example, negotiations and council meetings were analyzed for what they have in common with business meetings, the corporate workplace and its organizational structure. While we would not dispute the necessity of looking to the business world to help draw analogies, this overlooks the greater picture of group meetings in general. It also perpetuates certain presumed givens, which could have been doubted: Are all the delegates and workers who will occupy the space of the U.N. accustomed to sitting in Western-type chairs? Would people coming together to resolve world problems have to carry along a staff structured in much the same way as a corporation? Is a high rise office tower the only form which can accommodate a large number of people working closely together?

No program was developed for the design of the United Nations complexes, but, a "Summary of Requirements of the United Nations" was formulated instead. The basis of that summary was a questionnaire answered by the Secretariat, the administrative arm of the U.N. The questionnaire focused on what were the eleven considerations of design: The Assembly, the Economic and Social Council, the Trusteeship Council, specialized agencies, The Secretariat, the library, restaurants, the National Delegation, living and communications.[4]

This narrow focus created a one dimensional space allocation program. The problem was reduced to area tabulations. What was overlooked is that this was supposed to be a unique environment with a unique working etiquette, unique cross cultural interactions, unique people with a unique mission; it is instead a lost opportunity.

In contrast, Camp David is an example of a unique situation that has been programmed for more informal negotiations. Camp David was the place for a Mid-East Summit. Although the Camp David talks were between Sadat, Begin and Carter, they were not limited to those three men. Hundreds of support personnel and negotiators were present and played an active role in the peace process.

Jimmy Carter, his wife and staff must have found themselves in a similar situation as the designers of the U.N. They had no precedent for an environmental program for conflict resolution. Like outer space, Camp David was a special place where special things could occur. What strikes us is how carefully the Carters and their staff managed the micro-environment, sight lines and pathways. Every detail was forged to serve their ultimate guiding purpose of the environment. Paul Frankl describes the role of environmental design in fulfilling purpose in Principles of Architectural History:

> ... architecture forms the fixed arena for actions of specific duration, that it provides the path for a definite sequence of events ... the principal and secondary passages existing within each space have their logic. The clearly prescribed circulation, which leads us through the different spaces in an opera house, through the vestibule to the ticket office, or through the corridors and up steps to a cloakroom, presupposes a definitely ordered activity, and the spatial form is completely dependent upon the particular type of activity.[5]

In developing their program, the Carters' first priority in designing the environment reflected the highest priority of the Summit: to reach an accord. Hence the environment's most important function was to facilitate that accord. For the Carters always keeping the big picture in mind simplified the resolution of many other facets of the design; from the importance of accommodating prayer, a five-times-a-day ritual for most of the Egyptian delegation, to special food handling and preparation for the majority of the Israeli delegation which kept kosher.

The entire temporal as well as spatial environment was altered to help bridge the relations of the two different and opposing groups by providing for their specific needs and providing cues that helped each side perceive the common ground that it shared with the other. Attention was paid to when and where people would cross paths, whether they would be alone or with company during times of contemplation and what environment would be best for each of these purposes. Cues were provided that allowed them to see what they had in common; a photograph of an adversary's child, movies which would be enjoyed by both sides. These cues gave the participants the opportunity to see one another as fellow human beings; the love of one's children could not be denied.[6]

Since in the future space stations are likely to be manned by astronauts from several different nations, we suggest aditional research and study of all the settings which have been designed especially for international negotiations and cooperation.

Flexibility and Order

Unique problems must be accommodated when designing a unique environment. We will learn the most about the needs of the space station environment after it has been placed in orbit, after teams of astronauts live in it. More than likely, we will need to make changes in the space station, so designing for change becomes a central design goal.

Three basic ways to deal with change are possible. One might construct a whole new space station and place it in another orbit, but this method would be costly in terms of money and resources -- and leaves the problem of the old space station. Retrofit -- or remodeling as we call it in architecture -- could be a way to accommodate changes, but that too would be costly and presents a whole new set of problems. A third approach is designing flexibility into the environment. Thus, the space station could be designed with changes in mind. Post occupancy evaluation and improved programming merge in the physical design itself.

Flexibility emerges as one of the general goals for the physical form of the space station interior. Another general goal has emerged from our observations -- the need for perceptual order. Flexibility and order might seem contradictory but they are not. The need for order is real, but the type of order might vary as the sub-culture of the group or even the international and global purposes of the entire enterprise evolve. Thus the same arguments against starting over with unchangeable and abandonable stations or expensive retrofitting apply regarding spatial order.

Why Be Concerned with Perceptual Order?

We are continually engaged in making sense out of the world around us. We have built defenses against the absurd in the human condition and at the same time developed a scheme that will make possible reasonably accurate predictions of the behavior of others. Although some of us may tolerate doubt, few can tolerate meaninglessness. To survive psychically, we must conceive a world that is fairly stable, relatively free of ambiguity, and reasonably predictable. Some structure must be placed on the flow of impressions: events must be viewed from some perspective. We look at the world through mental patterns or templates which we create and attempt to fit over the realities of the world. The fit is not always good. But without patterns the world appears to be such an undifferentiated homogeneity that we are unable to make any sense out of it. (Barnlund, 1968)

We recommend that the functional arrangement of the module's interior be reinforced by a visual organizational pattern. This would help reduce the sense of instrument clutter and visual discord frequently seen in spacecraft interiors. (See Figure .)

The manipulation of various textures can be used to establish a clear visual order in interiors. Particular elements of the interior can be emphasized while others can be played down. Color can be used in a consistent manner. Subtle or pronounced changes in color, or texture, can organize the environment. Light can be manipulated as well. For example, the gradation of light through a space can layer the interior into distinct areas, or reflected light off of a wall or ceiling can emphasize a plane. Light, more so than color or texture, is extremely flexible. It can be easily directed to highlight different surfaces. In addition, the intensity of light can be varied to greatly alter our perception of spaces. These elements, texture, light and color, can be orchestrated to produce a recognizable gestalt.

The typical office building offers a familiar example. The particular functional arrangement of space is reinforced by textural layers that provide psychological cues. The simple change from the cold, concrete sidewalk and steps to the warm terrazo and then carpet signals us to adjust our behavior and attitudes accordingly. At times, these cues are totally subliminal, yet they affect our behavior and attitude constantly.

The Transition between Personal Space and Workspace

We desire and seek out communication with others. Each of us has personal needs that can only be satisfied by interaction with others. We also need to control our environment, and regulate social contacts. Privacy is required by all of us. Many of the familiar methods of privacy maintenance are not possible in limited spacecraft interiors. The restricted physical space leads to forced interactions and increases the probability that the individuals will feel a lack of privacy. This has led to aggressive behavior or withdrawal from others. The habitation module should provide relief from constant overstimulation, afford privacy, and individual control.

