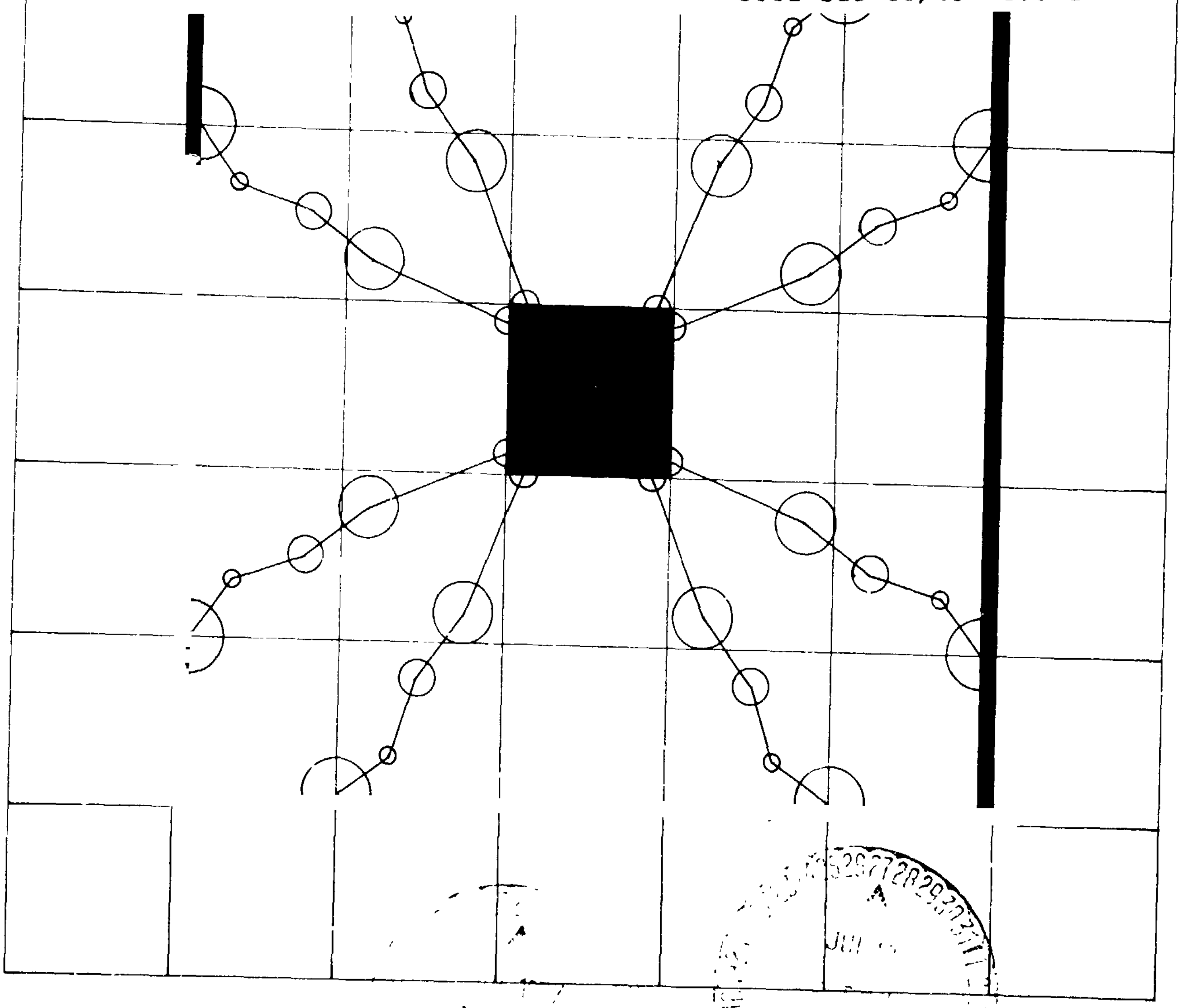
FINAL-REPORT

(NASA-CR-151450) AN INVESTIGATION OF THE NEEDS AND THE DESIGN OF AN ORBITING SPACE STATION WITH GROWTH CAPABILITIES Final Report (Rice Univ.) 103 p HC A06/MF A01 CSCL 22B G3/15

N77-27169

Unclas 39612



REPORT 5

RICE UNIVERSITY SPACE STATION STUDY / NASW 2776 / DOSSEY / TROTTI

AN INVESTIGATION OF THE NEEDS AND THE DESIGN OF AN ORBITING SPACE STATION WITH GROWTH CAPABILITIES.

TO:

NASA-JSC
PROGRAM PLANNING OFFICE
AT2/DENNIS FIELDER/RICHARD F. BAILLIE

NASA-MSFC
ADVANCED SYSTEMS GROUP
PS04/D. CRAMBLIT/D. SAXTON

SUBJECT

CONTRACT NO. NASW 2776

"AN INVESTIGATION OF THE NEEDS AND THE DESIGN OF AN ORBITING SPACE STATION WITH GROWTH CAPABILITIES."

Enclosed is the final report in compliance with the subject contract.

PRINCIPAL INVESTIGATORS

JOHN R. DOSSEY
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January 1977

PREFACE

The Rice University Study is a twenty-two month effort to explore the needs and design of an orbiting space station in evolutionary growth from a small manned satellite to a fully independent, self-sustainable space colony facility. The study is made up of the following tasks:

TASK	I	DATA COLLECTION
TASK	II	DATA SYNTHESIS
TASK	III	CELLULAR GROWTH STUDY
TASK	IV	REFINEMENT OF CELLULAR GROWTH STUDY CONCEPTS
TASK	V	DESIGN FEATURES AND CRITERIA FOR MODULAR GROWTH OF A SPACE STATION

The study goal is to provide an architectural approach to the cellular growth of space stations and aid NASA's Program Planning Office in their long range planning efforts.

The work is being done in the School of Architecture at Rice University. The principal Investigators are John Dossey and Guillermo Trotti. Any questions regarding the study may be directed to the Principal Investigators at Area Code 713, 521-9819.

TECHNICAL PROGRESS

Work under Contract NASW 2776 began on 19 February 1975 with Task 1, Data Collection, and was followed shortly thereafter with Task II, Data Synthesis, and Task III, Cellular Growth Study.

The progress which was achieved during each of the three tasks was subsequently related in Bi-Monthly Reports submitted to the Program Planning Office, NASA JSC, reviewed and forwarded to NASA, Washington.

The fourth report marked the mid-term review of the study and was an opportunity to outline work expected for the remaining study period.

This is the final report. In it, reviewed for consideration, are the study conclusions.

INTRODUCTION

Space technology has developed to the extent, in the last few years, that man is no longer required to merely "survive" in a capsule pressurized against a hard vacuum, enduring psycho-motor disfunction caused by "zero-G", and living on peanut butter, laced with B vitamins squeezed from a toothpaste tube. Basic functional problems of survival, of equipment configuration and optimization: general requirements of human existence in the inhospitable environment of space have, for the most part, been resolved. Generally, habitation of space is no longer barely possible; it is simply different, more highly sophisticated. There are, however, new problems which, now that the more immediate ones of survival have been overcome, must be considered.

Previously, manned space flight, whatever its ultimate goal, was carried out by highly trained, meticulously screened and conditioned personnel, who were groomed for space travel through years of intensive training. The new pioneers, those who we envision will man future orbital space stations, will not be privy to this intensive training. Their skills will be too diverse. They will be men and women. They will be younger and older than the handpicked few who have, thus far, been utilized in the space program. Though this group will be highly specialized, physically well conditioned and generally above average, they will still be more prone to human frailty than those individuals undergoing space travel and prolonged environmental confinement in the past.

ARCHITECT'S ROLE IN SPACE PROGRAM

There are, therefore, two factors which involve the architect as a member of the design team which will provide the habitat in which future space station personnel will work and live:

1. Technology is sufficiently sophisticated to insure survival, thereby allowing us the luxury of more pleasant surroundings; facilities which are less spartan then those of the past;

2. The human cross section which we are now to utilize as personnel for this venture reinforce the need for less mundane environments. They will tend to be more average, more prone to problems and will require amenities which heretofore have not been needed or feasible in the space program. The design of these amenities, of these spaces which now are to be utilized by individuals less accustomed to the rigors of confined zero-G habitation, must include the social scientist and the architect. Prior to this study there has been relatively little thought given to the architectural aesthetic in space station design.

The architect deals with the creation, organization and human use of space. These issues will become more essential as the space program progresses and man begins to stay for extended periods in space. There are several areas in which architectural synthesis affords effective solutions to certain problems. This synthesis can only be defined as providing a solution to a problem based on limitations of technology and human resources. The architect looks at what a space must be to perform a certain function. But, beyond that he also seeks to find what a space can be in its broadest most extreme sense. By stretching a solution to its extreme, the architect provides a solution which is more than functional or pragmatic. This synergistic approach, that of combining parts or elements of a problem into a solution which is more than the mere sum of the parts, is the essence of successful architecture. It is this symmetry, this correctness, which separates the Rembrandt from the starving artist; the Azimov from the journalistic hack.

The largest scale of architectural effectiveness is that of urban design. In a large complex space environment, issues of transportation, "land use", urban economics, density, public services, and so forth, become important problems. Urban design principles which are used on earth will work for the most part in space. A "zero-G" environment actually offers many new opportunities in the application of these principles since the design occurs in three dimensions instead of on a two dimensional ground plane. Visionary urban design such as that of Polo Soleri, which also seeks to escape the ground plane, would have practical applications in weightless space.

A particularly important contribution the architect can make is the design of modular spaces that are aesthetically pleasing to the habitant. Though some spaces can be very small, they may be designed to give an impression of greater dimension. It has been established that prolonged confinement in a spatially limited environment induces psychological strain. Improving this environment, by such superficial amenities as pleasing colors, textures and lighting, will play a substantial part in minimizing this strain. More importantly, however, is a manipulation of spaces to reduce the feeling of enclosure, creating variety, and to adapt to human scale. Graphics, symbols and symbolic forms give identity to space. In the same way, electronic media can be utilized in various ways to create a liveable environment.