Sleeping spaces, if designed correctly, can provide the desired sense of control and privacy. Personalization of sleeping quarters should be stressed, along with the opportunity to associate with others in various degrees. Flexible association with others is important. Sometimes, these quarters may serve as a semi-private zone for two. With volume being at a premium, these spaces must be designed not solely for sleeping, but also for personal expression, privacy, and territorial control. Unless these basic issues appear on the initial agenda, they will probably not be applied in the final design.

In the workspace, the activities and presence of others can be as imposing and distracting as in other areas. The same needs for control and flexibility should be stressed even more rigorously since the individual cannot dictate the activities of others. Our need for space expands and contracts depending on the activity performed and the level of stress we experience. Work space should be designed to allow for this fluctuation. Working may be very social. A flexible design can reinforce the pleasure of working and being together and adapt to more private work at other times. Here lighting could be crucial, flooding a central space on the social occasions while lighting individual workstations at the perimeter of the same space during private work phases. The need for flexibility within a perceptually ordered system emerges yet again.

We cannot focus on the design of a personal space or social workspace alone. The elements that link, or overlap, spaces are as important as the individual spaces themselves. We are universally accustomed to transitional elements that denote the gradation from the public to private realm. Establishing a network of transitional elements is especially important since distance and volume are restricted. Although walls work as boundaries, their function as screening devices may be much more efficiently and flexibly achieved by using color, light, and texture. These elements, when combined in unison or oppositon, create powerful, yet flexible, transitions when considered in the context of a small space capsule.

We suspect that a spiral organization of volume may offer the best definition of separate areas without sacrificing the maximum perception of the whole interior or wasting space on dividers. Such a baroque form could provide a perception of greater space since something would be around a bend, without losing a feeling of largeness.

Conclusion

Given the example of the chair, our difficulty in freeing ourselves of cultural assumptions is remarkable. Therefore, we call for an experimental approach which would allow designers to separate cultural assumptions from logistic, social and psychological necessities. Simulations, systematic doubt and monitored brainstorming should be included as a part of basic research so that the designer approaches the problems of space module design with a full and complete program. A complete program represents a well-defined problem and a well-defined problem is already on its way to becoming a solution.

ANNOTATED BIBLIOGRAPHY ON AEROSPACE by Alice Eichold

Ames Research Center, Living Aloft: Human Requirements for Extended Spaceflight, (NASA, Moffett Field, 1985).
a study of physical and psychological design parameters

Bodde, Tineke, "The Body's Answer to Zero Gravity," BioScience, Apr., 1982, p. 249.
metabolic changes and osteoporosis

Boeing Aerospace Co., Space Station/Nuclear Submarine Analogs, (National Behavior Systems, Granada Hills, 1983).
an examination of the working and leisure facilities for crew of nuclear submarines including procedures, equipment and psyco-social factors

Boeing Aerospace Co., Space Station/Soviet Space Station Analog, (National Behavior Systems, Granada Hills, 1983).
chapter headings: 1. Environment, 2. Extra Vehicular Activity, 3. Organization Systems, 4. Personality Systems, 5. Physical Condition of the Cosmonaut

Brookman, Denise C., "The Manned Space Station: Halfway House to the Stars," Design News, Sept. 9, 1985.
the manned space station for civilian-oriented tasks may have military uses as well

Cohen, Marc M. and Rosenberg, Erika, Proceedings of the Seminar on Space Station Human Productivity, (NASA, Moffett Field, 1985).
seminar minutes: both design configuration and mission functions are considered

Cohen, Marc M., Human Factors in Space Station Architecture 1: Space Station Program Implications for Human Factors Research, (NASA, Moffett Field, 1985).
four premises pertaining to launch, orbit, power supply and microgravity shape the entire space station program

Douglas, William K., M.D., Human Performance Issues Arising from Manned Space Station Missions, (NASA, Moffett Field, Nov., 1985).
interviews with ten former NASA astronauts discussing thoughts, opinions, conclusions or suggestions which might have evolved since they left the astronaut program

Gorman, James, "Righteous Stuff," Omni, May, 1983, p. 46.
astronaut consciousness of religion and metaphysics

Griffin, Brand Norman, Design Guide: The Influence of Zero-G and Acceleration on the Human Factors of Spacecraft Design, (NASA, Houston, 1978).
reference for zero-g anthropometrics

Haines, Richard F., Space Station Interior Design: Results of the NASA/AIA Space Station Interior National Design Competition, (NASA, Moffett Field, 1975).
history of and some entries from the competition with guidelines and constraints

Johnson Space Center, Space Station Program Phase B Kick Off Meeting, (NASA, Houston, 1985).
a program overview for a one day meeting concerned with aspects of management and engineering emphasized

Johnson Space Center, Skylab Experience Bulletin No. 17: Neutral Body Posture in Zero-G, (NASA, Houston, 1975).
an examination of the impact of Skylab's having been designed as though for one-gravity with recommendations that the space station be designed for zero-gravity human factors

Joyce, Christopher, "Space Travel Is No Joyride," Psychology Today, May, 1984, p. 30.
behavioral methods may alleviate some of the discomfort that accompanies weightlessness

O'Neill, Gerard K., "The New American Frontier," Discover, Nov. 1985, p. 70.
design ideas for large industrial colonies and factories in space with an emphasis on cost effectiveness

Overbye, Dennis, "Success Amid the Snafus," Discover, Nov. 1985, p. 52.
an investigation of research projects planned for or executed by the space shuttle or the give and take between flown and gown

Raasch, R. F., Peercy, R. L. Jr. and Rockoff, L. A., Space Station Crew Safety: Alternatives Study -- Final Report, (Rockwell International, Downey, 1985).
assesses risks and aggregates released data that has been in preparation by the aerospace community since 1968

Roland, Alex, "Triumph or Turkey," Discover, Nov. 1985, p. 26.
the story of NASA requesting a re-usable space craft for servicing space stations as early as 1969 and impact of the price tag determined by Congress and the Office of Management and Budget (then directed by Casper Weinberger) on the outcome

Space Craft Design Division, Crew Station Specifications, (NASA, Houston, 1982).
specifications for crew station design and operations

Stokes, J. W., Man/System Requirements for Weightless Environments, (NASA, Huntsville, 1976).
reference guidelines, constraints and criteria for developing manned orbiting payloads with none of the illustrations reflecting zero-g neutral body posture

Stuster, Jack W., Ph.D., Space Station Habitability Recommendations Based on a Systematic Comparative Analysis of Analogous Conditions, Anacapa Sciences Inc., Santa Barbara, 1984).
14 behavioral issues identified and examined for conditions such as: Sensory Deprivation, Antarctic Research Stations, Remote Military Outposts, Nuclear Submaries, Undersea Habitats

Systems Engineering and Integration Space Station Program Office, Space Station Reference Configuration Description, (NASA, Lyndon B. Johnson Space Center, Houston, Aug. 1984).
configuration of the Grumman Power Tower including descriptions of all major systems

Tanner, Trieve and Cohen, Marc, Concept Development Group: Space Station, Habitability Module Considerations, (NASA, Moffett Field, 1983).
predesign studies including module configuration and contingency factor identification covering: volume, sleep, privacy, galley, wardroom, exercise, personal hygience and radiation shelter

Taylor, Thomas C., Space Station Architectural Elements Model Study, (NASA, Moffett Field, 1985).
studies of design options for a central beam configuration of the module interior

Wortz, E. C. and Gafvert, M. R., Proceedings, 28th Annual Conference, California Council, the American Institute of Architects, Nov. 24, 1973.
habitability: perceived quality of life as defined by a group of nine architects

BIBLIOGRAPHY ON UNITED NATIONS by Linda Weinstein

Frankl, Paul, Principle of Architectural History (1968).

Mumford, Lewis, "United Nations Assembly," New Yorker Magazine, (1953).

Falk, Richard, "The United Nations After 40 Years," The Nation, Sept. 21, 1985.

Bourdet, Claude, "The U.N. Revisited: The Soul of the 'Machine,'" The Nation.

Harrison, Wallace K., "The U.N. Building in N.Y." Transcript of Director's presentation before the RIBA, RIBA Journal, February 20, 1951.

Rudolph, Paul, "U.N. General Assembly," Architectural Forum. October 1952.

___________, "Planning for Peace," Architectural Record, April 1947.

Beres, Louis Rene and Torg, Harry R., Planning Alternative World Futures, Values, Methods & Models, (1975).

Carter, Roslyn, First Lady from Plains, (1984).

Hall, Peter, Great Planning Disasters, (1980).

___________, "The U.N.," The Builder, Feb. 23, 1951.

___________, "Six Recent Buildings in the U.S.A.: U.N. Headquarters, N.Y.," The Architects Yearbook, VS 1953, p. 133-169.

___________, "Permanent Headquarters, New York for the U.N.," The Builder, August 15, 1947.

___________, "N.Y. Proposes a World Capitol for the U.N.," Architectural Forum, November 1946.

___________, "The New General Assembly Building in N.Y.," Arch. and Building News, October 16, 1952.

___________, "U.N. General Assembly Meets a Complex Plan Problem with the 'Visual Poetry' of an Elegant Concave Shape," Architectural Forum, May 1950.

General Assembly Headquarters Advisory Committee, Planning the Permanent Headquarters of the U.N.: A Short Summary, (1948).

Jeanneret-Gris, Charles Edouard, U.N. Headquarters, (1947).

U.N. Headquarters Commission, Report to 2nd Part of 1st Session of the General Assembly of the U.N., (1946).

Friedlander, Melvin, Sadat and Begin: the Domestic Politics of Peacemaking, (1983).

Carter, Jimmy, Keeping Faith: Memoirs of a President, (1982).

FOOTNOTES

1. Boeing Aerospace Company, Space Station/Soviet Space Station Analog, October 1983, p. 203.

2. Jeanneret-Gris, Charles Edourd, UN Headquarters, 1947, p. 2.

3. Mumford, Lewis, "United Nations Assembly," 1953, New Yorker Magazine, pp. 108-110.

4. Report to the 2nd Part of the First Session of the General Assembly of the U.N., U.N. Headquarters Commission, 1946.

5. Frankl, Paul, Principles of Architectural History, 1968, pp. 157-8.

6. Carter, Roslyn, First Lady from Plains, 1984.

SPACE STATION HUMAN FACTORS RESEARCH REVIEW
ARCHITECTURE PANEL DISCUSSION

Tom Taylor - Taylor and Associates

Michael Kalil - Kalil Design Studio

David Nixon - Southern California Institute of Architecture

Colin Clipson - University of Michigan

Galen Cranz - University of California, Berkeley

Marc:

We have convened this panel of today's speakers to discuss design implications from the research we've seen today and, if appropriate, yesterday. Since Tom talked the longest ago, we'll let you start.

Tom:

I'll go back to the Alaskan experience first. We found a vast difference between vice presidents within our company who came up to spend the weekend with us and those of us that had to spend ninety days there. We're in that situation now, where we go up in the orbital vehicle and spend seven days and find ourselves cramped in a 2,000 cubic foot environment with eight people which was probably designed for five people. We're going to find that situation plus other problems stemming from the fact that we're spending ninety days, and the human factors of those ninety days really come to bear on you. We noticed that in Alaska. We noticed a vast difference in the abilities of individuals to withstand those stressors in that environment. Our staff, who was a college educated staff, was supervising a union, sourdough kind of Alaskan labor and skilled workforce. We would lose thirty percent of our staff just due to psychological problems every year. These were funny kinds of problems, like they'd go out and slash the tires on their boss' pick-up, or they would spray paint this pick-up, or they would do something psychologically motivated against somebody they didn't care for. I'm not saying we're going to find that in highly motivated individuals like astronauts, but those same indicators are probably going to be there. That makes human factors more important than we're really giving it credit for even now that its really starting to emerge. I don't know how you get a handle on that because the laboratory tests may not give you the same flavor. I don't have a handle on how the research should be done, but I do suggest that it is a bigger problem than we realize.

Marc:

Well what about any design implications that you see?

Tom:

Well, again, I just draw from Alaska, and I found a difference. I wasn't there just as an observer, I was there as a supervisor and an engineer and a part of the staff. In Alaska, I noticed a difference between the two camps I lived in. The way that I can quantify them is that one camp had a security staff that would choke a horse, like one security person for every twenty-two individuals. On the other side of the field, we had a camp that was well designed inside and that impressed me and I felt warm and productive and different in, and it had no security personnel. It had less prostitution, less gambling, less drugs and near no alcohol. The camp on the other side of the field that was just shoved together trailer houses, which were poorly designed from an interior point of view and a human factors point of view, had the security personel, had more alcohol that was visible to me, had more gambling, and if we ever had a day that was too severe to go out in the weather, that was about minus 80-90 degrees wind chill, we just wouldn't take the troops out of the camp. We found that they would tear-up the camp, and it would cost us literally thousands of dollars to repair doors, repair partitions, repair out-of-hand poker games. I don't suppose I've answered the question.

Marc:

Well, it does not answer the question, but it raises another issue which I won't put to you, but I'll make one point which is this whole issue of what the management structure is and to what extent, in your example, the security function was in itself a source of stress. There is one study that I recall that was done in Philadelphia in 1975 about gang warfare in north Philadelphia during the period of Mayor Rizzo. This study, at the University of Pennsylvania by the Department of Criminology, I believe, found that there was a direct relationship between Rizzo sending mass police presence into those neighborhoods to wipe out the gangs and an increase in gang violence. The reason being, quite simply, that it was no longer possible to have a rumble at an arranged time and place because there were so many well paid informers; they had to go to Mafia-style hits. Each time the police moved into a neighborhood the teenage gang death-rate increased.