In relatively small, restricted enclosures, such as a space vehicle, efficient functional use of space is important. In conditions of weightlessness where basic assumptions about the use of space no longer hold true, the designer must have a sophisticated understanding of how people use space. Perhaps the most critical area of consideration is that of orientation. Optimum use of a spacecraft will be achieved when a user understands his orientation within a particular space and within the spacecraft.

The way spaces control or stimulate social activities is also important in a large complex space community. An individual should have areas of privacy, public contact and limited public contact. There should be areas which encourage spontaneous activity and personal expression. Some areas should be left free for the individual to personalize. The architect understands how people act in various kinds of spaces. This understanding enables him to design and organize a variety of spaces to accommodate the complex social interactions.

As a member of the design team, the architect will be useful as a consultant to the engineering specialists in situations where structural systems relate to human activity or interior design. In any area that involves the practical deployment and human use of space technology, the architect will have a role.

The space environment presents many absolutely new opportunities as a living environment. Views of the sky and landscapes in an earth structure are replaced by views of whole earth and space in a space vehicle, weightlessness allows new ways of using the human body, new materials in living environments and new ways of putting materials together. Activities such as dance, art, theater, and sports literally gain a new dimension with weightlessness. A space community of highly trained, dedicated workers will have a unique sense of community. These opportunities must be exploited to the fullest and should be reflected in the design of the environment.

These are areas where architects can make a contribution to the space program. As technology increases and more flexibility and opportunities are available in space vehicles, decisions will have to be made about how they will be designed. The skills of the architect will be more than useful in solving many of these problems. The solutions must be better than common denominators of design. They must be because they can be.

The architect must deal with other specialists to successfully complete his function. Engineers must explain the flexibility of the technology. Social scientists can provide pure information about human psychology and social systems. Users tell how they hope the design will function. Administrators explain problems of financing and politics. The synthesis of these ideas and their translation into physical forms is the job of the architect. He is an expert in the creation and successful utilization of human space.

ARCHITECTURAL APPROACH

This study is unique in several aspects. Initial investigation revealed that prior works were initiated with specific cutoff points in mind. That is, space station design was approached from the standpoint of an initial configuration containing a small number of personnel progressing to a larger configuration containing a maximum number of personnel. The top end figure was always predetermined. There was always some point at which further expansion became infeasible due to structural limitations or other constraints. Designing a space station of a specific size, containing limited specific functions has been the approach. It was determined that a configuration capable of infinite expansion, containing an ever-increasing number of personnel will be more responsive to the unknown requirements of future space missions.

Our study, then, became one of evolution of an urban system; beginning initially as a facility of a small number of people, possessing an unlimited growth capability, designed for an unknown future. There was no program as such for this study, since there was no precedent to go by. We set out not to simply design a space station, but a space community along with all of the associated facilities and amenities. This project encompassed large scale urban planning as well as circulation problems, systems of growth, typical social structures and detailed interior design.

Our study then went from the small scale of the initial outpost to the large scale of the urban community containing the microcosm of detailed interior spatial studies. These facets led us into many disciplines and required the interface of engineering, social science and architecture. There was no handbook to delve into for guidelines; there were no ready answers.

TASK V DESIGN FEATURES AND CRITERIA FOR MODULAR GROWTH OF A SPACE STATION

From the beginning of the project, it has been our intention to develop a systematic approach to the planning and design of habitats expected to accommodate large numbers of persons working in space, in short a city.

Our investigation is architectural, and by its very nature, functions from a foundation of primary assumptions and givens.

Adding to our basic goal-set, the following considerations helped to form the project's working assumptions:

1. Construction of the project must be feasible in terms of available materials, and conform to current engineering practices;

2. The construction must be modular in its approach to accommodate expected growth;

3. The construction system must be flexible enough to be modifiable for any current or future mission;

4. The overall planning approach must consider the dynamic principles of human habitation; and

5. The project must incorporate the basic principles of urban development in its planning process.

Having established the goals and an overall sense of direction, we proceeded to identify and list a series of related tasks and subtasks which would allow the systematic approach to a solution while assuring significant input from other disciplines. The basic tasks were:

1. State the goals;

2. Identify, locate, and collect the base line data;

3. Analyze the data in terms of the goals;

4. Define the problems;

5. Develop initial solutions to each problem within a clearly delineated overall

solution; and

6. Review and define the initial concepts developing a cohesive, consistent design proposal.

For the last 22 months we have investigated these basic considerations starting with a detailed review of growth systems which would allow a habital space station to expand from a singular core unit to a complex of much larger dimensions.[1]

From the analysis of base data[2], two major problems were identified and systematically studied:

1. Is it possible to develop a modulated system with unlimited growth potential capable of incremental expansion at a minimum expenditure or investment of resources; and

2. Given such a growth system, can it be sufficiently flexible to adopt to a vast variety of missions, some perhaps not even being currently considered?

The growth concepts presented in this report specifically addresses the requirements for non-committal growth capabilities with minimal resource investments.

SHUTTLE DELIVERED SYSTEMS

The first three reports contain discussions of the specific data collected and the particular structural or delivery systems studied in the early phases of the project. The studies are directed towards space stations which can be shuttle delivered in violation of the weight to volume constraints and once delivered, constructed or assembled from the shuttle bay with in-flight personnel functioning in the "hard hat" role.

In seeking solutions to the volume/weight ratio problem, three conceptual systems were st ed. In discussing them here the purpose is to illustrate the potential values of each assembly concept with the technical character of the examples serving only to illustrate that concept.

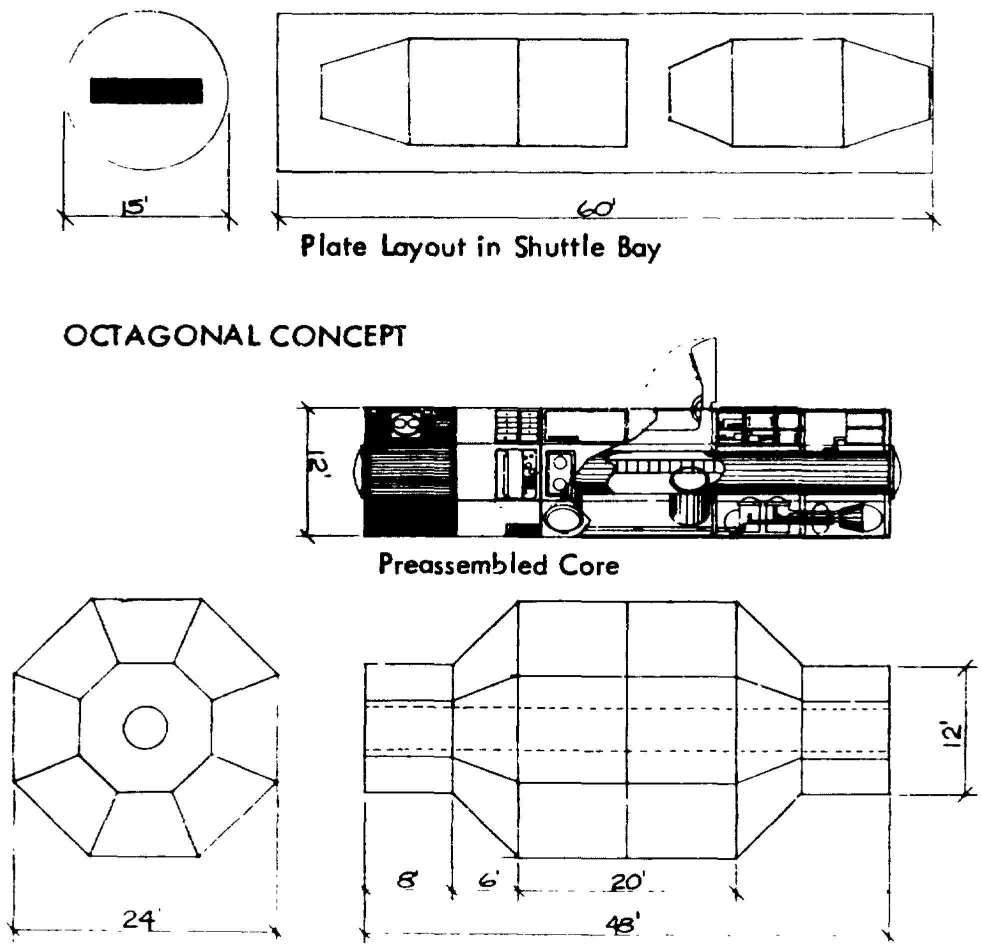
1. FLAT PLATES: The selection of one inch aluminum plate for the outer structure is meaningful only in that it can retain a one atmosphere pressure within normal stress limits. Similarly, the selection of 10' square sections is primarily based upon ease of management within the fifteen foot diameter of the space shuttle cargo bay. Actual application of the concept would require building materials reflective of the current state-of-the-art and engineered for their specific requirements.

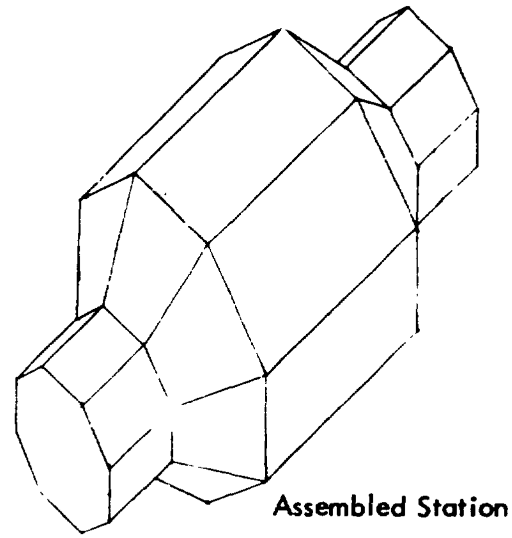
   This assembly approach allows for maximum payload utilization of the up-leg of the space shuttle; weighting out the flight limitations prior to exceeding the volumetric constrair

   The use of inflight persor n a "hard hat" role is based the techniques being well within their physical capabilities and compatible with the dexterity afforded in an E.V.A. situation. The dependence upon automated assembly devices can be substantially reduced, if not eliminated, together with the related cost of developing, testing and transporting such devices to orbit.

   Within these general conditions, two general configurations have been considered, an octagonal and a hexagonal structure, both being achievable in two shuttle flights. (See Figures 1 and 2.)

   The concept is a continuous growth





OCTAGONAL VOLUMES

Prefab Core	5,780 cubic feet
Core Sleeve Tubular Addition for 20 foot run	7,200 cubic feet
Transition Section	1,920 cubic feet
Approximate Total	14,900 cubic feet

Surface Area Added to Core 2,978 sq. ft.

FIGURE 1

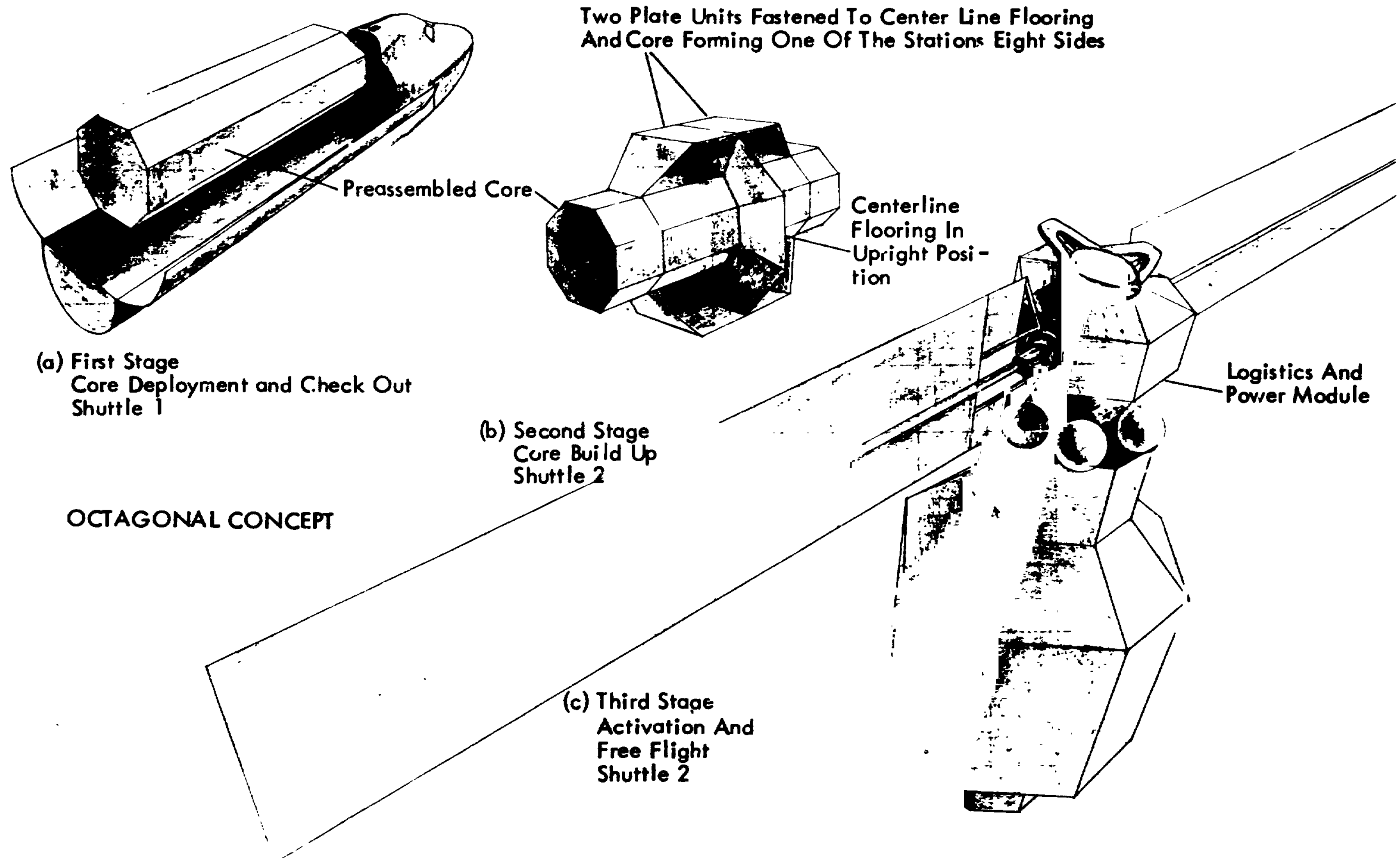
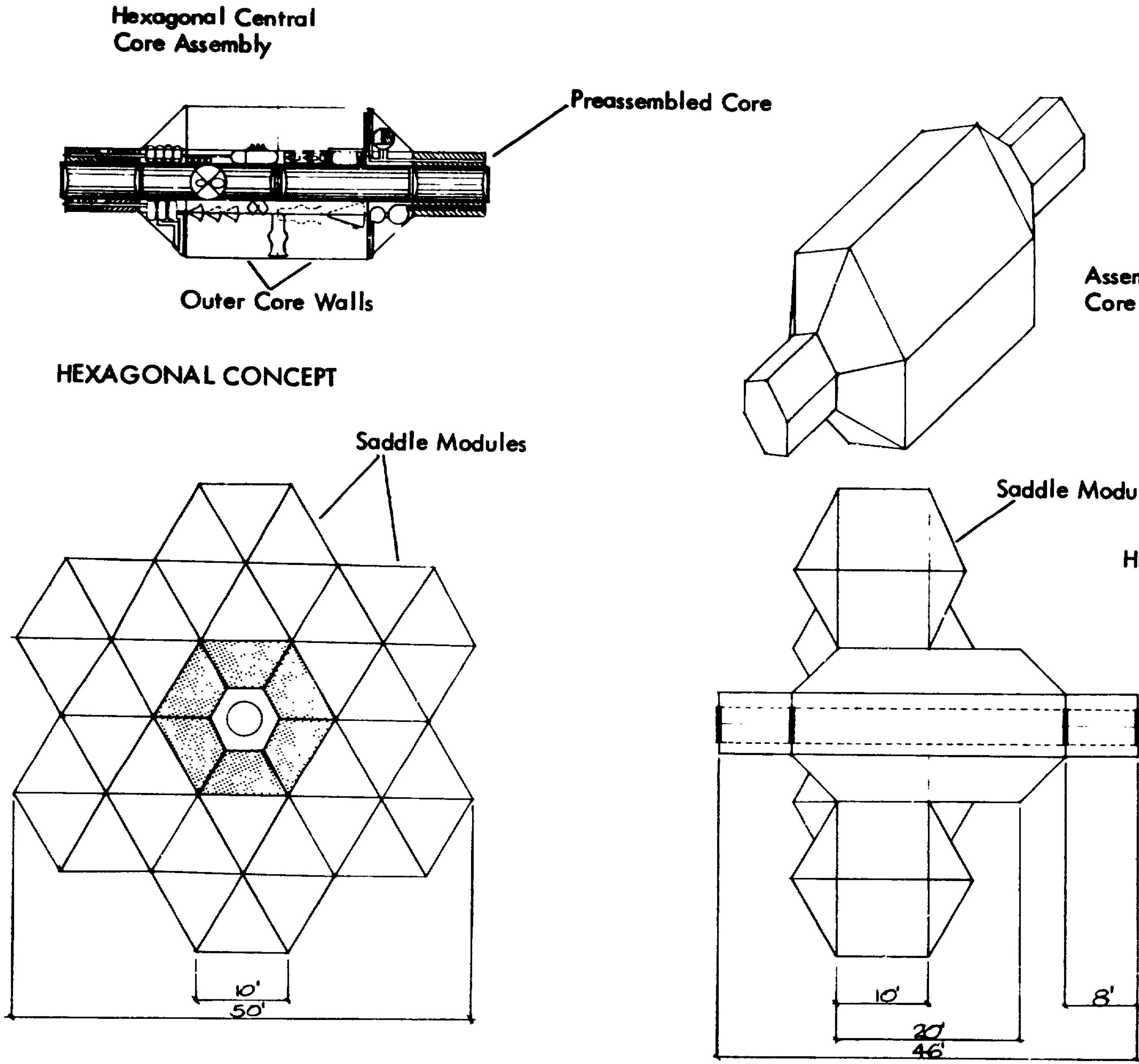

Two Plate Units Fastened To Center Line Flooring And Core Forming One Of The Stations Eight Sides
Preassembled Core
Centerline Flooring In Upright Position
Logistics And Power Module
(a) First Stage Core Deployment and Check Out Shuttle 1
(b) Second Stage Core Build Up Shuttle 2
OCTAGONAL CONCEPT
(c) Third Stage Activation And Free Flight Shuttle 2

FIGURE 2



HEXAGONAL VOLUMES

Core	3,072 cu.ft.
Sleeve	3,840 cu.ft.
Transition	740 cu.ft.
TOTAL	7,652 cu.ft.

SADDLE MODULE

Hex Module	2,560 cu.ft.
Caps	853 cu.ft.
TOTAL	3,414 cu.ft.

FIGURE 3

capability which allows additions to occur at any time. The initial station (using either geometry) is developed in a build-up sequence around a pre-assembled core section containing the complement of fundamental systems and equipment required to make the station habitable and operational. The initial construction might occur in three phases: (See Figure 4.)