Tom:

Well, getting back to that, I see a problem area developing in that regard. We were an autonomous unit in Alaska, and we had good relations with our home office. I've been in a variety of other situations where fifteen or twenty different projects had the same home office, and it wasn't that good a relationship. I see that same relationship between the ground crew and the orbital station crew. Everytime I see this, "Our timeline is too tight," and there is a little friction there, I see that magnified in the space station. The autonomy issue is much more important than we're giving it credit for. I don't know how to give you examples of that, but we were very autonomous in Alaska, and we appreciated it. We made our own decisions, and we felt good about that. I don't see that same autonomy developing at the shuttle level right now. For a ninety day stretch or permanency like we're talking about the autonomy issue is much more important than the automony that I don't see in the shuttle system right now.

Bruce Pittman:

Marc, I think I can add something to what Tom said. When I was in college I participated in one of those Skylab isolation experiments, so I spent 105 days in an 11x17 foot room with two other guys with no door or windows in one of the circadian rhythm experiments. I don't know what it did for the circadian rhythm, but the thing I would say about the space station is whenever you get an enclosed environment like that, nuances become very important. A squeaky chair is something you'll kill over. Bad food, that you would normally slough off in your everyday life becomes very important, not being able to watch a TV program that you'd been counting on seeing. Those things in a closed environment take on much greater importance. So, if you don't like the color of a certain room, you'll just go to another room. I applaud your efforts to be careful. That's what I would say, to be careful of trivia, careful of nuances that would normally be sloughed off because when you can't get away from them, they take on much greater meaning.

Tom:

One of my few pleasures living in the Arctic was to go to the movies at night. When that movie would change or somehow the power would go out, I can remember a lot more disappointment over that than I can remember feeling from a real disappointment in my life in the lower forty-eight. So you're right about trivia and the fact that something you've looked forward to, which is your only hour of recreation in the whole day.... I happened to be supervising crews in the summer where I would spend sixteen and seventeen hours with the crew because they were painters, and we only got thirty painting days a year. My free time was down to maybe 10-12 minutes or 15 minutes of enjoyment time besides eating and sleeping, and if I couldn't even sit in on part of the movie I had anticipated, I really got disappointed. It was worse after eighty-nine days than it was after only two days. So there was a decrease in my ability to withstand disappointment or the irritation that trivia would give to me whether I'd gotten there the week before or if I'd been there thirteen weeks.

Marc:

Let's give Michael a turn here. Michael, design implications?

Michael:

I think the interesting thing that has come out of these three days is the turn-about in what I've been looking at for the past two years. Humanity in this whole space station system seems to be a servant to the machine. But what these past two to three days has been doing has been turning it around for me. It seems that machinery is finally starting to serve basic human needs. This is a big change from everything I've been seeing. I think that a major important thing to look at, because it's a very different point of view -- that you are the master to the machine and that the machine is not the master to you. That you don't start becoming a sort of test object or a gopher in a cage. This is a very important place, and this is a very important time, and that's made a big impression on me.

Marc:

Nothing that you would see as a specific design implication?

Michael:

I think that is in a larger sense, and that we can bring it down to smaller details, but I do think that is a very large design implication.

Marc:

I see your point, certainly. Designing with the idea that people are running the machines and not servicing them.

Michael:

No, designing the machines for the people...

Marc:

So that the equipment is designed with the idea that people are in charge of the machines and not the people simply servicing them.

Tom:

It may be, being in charge of your own living space is the first step toward that end. It may be the individual who is working with a machine can alter it to his needs, change his adjustments and sight lines and all that, but even more important is your ability to change the the living space, and I think we all agree on that. Except that I don't think we'll go far enough being able to choose your own color, your own texture and choose your own programming for your entertainment devices. But that's very important, and it shouldn't be done halfway. We ought to overdo that area rather than underdo it, overflexible in that area, rather than underflexible

Marc:

I see,... David?

David:

Well, let me start with a highly personal view of what space station habitability is all about. To me it is what happens when a soft, articulate, intelligent life form comes into close contant with a hard, fixed, inanimate object for considerable lengths of time in hostile circumstances at very great expense. I think we can draw on the conclusion that it has to be done in such a way that all the issues are met, including ones of physical and psychological comfort. One of the things we probably have to demonstrate is that we have a role to play in space design. Indeed there is a considerable body of thought still around that mankind shouldn't be in space at all, that it should all be done by remote control. So we have a long way to go to prove that we can go into space, that we should go into space as people and can survive and be happy there.

There are a couple of threads that I picked up in the conference so far. These are only a couple, there are many more. One is that variety and complexity are probably preferable over simplicity and uniformity from the point of view of psychological and physical well being. A number of speakers have raised this point in one form or another. Another consideration is that it is simply not possible to plan or pre-plan for every space station operational situation, so don't even try to do it. We have to accept that fact and understand that whatever we design will change and will evolve whether we like it or not. Finally, we should all remember that it's no longer a case of dealing with the right stuff. The kind of people going into space are not going to be those kind of people anymore. That is already changing and will continue to do so, and therefore the question of habitability becomes much more pronounced when you're dealing with a group of people who are not used to the kind of operational conditions that ex-military personnel are familiar with.

Marc:

Colin?

Colin:

Being a total novice to space planning in this sense, some of these comments may seem a little naive. I've been very impressed by the elegance of some ideas. I think in the fishnet interior idea [Eyal Perchick, SCI-ARC.] there is an elegance to it, and the sort of things that Michael was talking about. They're both practical and metaphysical. The other thing which has design implications is this looking into the grocery stores and the hardware stores rather than always looking out into space because, as David's little folding picnic table showed, there are marvelous things that come from relatively primative technology.

I must say I am surprised, however, at the lack of some things. One would be that there hasn't been very much, as someone who comes from a training in cybernetics as well as architecture, that there has been very little talk of interactive environments. The environments still seem to be very fixed. They don't respond to whims and changes. One would have thought, if you listen to the kind of things that Nick Negraponti is doing now at MIT with speaking to the walls and calling up colors and blinking to change conditions, that in fact one might think here of a much more robust environment, in which you may not have to stretch your hand out here in the anthropometric sort of drawing to do this. In a way there is a kind of design in planning here that ought to be on a continuum. What I've seen are very impressive things but things which are very fixed. They're fixed in a point in time, and I don't think we can design that way. We have to design on continuums. A good example would be to look at the natural evolution of the bicycle where you see a beautiful example of robust design. It's hardly changed at all, but you see a couple of centuries of those changes. I know you can't design a spacecraft like that, but you can have a design methodology which looks at the planning of space vehicles on a continuum. What we've seen is a lot of very good work looking at a very fixed point in time and not very much about the present technical potential for interaction with the environment. Remember that Nick Negraponti, years ago, had all those little gerbils running around in a glass box. Do you know about that? It was a sort of conceptual piece where you have a big glass box filled with very light styrofoam cubes, and he let a lot of gerbils loose in the box, and the gerbils ran around and knocked the cubes over. Well, all the cubes are linked into a computer, and the computer begins to do drawings of the gerbils' environment. The gerbil changes the environment and reshapes it. This is a very simple but very nice cybernetic model of how whims and fancies and unorthodox behaviors might change the spacecraft's environment within safe parameters and within efficient parameters. There has to be, I would suggest, particularly in this area, in bringing in odd-balls like me, that one could be a little bit more risky. It doesn't cost a lot to have that view. I would say that some of the things are very thorough and very well considered, but on very much a fixed point in time rather than on a continuum.