1. The first shuttle containing the core and base plates achieves orbit, lifts the core from its bay on a hydraulic rotisery hoist and readies it for plate addition.

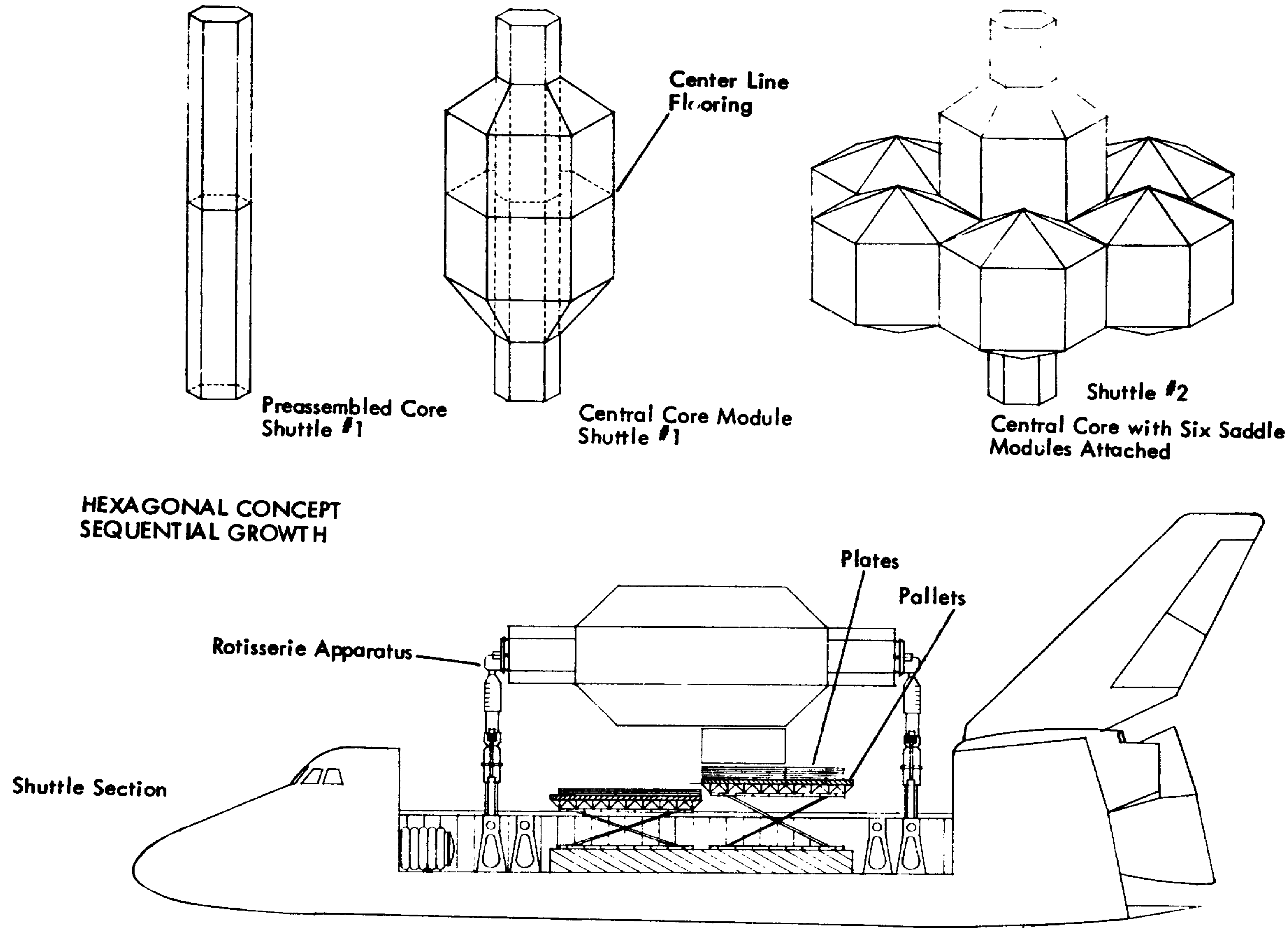
2. As the hoist rotates the core, plates are lifted from the bay by E.V.A. crews and connected enclosing the first volume. (See Figure 5.)

3. When the first volume is complete, it is pressurized making it habitable and locking the plates in place. Subsequent shuttle flights will bring the addition of the six saddle units which will be placed around the core. (See Figures 6 and 7.)

Expansion may now occur longitudinally, laterally, or in both directions simultaneously. (See Figures 8 and 9.)

1. Longitudinal growth requires the addition of core units as well as pod space as the station grows along its axis.

2. Lateral growth is perhaps the most simple and yet allows the most variations. With the addition of just three wall plates a completely new volume may be added. If needed, additional cores may be included almost at any point. Whole new sec-



Center Line
Flooring
Preassembled Core
Shuttle #1
Central Core Module
Shuttle #1
Shuttle #2
Central Core with Six Saddle
Modules Attached
HEXAGONAL CONCEPT
SEQUENTIAL GROWTH
Plates
Pallets
Rotisserie Apparatus
Shuttle Section