Another thing which you should bear in mind, and this came from another environment and not necessarily a hostile one, but a different one; it was in Saudia Arabia. I have had many trials and tribulations over cross-cultural references of planning in Saudia Arabia, but it did come home to me when a Saudi prince told me he had sacked many Western architects because they couldn't think of anything else but efficiency. Whenever he asked them to design something they always close packed it and made the distance from this point to this point the shortest, and he said, "I just can't seem to get through to them that is not what I want. It is not what we want. It just doesn't naturally fit our culture." I'm not saying by implication that one wants very big spacecraft, but I am saying that we have, culturally, a built-in view about designing for economy and efficiency in payloads which, very often, may run counter to what we are talking about for extended life and comfortable life in space.

One last thought, but I have to say it, and that is the C.P. Snow thing of the two cultures, except there are many cultures. We are still coming to where we have architects and mechanical engineers and hydrologists and so on, and we have no meta-language. We have no language for action. People start off by introducing ourselves as clinical psychologists and architects and so on, and attempt to get over the barriers of what separates one language and one set of methodologies from another. So some people are comfortable with Michael, and other people are more comfortable with numbers. The trouble is it's like an old automobile factory. Remember General Motors? They used to have the transmission factory here and the body factory twenty miles away, but they are all designing the same bloody car, but they're in competition. I think what we have here is still the residual problem of the meta-behavior on the meta-action. We haven't designed a language or we haven't designed an organization to deal with these problems. So what we have are residual problems of working from a professional basis, and I know this is beginning to sound a little highfalutin, and I'm sorry, but those things are still quite obvious when we start thinking about designing in these novel situations.

Michael:

When I'm working on the organization towards space, I keep tripping over the words. I keep tripping over "bathroom" and "living room" and "wardroom" and all of the words we seem to have. Then when we get down to discuss this with other professional systems such as engineers, I keep tripping over the specialization of our education. I can't get past a certain point, and I find myself constantly tripping over vocabulary. In trying to analyze this space, understanding it back to the point of mud hut and looking at this sort of unity of the human ideal of a whole, I can't find a word for the space station. I don't know if it's a dwelling, if it's a shelter, if it's a house, if it's architecture. Architecture seems to be getting in my way, and my own profession is on the line. I have to support what you're saying because I keep falling over these words. I can't seem to get a unity out of the fact that we have so specialized our experiences, both in terms of our education and in terms of our environment, that I can't seem to get past that.

Sharon Skolnick:

I think it was you Michael, that talked about that. That we are sending up a new planet, actually a microcosm. Maybe a new planet needs a new vocabulary and the idea of thinking of things in terms of their function instead of rigidifying them in their noun. It's a learning experience for everybody. I'm really happy about the humanistic bent the conference is leaning towards. I have one question, is it out of the question to think of sending human factors engineers or designers up there for ninety days so that the design can happen up there?

Marc:

To answer that question, I'm trying to find that out myself. In fact we were solicited a year and a half ago for technology development missions for the space station, for the Langley so-called "Data Base." (Those people in NASA know what I'm talking about.) Anyway, we have not been able to get a confirmation that they've received the proposal although we've sent it a number of times. That's about where it stands.

Colin:

Could I just make a comment on that, because I think it is very interesting, what you just said, and it's sort of following on my comments. There are two points of view. You want to get designers on the spacecraft, which I think is right, except I think that maybe we ought to think about what designing is. That you have designers who do all the design work, and you have the astronauts who go on the ship, and you have scientists who go along, suggests an obstacle to a meta-language. In fact, maybe what we need before we go there is a new kind of design. I don't mean to set up a "soviet," and I hadn't heard that. It was very interesting with what you said about participation. If one thing has come through in the work I have done in other environments, unusual environments, it is that the experienced user and the professional and anybody who has a vested interest in it, all ought to be involved in this new type of designing. They all ought to be involved. While I would agree with you, I hope that we don't try to get the AIA represented and ESA represented and a certified engineer just so that we all get on here to be represented. I think we need to get our cups on the shelf in the right order before that even happens, which may mean a new idea about designing. That's kind of threatening to professional groups. I know; I'm in one, and I know how threatened we are.

Yvonne Clearwater, Ames Research Center:

I'd like to address something here. It's probably so patently obvious to everyone here that it's neanderthal for me to bring it up. I think it's fascinating that the psychologists, and I only had twelve years of experience in architecture before coming to NASA so I still don't have as much experience as some of you.... But, it's fascinating that the psychologists were up yesterday talking hard numbers and trying to quantify and develop quantitative models for immediate input and talking about tradeoffs between guys who want immediate criteria and others who want evaluative models and who just want formulas, just give us formulas. And today the architects are shunning the numbers and going for more global thoughts. Marc, you've done a marvelous job of pulling together people who really can break set. I think that we are already a perfect example of going ahead and breaking the jargon barriers and doing that. I think we have to hand it to the members of the other NASA centers and the contractors particularly for coming and for bearing with us through this. I think we are a perfect example of doing exactly the things we're telling each other we should do.

Martin Pollack, Grumman Corporation:

The models that the psychologists put up yesterday, and the models that you put up today seem to be very similar.

Marc:

Okay, Galen, design implications?

Galen:

Well, since I'm a method type, and design implication for me involves a process too, so right off, I'd like to underscore the importance of the process of going to field settings. When you ask what the field is in this case we're talking about being up there in those space modules. So I begin to have questions about what kind of debriefing of the astronauts occurs. If you can't be up there among them, observing them and being one of them, how are they interviewed, or are they video taped, and would it make sense to have some very highly trained observers of behavior analyze them, and to have some very highly trained designers interview them. Are they interviewed from a design point of view? If I were in charge of developing something, I would go in that direction, to milk as much as possible out of the experiences of the people who actually operate in the field in question. That might be through visual analysis of their recorded behavior, and it also could be through in depth interviewing. Like I said, I don't know what is already done, but I'd really milk it.

Second, I would also explore flexibility and what exactly it means. We called for it. I know you can get different kinds of modules for your kitchen, and different kinds of stackable and changable cabinetry and so forth in work environments, but I personally don't know much about it, and would want to know more about the Negraponti kind of flexibility. I would try to operationalize the concept of flexibility in as many ways as possible. One of the students in my class operationalized it in a very interesting way. He said flexibility was uniqueness. Huh? How could that be? It was Klaus Hottes. H e said that if you get every system changing simultaneously at a point where something happens, you create uniqueness at that point, but it's been produced by flexible systems all changing at the same point. So he had a very unusual notion of flexibility. I would spend a lot of time trying to figure out what flexibility could mean under every circumstance I could think of.

The third thing I would say comes out of my particular position in the School of Environmental Design as a social scientist, is about the importance of perceptual order; that is, what people often call art. You might say art is a luxury; we don't need art up there. What's that all about? I would argue that perceptual order is art, yes, and art IS social. Art comes out of human experience. It is what we need psychologically and cosmic metaphysically and socially to know where we are in space, in life, in relation to one another. I really hate it when people make a distinction beween art and human factors. It makes my blood boil. That happens to me a lot because I'm a social scientist, and all the architects say, "Well you wouldn't understand the need for something beautiful." Well, I do personally and I also would say professionally that those two have to be linked. It is worth every penny to think of art in the context of social factors.

David:

Art ain't all paint.

Galen:

Art ain't all paint -- okay, That will be my motto. I saw a little bit more about that question about where would I turn to, to question my own assumptions or group assumptions. I thought, well actually, I suppose NASA's done this because science fiction writers are famous for this, for going through the intellectual exercise of changing one variable and then thinking of all the consequences for social life of changing that one variable. So I would think they would be great sources of that imaginative power, and it would be useful to have science fiction writers on think-tank type teams. I think film-makers go a long way in that direction as well. Brunuel's "The Discrete Charm of the Bourgeoisie" comes to mind in thinking about challenging cultural assumptions because, remember in that film, people sit together on toilets and socially read magazines together. Then they excuse themselves and go into this little cabinet, and they shut the cabinet and this little tray comes out and they fertively eat, and then they come back to the group. So they change the one thing that we see as social and wonderful and requiring a round bowl... He was playing with letting that be -- putting it in being the private, horrible act, and letting it out being the social, collective act. So, we can look to people who write fiction, whether it's science fiction or other kinds of fiction.

And then, finally, I have a question for you all, and it goes back to the chair and the cultural presumptions we make about the chair. What is a picnic table without chairs that is also portable, also foldable, also operable by one person, even lighter than this folding picnic table, and certainly cheaper?

Audience:

A blanket...

Galen:

A blanket. See, if you don't presume you have to sit to eat, you have this wonderful little piece of technology right there -- tucks right under the arm.

Colin:

Go to the drapery store as well as the hardware store...

Galen:

Go to the sheet store...

Magoroh Maryuama, University of Hawaii at Manoa:

In many cultures, you just don't have a table and chairs, you just spread a mat.

Frances Mount, Johnson Space Center:

I'd like to answer your first two points. One is that we do have people at JSC, industrial engineers and psychologists who attend the debriefings of each mission, which for the human factors aspect take maybe half a day. They do sit and observe tapes of all the missions that have occured and take notes, and they have written documents of specifics. They'll just observe eveything to do with eating and take notes on it -- and all EVA and take notes, and this is being done for our edification.

Galen:

Is that how "Living Aloft" was written?

Frances Mount:

No, "Living Aloft" is a literature review. This is an observation technique for behavior. And the other thing with the variability at JSC, ever since John Frassanito first came up with his center beam concept a year and a half ago, we are pushing the reconfiguration of everything. We are now, I'm speaking for JSC (maybe not everybody at JSC), fighting with the other centers to make sure the common module is something that includes just a module, just a cylinder, so the items inside can be changed out and upgraded and whatever you want to call it over the years, because we know things don't last forever and what's good today won't be good ten years from now. But some people at other centers think that everything has to be welded in place. This is a battle that some of us are fighting. So it is a consideration. Flexibility is something we are considering and we are fighting for.

Galen:

Is that considered the West Coast position?

Frances Mount:

No, That's been a JSC position for at least two years, I know for sure a year and a half. We try to phrase it in terms of maintenance and maintainability because that's something that means dollars and cents and people can relate better to that, but it covers a whole spectrum of needs and why it should be implemented.

Bruce Pittman:

The one plea I'd like to make is, coming from the hardware side of this, and the engineering and all those bad things that everybody talks about.... I'd like to make a plea that the architects and the social planners and everything go and do like I try to do which is to go sample everybody's world. Just as I find it very enlightening to come into your world and see the kinds of things that you're thinking of that never would have occured to me in a million years; I never would have thought of some of these things if I sat and thought forever. But, on the other hand, I guess what I'm saying this for is that I tend recently to make a study of systems. In this problem of big complex systems is this problem of communication, of the vocabulary catagorizing people and segmenting people from each other. So one of the ways to get around that is at least somebody, if they really want to have a good handle on space station, they've got to go around and learn all the buzz words. You've got to have a Rosetta Stone.

Colin:

No, no. I have to tell you that's not far enough. You're not going far enough. That's what I meant when I showed you those slides of the people at Volvo. It's in car factories; it ought to be in this factory. If you go back and you say that you take all the people, the constituency, and you have those people learning from the beginning the new organization and the new language, maybe we'll come up with another Calma ten years later and ten years after that. Maybe you'll come up with a new approach to work, to work environments. Sending someone around for the buzz words, I'll admit is better than nothing, but you're still in you own baliwick. That's no way to design. If you're going to have innovation or if you're going to make any leaps forward, there has to be a radical change in the way that the problem solving work is done in the first place.

Bruce Pittman:

But the problem is what can you do in the next eighteen months, which is about all the time you have, to significantly impact this process?

Colin:

Well Volvo's going to flood the world that they cover with a new car two years from now, and one of the plants that makes that car will be Calma mark two. Maybe that's less of a problem than what we're talking about here. But, in fact, that's a big economic and that's a big marketing and a big industrial problem which they are facing in a way that, I think, is more progressive than going around and learning the buzz words.

Marc:

I'd like to interject something with regard to this issue of how far do you get into understanding someone else's point of view. What I happened to learn from Galen working on my thesis in architecture was, first of all, to appreciate that everybody's point of view has equal validity. In order to understand that there is a whole set of levels of world view. We used a technique at the time of cultural anthropology called cultural ethnography.

Galen:

Semantic enthography...

Marc:

or semantic ethnography.

Galen:

It's been twelve years.

Marc:

They change buzz words.

Galen:

No, it's your memory I'm commenting on.