FIGURE 4

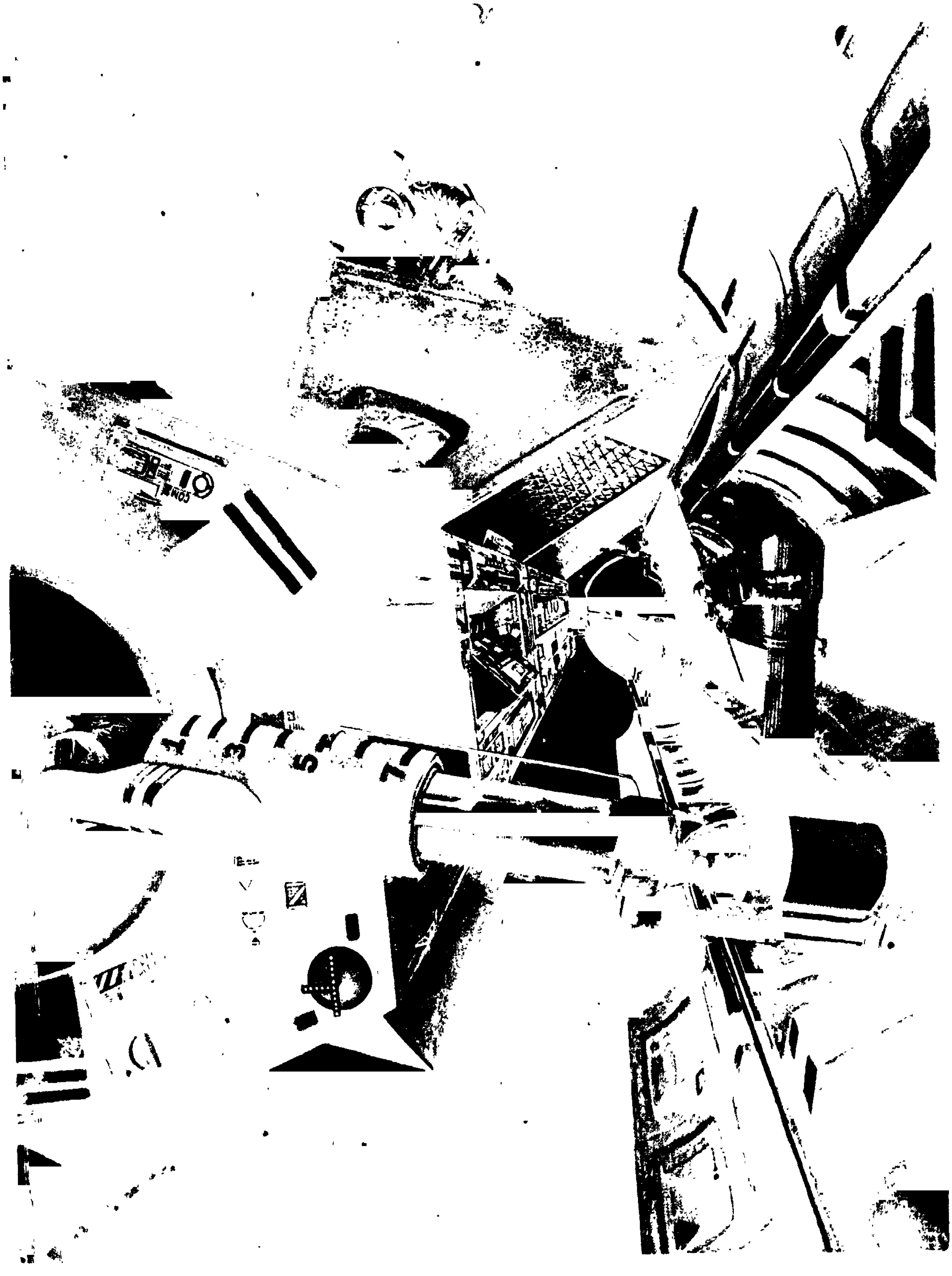


FIGURE 5

FIGURE 6

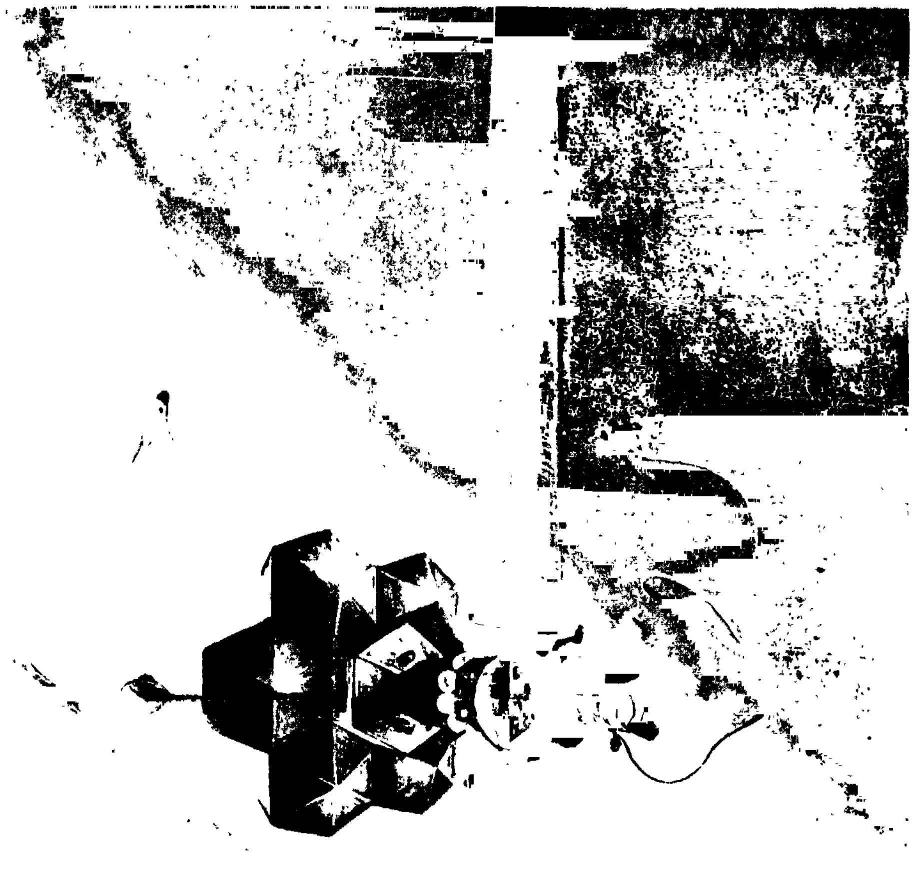


FIGURE 7

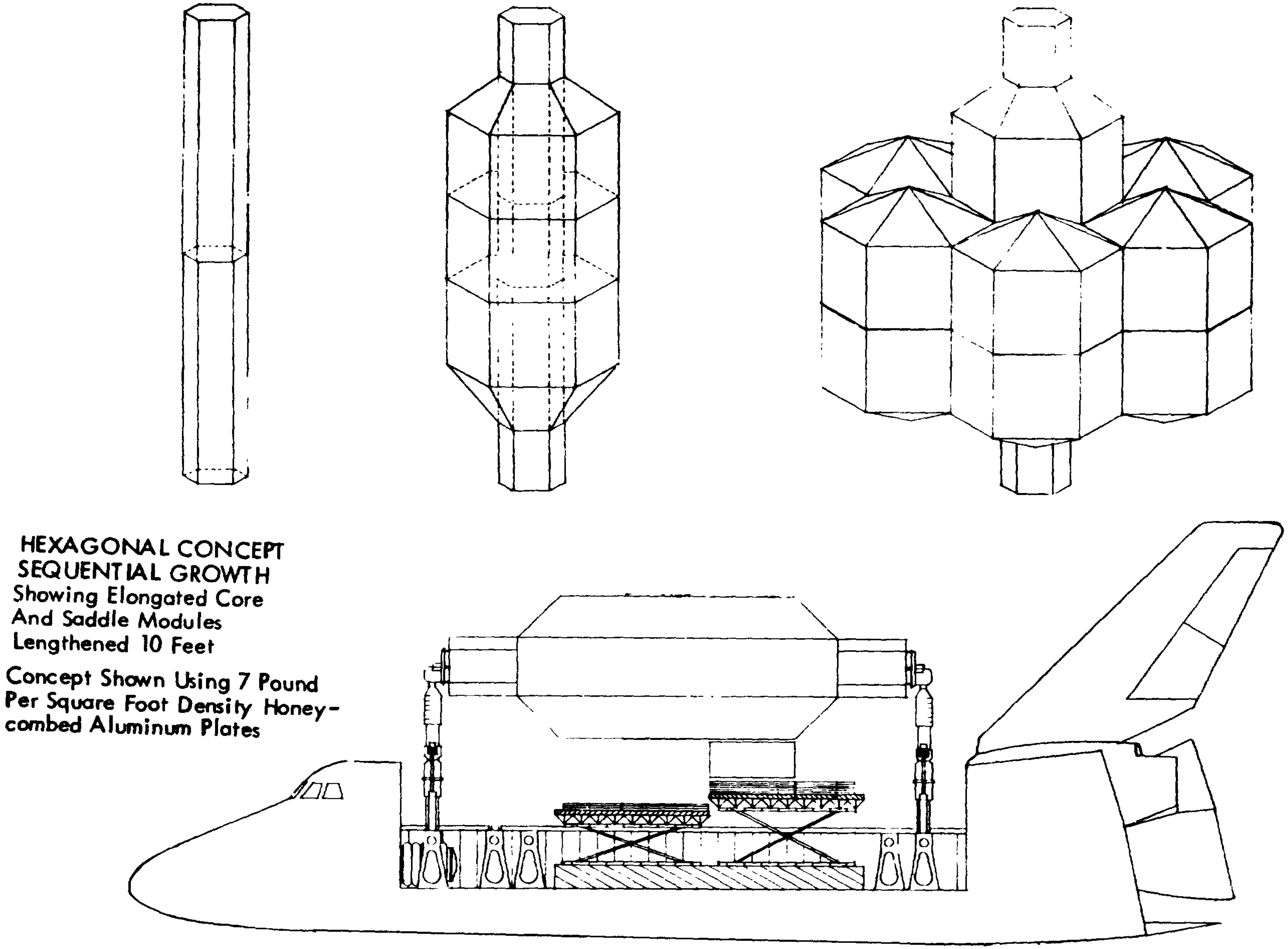
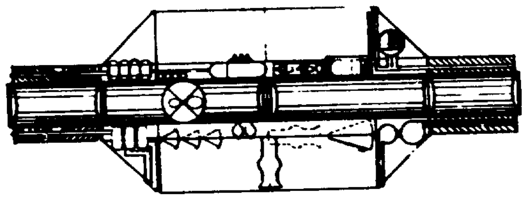
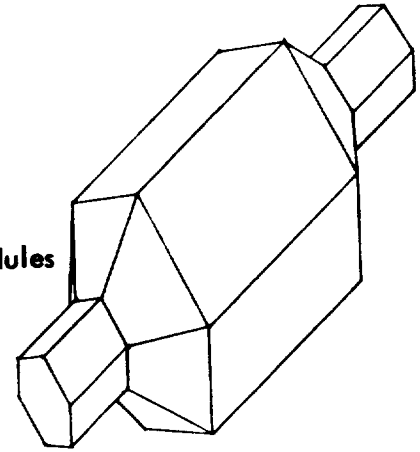
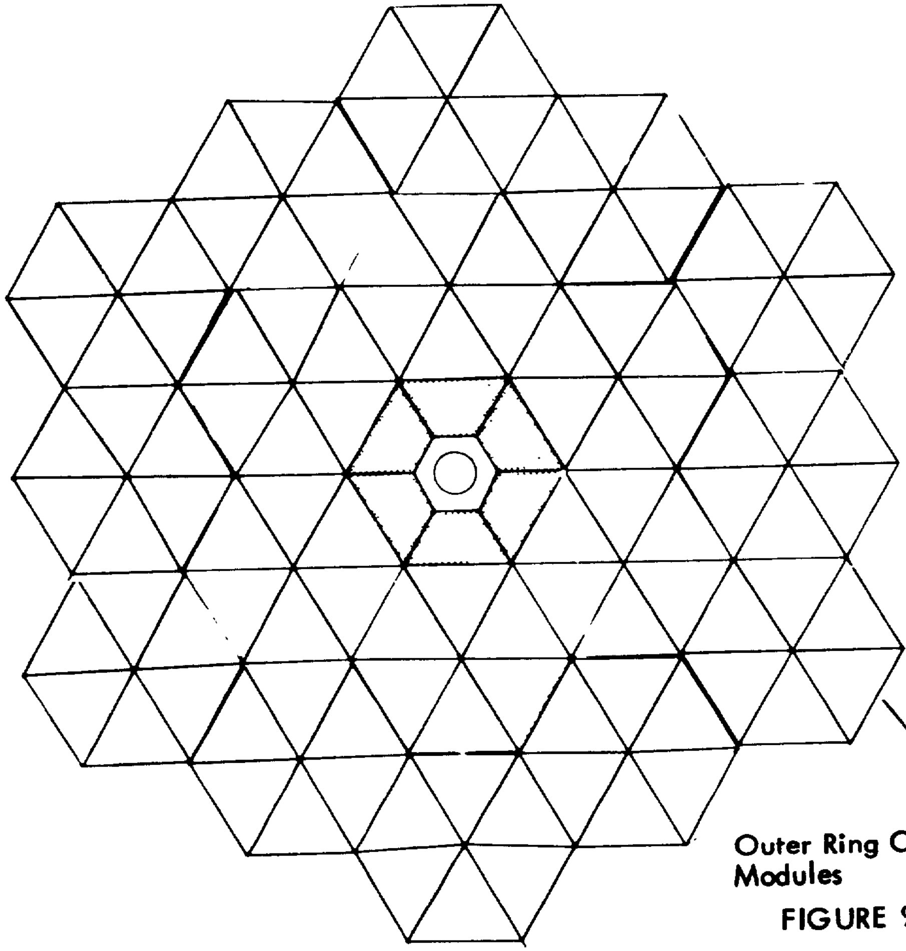

HEXAGONAL CONCEPT
SEQUENTIAL GROWTH
Showing Elongated Core
And Saddle Modules
Lengthened 10 Feet
Concept Shown Using 7 Pound
Per Square Foot Density Honey-
combed Aluminum Plates

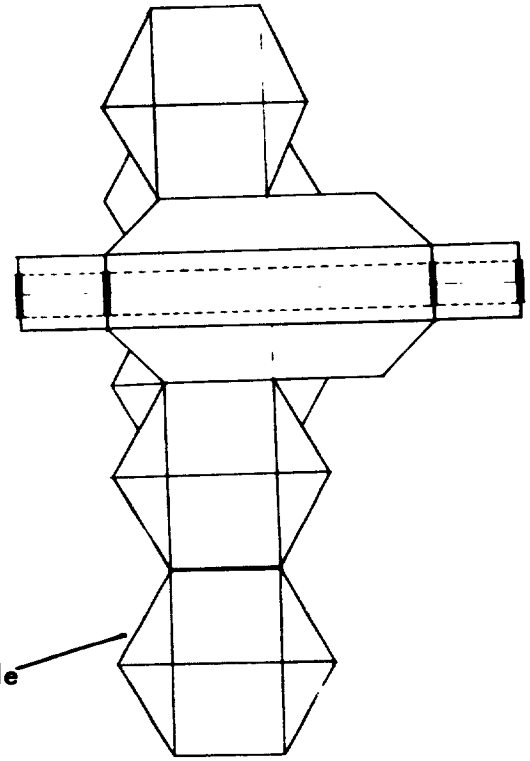
FIGURE 8



EXPANDED HEXAGONAL CONCEPT Shown With 12 Additional Saddle Modules







Outer Ring Of Saddle Modules

FIGURE 9

tions developed concentric to the new core connected to and contiguous with the older structure.

An interesting note about the plate structures; the honeycomb configuration allows each new wall to become an equal structural member; neither adding or subtracting from the others structurally. This allows uniform thicknesses without the usual consoderations for structuring normally found in "Gravity" situations.

2. PNEUMATICS: The concept of using inflatable units composed of thin membraned skins, expandable frame/skin components, or combinations of the two allows for a maximum payload which results in a structure considerably larger than the volume of the 15'x60' shuttle bay.

As with the Flat Plates, the material discussed is meaningful only in that it can retain the pressures required. It has been demonstrated as reliable in its expandable capacities, and is used to demonstrate the creditability of the concept.

The concept considers a station deliverable in three or four flights and consisting of a package folded into the shuttle bay, and designed to be expanded about a core unit once in orbit. Life and technical support would be contained in the core. Permanent internal support could be afforded with expandable folding frame systems adopted from the orbital assembly maintenance study. An analysis of this combination may be seen in Figures 10 and 11, titled "KEVLAR 49, an 80 Foot Sphere".

An artist conception of this type of structure may be seen in Figure 12.

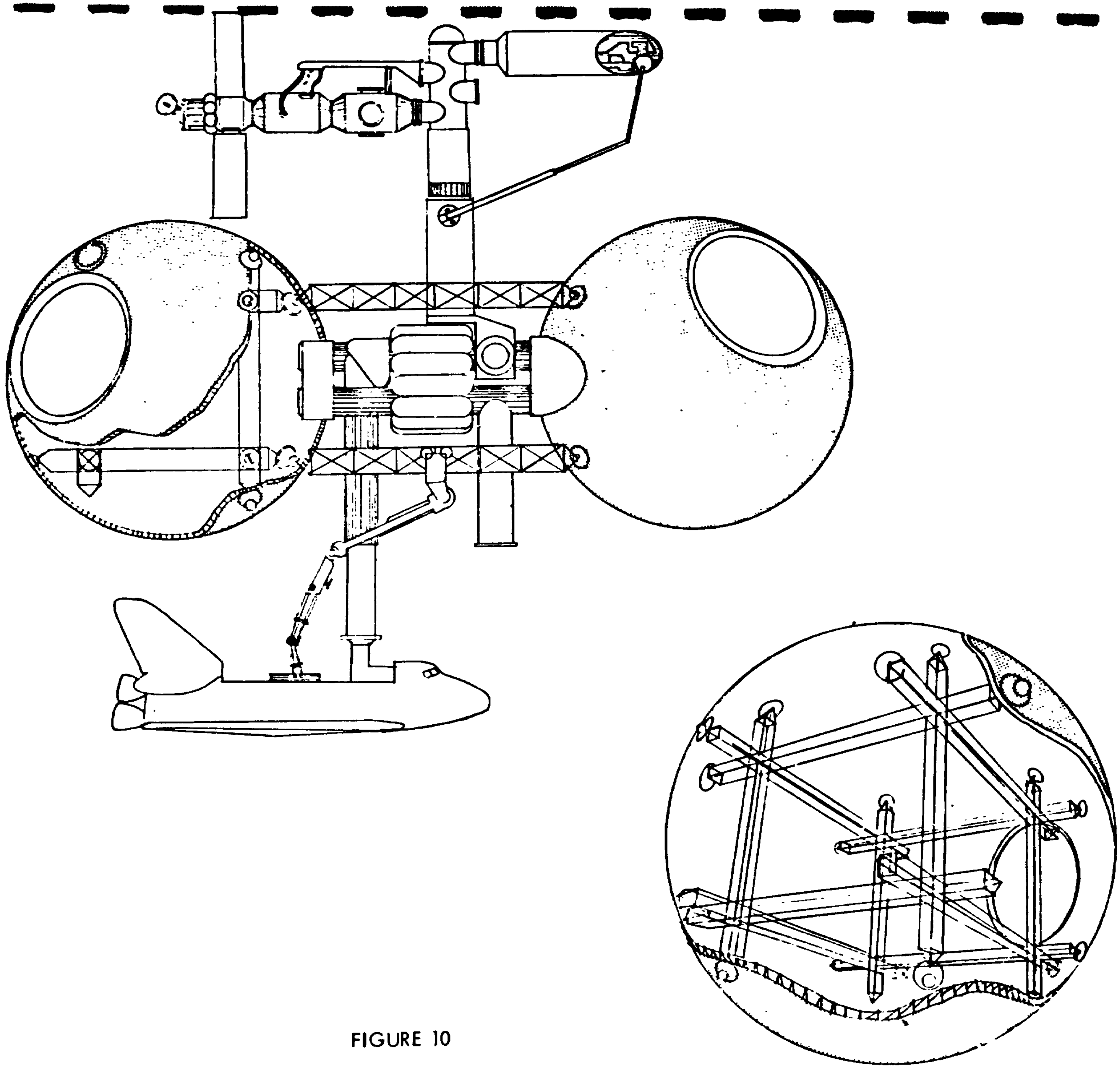


FIGURE 10

PNEUMATIC SPACE STATION MEMBRANE

EXAMPLE: TEFLON TREATED KEVLAR 49 MEMBRANE

- 80 FEET DIAMETER
- PRESSURE 10 PSI
- STRESS ON MATERIAL: 2400 lbs/in
- SURFACE AREA 20,000 ft^2
- TOTAL VOLUME 268,000 ft^3

	PESSIMISTIC	OPTIMISTIC
· MEMBRANE THICKNESS	0.31 in.	0.078 in.
· WT/FT^2	2.6 lbs/ft^2	0.65 lbs/ft^2
· TOTAL WEIGHT	51,271 lbs.	12,818 lbs
· WORKING LOAD	7800 PSI	30,769 PSI
· FOLDED VOLUME	1025 ft^3	256 ft^3
· SHUTTLE VOLUME	10,602 ft^3	
· GAS WEIGHT	13,371 lbs	
· FOLDED TO EXPANDED VOLUME RATIO	250 TO 1	1500 TO 1

FIGURE 11

FIGURE 12

3. The Pre-assembled modular components were studied in detail and have tremendous potential as additive and support units, structured for a specific task and manufactured either on Earth or in Space. They will be discussed later.

From these studies, growth is strongly suggested as possible and structures could be delivered by the shuttle, which when deployed could have a high volumn/weight ratio.

Within the last decades, building solutions to human activity on Earth has become considerably more complex and frequently addressed the problems involved in growth and change.

Through the techniques of master planning, complex buildings such as airports or hospitals may be designed and managed so their inherent need to change and expand does not become an afterthought or a future problem requiring expensive solutions. These techniques have been modified and refined to respond more and more to rapid, complex changes. Consideration is given to functional planning, the saturation of space, limits to the structures, limits of circulation and volumn, and so forth; all within a framework of expected growth, or change and minimal or fixed monitary resources.

As an example, consider an airport scheme which, in many ways, is analogous to the operations of a space station. The economical essence of an airport is the complex interchange of transportation systems. It has external factors such as air and ground transport arriving and departing; internal needs to move both passengers and material from one connecting point to another; energy requirements; habitant comfort considerations; and prime most, a profit to make from its investment.

It is very important the building be planned so expansion does not interfere with the external transportation and yet allows for the increase in traffic corridors and internal transportation as the total mass increases. Similarly - the issues of growth and change in a space station design presented many of the same problems, each had to be investigated. The first was to provide maximum flexibility in a structure which would allow both internal and external growth, which did not restrict the internal function, and which ended without being excessively over designed or requiring major re-design as the station grows. The objectives of the solution were:

1. How can circulation corridors expand in both length and capacity;

2. How can increasingly larger and more complex spaces be provided for the more intricate functions which develop as the station evolves;

3. How can the major elements of the structure be replaced as needed;

4. How to accommodate radical scale changes such as conversion from research and development to industrial production;

5. How to provide an expansion of both power and utility systems to meet the scale change requirements as the station increased in manpower and industrial activity;

6. How to provide external accessibility to almost all of the components without enclosing the earlier parts of the station during and after expansion;

7. How to provide a growth geometry that

is easily navigable internally and not disorienting to the inhabitants considering the effects of zero gravity; and

8. How to provide a growth system with a constant geometry which directly relates to the flight characteristics of the space station?