Marc:

That's shot anyway.... What I learned to do, and what I've applied working with other people, is try to see their point of view. Whether it's an architectural client or contractor I need to supervise or an engineer I need to work with, I try to figure out how they see the world; what do they think is important to them; what is primary for them. You learn really interesting things. Some guy is in charge of where the bolt holes are placed in a wall. He may be making all his decisions based on his rationalization, his conceptual structure for that. Another guy who is going to drill the holes has a whole other concern; like he wants to make sure he's not going to drill through some truss underneath. Just from a very simple, basic task or need, a whole set of assumptions and beliefs will snowball. If you can figure that out, that's valuable. You also have to be careful, though, to not speculate about peoples' motivation, particularly on the psychological plane. You can do that, on the material plane, but you have to be careful to not do that for emotional issues, because it gets beyond what you can handle.

Ethan Clifton, Taylor & Associates, Inc.:

Well, I'd like to speculate on the use of language. Yesterday in one speech, I tried to make sense out of this, "Iterative multidimentional hierarchical functionality relationship compatability matrix."

Yvonne Clearwater:

That was not a NASA blessed sentence.

Ethan Clifton:

This is a way of differentiating yourself, of putting yourself in a chair and making everyone else in the room a groundsitter. That is what each and every discipline has done to render themselves some social signifigance in our society because everyone can put on a tie and everyone can buy a BMW, but you still must differentiate yourself. The sooner someone sets down the law about language, the way they have laid down the law about the keyboard, the sooner we're going to communicate and not differentiate and not hold people away from knowing what we know.

Carl Houck, Johnson Space Center:

I had a couple of comments on the architectures speaking from an engineering standpoint. We have a lot of constraints. We have to have an air circulation in the common module between five and twelve meters per minute. We have to have noise control down below approximately fifty-five db's. We have to make room in the aisle in the length of the module for sled operations for the otalith experiments. If we just had free architecture, you could make a beautiful job, but we have these constraints to live with. Backing up something that Tom said, it was reported not too long ago that the Russians in the Salyut didn't speak to the ground for two days because they overloaded them; they just turned their radios off. This was reported at a meeting we had among the space station people at JSC that we had last Spring.

Colin:

And it will happen again.

Carl Houck:

And it could happen again... but we do need good architecture.

Colin:

I agree. I don't think we should make these polarities. I'm very much for numbers. I'm very much for building performance specifications. I think that what we need, as I said, is a continuum. I think you need both.

Carloyn Dry, Virginia Polytechnic University at Blacksburg:

I think part of the problem is that now we're finding ourselves in this time crunch. A lot of people would like to go back to basics and question assumptions, but there's a certain stage where you can't do that when you have some of those requirements that the engineers are talking about. But if you do get the chance to go back and question some of those assumptions, I wanted to second something Galen Cranz said. Two years ago I was on a NASA project down at Cal Space, and we had a science fiction writer with us, Dave Brin who won the two top science fiction awards that year. He was incredible. The way he thinks is to see whole sets of assumption. His description of NASA assumptions was really eye-opening to everybody. I think there are people around who, because of their way of thinking, are sort of beyond particular mind sets.

Galen:

Is that published and available?

Carolyn Dry:

Well, you know NASA publications, probably in about a year.

Tom:

I know Dave personally, and he's very creative. The fact that he's a science fiction writer -- he's also very creative and innovative ...

Carolyn Dry:

And he also knows a lot of science.

Colin:

Can I pick up on a point that you made, because it goes back to something that I don't think I got an answer from, and I was going to load it back on you, Marc. That is, to what extent has the idea or concept of robust design, which is very common in other areas of engineering, been applied to this? There have been a lot of comments about, "Well we don't have time to do this because we can't have it finished by then." To what extent has, instead of designing to a fixed point, designing on a continuum which tries to look at those technologies further down the road.... To what extent has that been done by NASA? I would address that to you rather than any contractors because it would seem to be your responsibility to set the stage for these strategies. So my question is to what extent has robust design been investigated and researched by NASA?

Marc:

Well, thank-you for putting me on the spot. I have to answer you in an almost tautological manner, but which I think is a true one. Which is, that is precisely what we're trying to do here. We realize that we have a huge number of potential problems. We also know there are a lot of unexamined assumptions, some of which get crystalized into dogmas and they get into requirements documents. Every now and then you go into general specifications, and someone has put in, "bolt holes shall all be ten inches apart." You run into this stuff. Engineers will run into these things. Sometimes a requirement will be inserted somewhere just because someone wanted one thing. Let me explain the approach that I've taken. Within some very broad guideline, which we gave to all our design groups, we have to start with the assumption that anything is possible. Take the idea that if we're going to do something innovative, something robust. We can't start and achieve anything by saying well: we have a volumetric envelope; we have weight limitations; we have a center of gravity envelope; we have rack width; we have floor to ceiling height; we have all these types of constraints. We can't start with all those givens and then create anything innovative or any sort of robust environment.

John Lynch, SCI-ARC:

Why? Why can't you take givens and work with them?

Marc:

Okay, because we can't take them all at one time. You can take a certain given...

John Lynch:

Why is there such a need to suddenly become this wonderful, marvelous, instantaneous thing? We're taking the first step.

Marc:

Let me finish explaining. So for example, when I first presented the Triangular Tetrahedral Space Station concept in Williamsburg, Virginia in March of 1983, (I can't believe it was that long ago), the people present were not only incredulous, but many of them openly hostile to the idea...

Tom:

I was there. You're right... I was hostile, and I'm pretty open-minded.

Marc:

angle manner; to the idea that a berthing port was anything other than the Apollo-Soyuz berthing connector. Right now the berthing port is still very much like that, but you can't win all of them. People believed that circulation was something that occured totally randomly where these things smashed together. There were a whole bunch of these structural ideas that were just purely cultural. I mean a Cartesian coodinate system with right angle geometry is a purely Western cultural value. Probably the most significant thing that Buckminster Fuller did was to take the Platonic solids and re-order them from a face order to a vertex order. From that one rearrangement all kinds of consequences followed. That one change is really the root of many of the geodesic discoveries he made. So, what I'm saying is that you have to be willing to question everything. Buckminster Fuller could not have done what he did if he started out with the assumption that everything was made out of faces and planes, just the way Plato did. That does not mean that ultimately we do not come to grips with all of the constraints. Right now, our situation is that we have many more things to test and evaluate than we have time or people or other resources to do that. But as a research enterprise while you clearly have to know what you constraints are you can't deal with all your constraints at one time and go anywhere.

Colin:

You might test them, you see. I think something in between what you're both saying would suggest that when we looked at, let's say, console and interface design to instrumentation, one might ask why not take take that one on a continuum that goes from whatever the present order of schedule is and pushes it out to voice control and other kinds of cybernetic interface between display and the person which would free them from this seating posture to the instrument. Just take one or two of them, in an exploratory way, and push those out from a human factors point of view with the technology to the limits of speculative technology, to say, "What would happen?" So that in fact you would begin to work with certan degrees of freedom within that plexi tube that everybody's using, that would push beyond that. This may sound awfully presumptuous, of having people do that, but this is what I mean about examining the limits of that robust design by pushing out some elements within that design. Most of the interface situations seem to be of the very immediate, short term objective rather than pushing at what I believe is new knowledge of potential interface between people and equipment.

Magouroh Maruyama:

You've repeated 'cybernetic' several times. Do you mean feedback groups? Do you mean stablizing, maintaining, or pattern generating? What do you mean by that?

Colin:

I mean in some ways all of those things. I mean, in fact, if there were more direct feedback that didn't require always the conventional anthropometric, the touch condition. If there was a more homeostatic response between the people and their actions a more direct link between movements and gestures, and so on, and modification to the environment. That is part of a cybernetic principle also. Those things are possible. They're even being used in applications in other areas. That one could take something like the console/user interface and push that out by robust design concepts and ask all those 'what-if' questions. What would happen? It would seem that what we were looking at was in fact an intermediate response which is obviously geared to schedules which are part of your mission.

Audience:

I have a doctorate in engineering and a masters in creative wiriting, so I'd like to address this question of language. First of all, I have to disagree. I think jargon is essential to achieve precision. I also would like to stress that the only way to conquer this interface barrier is to learn the jargon of the different groups. It has been there for many years, and it'll remain. On the other hand, it's not a difficult task. Pick a standard text book and read it like a novel, just get from one end to the other, and put it away. You'll find that as the months go by and we keep interfacing all this will become very very clear to you.

Bruce Pittman:

You could probably get it by just reading the first chapter.

Colin:

I think you're short-changing the real problem. You think the real problem is just translating other people's words. Whereas what we're talking about with the new meta-language is getting groups of people together who not only design together, but who become a new culture to do this. Which isn't in fact just words; it's concepts.

Linda Weinstein, U.C. Berkeley:

Poppycock! I think we're all professionals or on our way to being professionals. In your work you deal with many different people. You deal with the people you work with, and you speak a certain language with the people you work with, buzz words, whatever. You also probably have clients that you deal with, and if you ever mentioned one of those buzz words to your client and they didn't understand what you were talking about, you wouldn't be working too long. So we know that we all have the ability to talk on a level that everybody will understand. I think it's very important for us to learn to communicate with each other and use that level and respect each other by using it. It's very important. If we were all going to spend time learning each other's lingo, buzz words, and jargon, we might as well go back and get a degree in each others work, and that doesn't accomplish anything but waste a lot of time.

Audience:

No, I have to disagree with you. I'm sorry, I don't think that one of the speakers yesterday could stand there and describe multidimensional analysis so that everyone in the room would understand it in a short period of time.

Linda Weinstein:

Well then it's probably not worth very much.

Audience:

No, it's extremely valuable. That's the point I'm making.

Linda Weinstein:

But if you can't communicate it to the world, it's not valuable at all.

Audience:

Well, in the name of good communication, allow me to finish the sentence. The point is, if that person could explain that to you five or ten minutes afterwards, or in a half-hour afterwards, if you'd like to understand it, then that's not an insurmountable barrier. It is an essential ability to control details and have precision. I know it's frustrating, but being that we are all here in this room does not mean that we have to conquer over the next few years, not by the next deadline...

Linda Weinstein:

The greatest amount of information that we all get, I think is through reading each others material. I know for us there's been volumes and volumes of material to read. I think we all realize that what we write gets read by other people. I think that is the opportunity to take the time to write it in English.

Carl Houck:

Language is not an insurmountable problem. At ESA we had eleven nations and eleven languages, and we built Spacelab on schedule, on time.

Marc:

Listen, I think there are a lot of good issues here around the problem of language. We're trying to talk about design implications, and some of the people here are indicating we need to go. I just want to take the last couple questions here.

Martin Pollock, Grumman:

I just wanted to make a comment here about the robust design. I believe that the RFP, the statement of work, I don't know how many of the panel has read it, but they have attempted to design with robust thinking in mind, for growth. That we don't know the answers now. The words in there are "modularity", "flexibility". There are words in there that say you should be looking at speech for the interface, natural language. There are words in there that say that you're supposed to be designing for maximum autonomy, for instance. I'm not sure they're doing that for the sociological/psychological reasons as opposed to the economic reason of the expense of this large cost on the ground, but all of those words are in the statement of work, and are all, you know, "Thou shalt design for these things."

Galen:

But still, one would want to spend a lot of time operationalizing flexibility. You can use the word, but it can mean, concretely, a whole lot of different things, and conceptually it can mean a whole lot of different things.

Martin Pollack:

I think, as somebody pointed out, is to say, "show how it's going to save money." If you can show how it's going to save money by making it flexible, you're probably going to get in there. It won't be a scar (which is another buzz word that is current). We're going to put that in there because it's going to operational, and it's going to show savings right now from the start. All we're going to do is accrue savings from that, as opposed to a scar that we might not have to use for ten years. So I think they're trying to do that.

John Spencer, Taylor and Associetes, Inc.:

One of the most important resources that we can all bring to the space station project is our individual and collective creativity. That's a very important resource. A creative idea can save tremendous amounts of money, just like you were mentioning, and it can provide great resources and opportunities to the project. It was mentioned in a few of the presentations: innovation, imagination, creativity. As designers and engineers working as a team, that's one area we should all work together to facilitate, to be open-minded and to really hold creativity on a very high pedastal bacause that's where the magic comes together --- where one thought solves many problems at one time. If that's a design goal, for us to be very creative, we're at least heading in the right direction.

1. Report No. NASA CP-2426	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SPACE STATION HUMAN FACTORS RESEARCH REVIEW Volume III - Space Station Habitability and Function: Architectural Research		5. Report Date October 1987
		6. Performing Organization Code
7. Author(s) Marc M. Cohen, Alice Eichold, and Susan Heers, Editors		8. Performing Organization Report No. A-86263
		10. Work Unit No.
9. Performing Organization Name and Address Ames Research Center Moffett Field, CA 94035		11. Contract or Grant No.
		13. Type of Report and Period Covered Conference Publication
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code 506-57

15. Supplementary Notes

Point of Contact: Marc M. Cohen, Ames Research Center, M/S 239-2, Moffett Field, CA 94035, (415)694-5385 or FTS 464-5385

16. Abstract

This volume records the third day to the Research Review with presentations by several architectural research and design groups. It begins with an extensive overview of Ames Space Station Architectural Research focused on in-house advanced development activities. Results of several contractor and grantee studies are presented including the Space Station Architectural Elements Model Studies and the Space Station Group Activities Habitability Module Study. Invited papers include Full Scale Architectural Simulation Techniques for Space Station and Social Factors in Interior Furnishings. The day concluded with a panel discussion of the principal speakers, an edited transcript of which concludes this volume.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Habitability, Architectural, Models, Group activities, Simulation Techniques, Social factor, Interior furnishings	Unlimited - Unclassified Subject Category 51

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	214	A10

*For sale by the National Technical Information Service, Springfield, Virginia 22161