Our approach to these questions was to analyze various growth processes as they occur in nature, evaluating each on its own merits. In doing this, we were looking for an overall growth system which would be applicable to an incrementally expandable space station.

The first system studied was a linear concept. We investigated and listed both the positive and negative aspects of a linear system growth process.

<u>Positives</u>:

1. Initially, the linear system has an easily accessible main circulation system;

2. It has very simplistic maneuvering characteristics; and

3. It may expand by attaching modules or units to either end.

<u>Negatives</u>:

1. There are definite limits to any kind of linear growth system;

2. There is inefficient distribution of utility systems;

3. There is no way to expand internal transportation systems, new systems must be attached externally; and

4. Each part of the system is over designed structurally until the limit to the linear system is reached, for that reason its final limits must be determined very early if it is to expand.

A progression of the linear system is called the two dimensional grid.

Positives:

1. The grid is easy to expand;

2. Because the grid is a basic X, Y coordinate system, internal orientation is excellent. One can locate himself anywhere in that grid;

3. Internal circulation is very good;

4. The external access is excellent in a space structure, approach to the grid may be made from either side; and

5. There are options in the transportation - system - routing in a two dimensional grid, one may move diagonally, along the central axis, or travel in a peripheral motion.

Negative:

1. Scale becomes a limiting factor;

2. Once critical size is reached, the transportation systems, internal circulation and power distribution begins to overload, the problem is basically the same experienced in a city when it expands. It just becomes crowded.

The grid concept was expanded into three dimensions and for the most part, found to be the same as the two dimensional grid:

Positive:

1. It has the same good characteristics in its early stages;

2. It is a much more efficient transportation system.

Negative:

1. As it grows into later stages, it becomes so complex that it is a limiting system within itself; and

2. Internal circulation becomes very confusing.

The next concept studied was a spherical growth or a nucleate growth system.

Positive:

1. The cylinder and sphere are ideal pressure and weight to volumn ratios for use as space stations;

2. These systems provide a very compact arrangement;

3. There is efficient point to point transportation within the system;

4. There is good utility distribution within a sphere or a cylinder, providing it has a centralized system.

Negative:

1. Growth is not in a straight incremental rate and makes it difficult to call it a modular system;

2. The amount of material required to add an increment increases significantly with each growth step, you are working with annual rings or spherical growth;

3. It tends to be a static structure and is difficult to replace the nucleus or the original parts found in the original structure;

4. It is hard to accommodate capacity changes and very difficult to service the center;

5. The space involved in the exterior operations are covered during expansion and require relocation of equipment, windows, exits, etc.

The final system studied was branching. As a growth system it has many aspects which related very well to the concept of an expanding space station.

Positive:

1. Branching allows for a scale change at any point;

2. It may be easily expanded along any point of its axis;

3. It has excellent modular characteristics;

4. The system would provide easy access to exterior components, they are all exposed;

5. The growth can be achieved in small increments or very rapidly;

6. The growth geometry remains basically constant throughout the growth sequence and virtually unchanged.

Negative:

1. Point to point internal transportation may require complex routing;

2. It is not a compact arrangement at all, there tends to be bending moments implied as the system grows, and these would have to be considered.

After examination of all these growth systems, a comparison was made of the problems which needed solving, the goals established, and the positive and negative quality of each of these growth systems. From the comparisons, two decisions were made;

1. Branching was considered the best overall geometric pattern; it seemed to satisfy the requirements of scale better than any of the other geometries studied; and

2. Within the branch geometry, each of the other systems may be used to its best advantage.

To delineate the concept, a series of illustrations are used that convey the overall principles. These are conceptual illustrations and should be viewed as visual aids rather than specific solutions. Two basic principles are:

1. The use of a geometry that remains fundamentally the same throughout the growth sequence. (Not necessarily the one shown.)

2. The use of incremental growth making small investments to achieve the desired level of growth. Cut off may occur at any point during the growth process. It may continue to grow again at any later time when the need arises.

The limits of the growth are determined first by structure, second by the saturation of the core facilities within the structure, and third by the utilization of the various capacities within that system. The system is composed of four basic elements; the specialized modules, the core modules, the provisional adapter, and structural connectors.

The system starts with a core module, delivered and designed to receive specialized modules.

The core is basically a tube with three connection points around its cylindrical walls allowing the attachment of from one to three specialized modules. The flat ends of the core modules are fitted with devices which allow the core to be coupled with other cores with specialized equipment such as solar power generators, or with the provisional adapter.

As the overall size of the space station increases the demands for the delivery of the supportive services proportionally increase requiring heavier bussing, larger plumbing, bigger transportation corridors, and transitional spaces which accommodate the increase, and at the same time, shift axis and scale. The provisional adapter is conceived as the functional entity which provides for this change.

Physically, the provisional adapter not only provides the basic support connections, but is configured to allow axial changes in growth; an important concept to 3-dimensional growth patterns based on a branching geometry; it affords unlimited growth potential.

First a specialized module is connected to a core module. When three such modules have been attached, the core has reached its maximum size (Figure 13) and the system

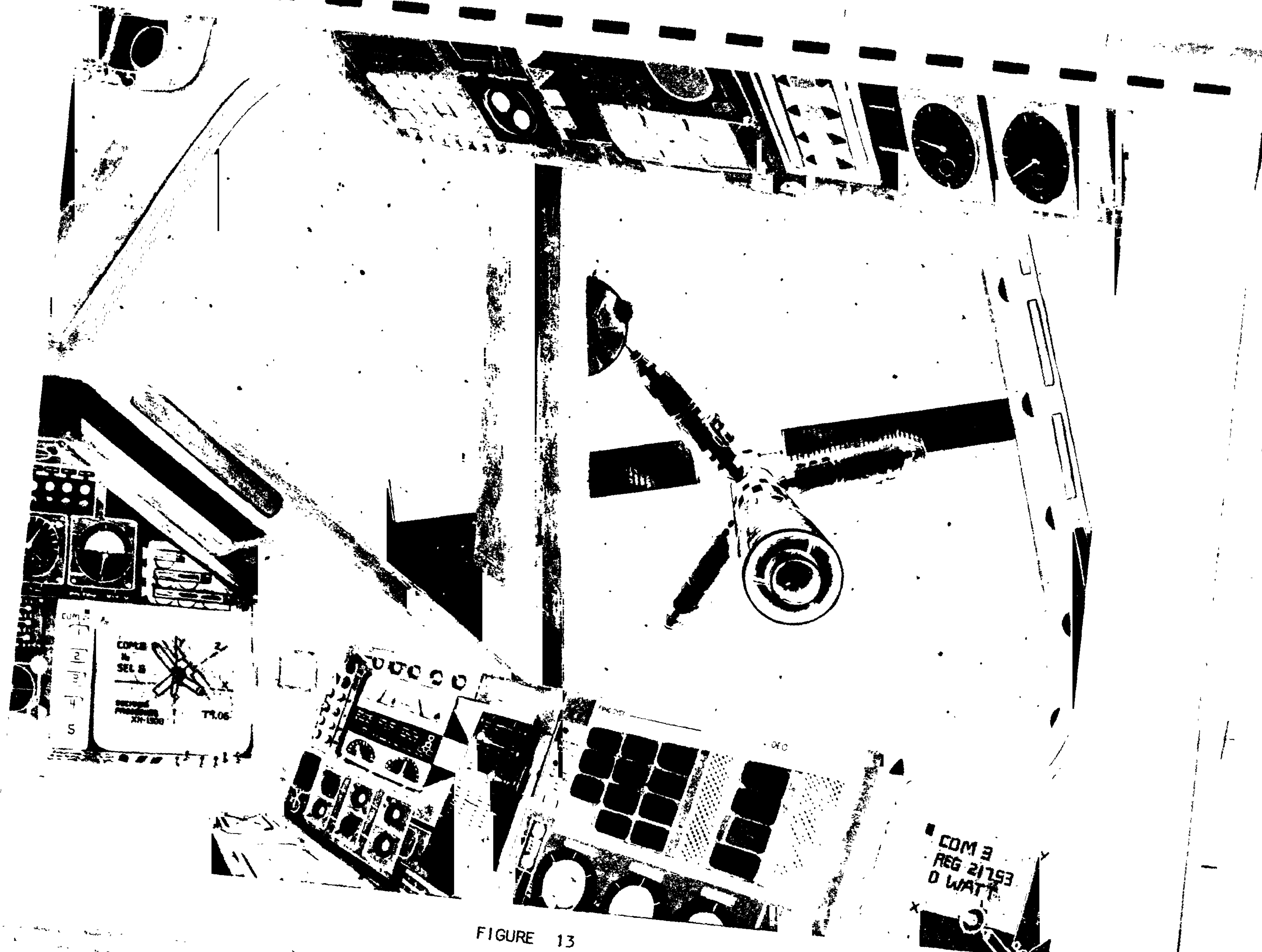


FIGURE 13

may grow only by coupling to another core; this coupling is the start of a "branch" which potentially may reach four cores in length, the predetermined limitation of this axis. With this first coupling of two cores, the station doubles itself; (Figure 14) at this point, if the decision is made to further expand, the second core is coupled to a provisional adapter. (Figure 15) It is important to note that the branch is only half way through its total potential length when the provisional adapter is added. It is the adapter which accommodates the heavier services, allows scale shifts and, most important, provides axial change. This pattern is repeated throughout the system; half way down any branch is an adapter, each adapter is designed to accommodate the next scale shift, to provide for heavier services and allow axial change.

Now, back to the budding station; after the provisional connector is coupled to the second core, the station acquires, (1) the ability to double itself along its original axis at the same scale by simply adding the third and fourth cores completing the branch; (2) by adding a structural connector to the provisional adapter, at right angles with the branch line, and another provisional adapter to the structural connector, the station has the potential to double its previous configuration. (Figure 16) But without the committment to do so. This pattern is repeated, but in three dimensions, as long as expansion is required. Figure 17 shows the first two branches complete and the next scale adapter being constructed. This addition will allow provisionally for the completion of this major axis illustrated in Figure 18. By the use of this concept it is possible to make incremental investments, obtain the specific level of growth desired, maximize the resources spent, retain the ability to expand, and do this

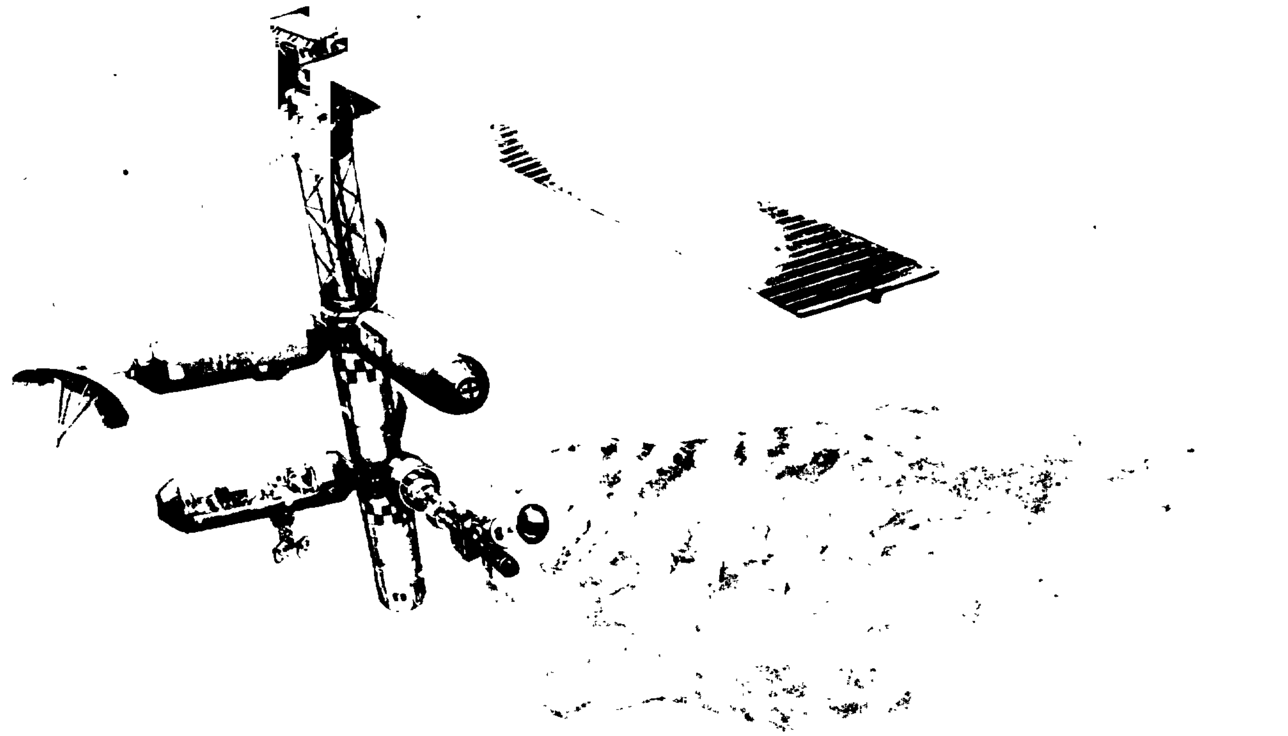


FIGURE 14

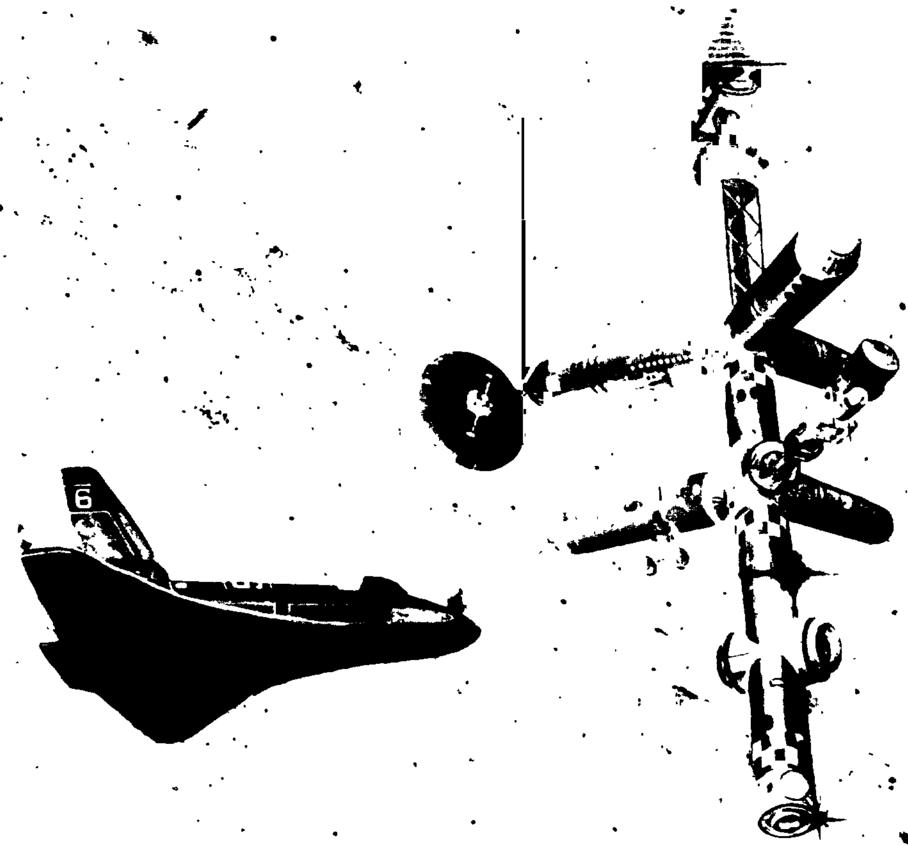


FIGURE 15

FIGURE 16

FIGURE 17

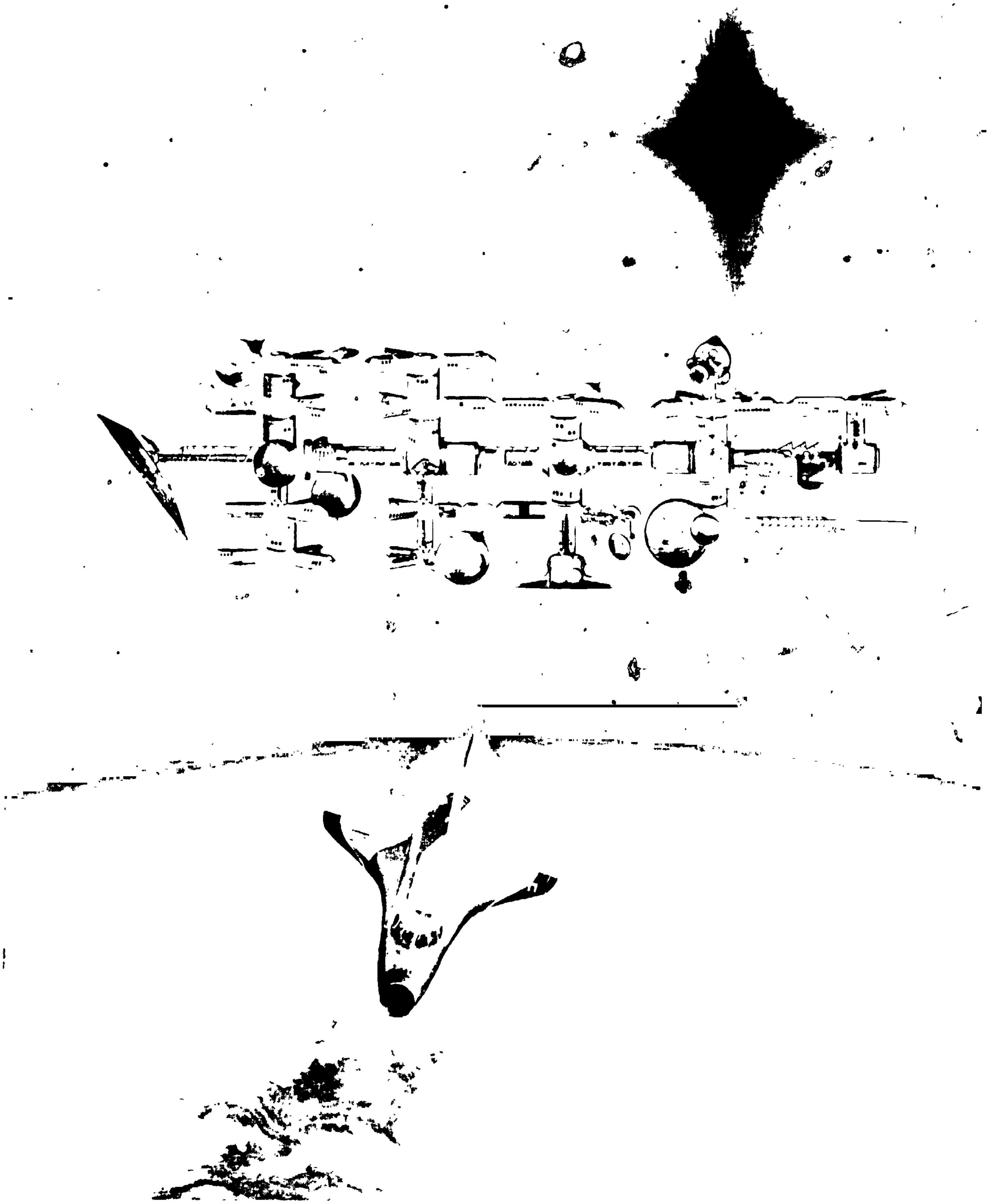
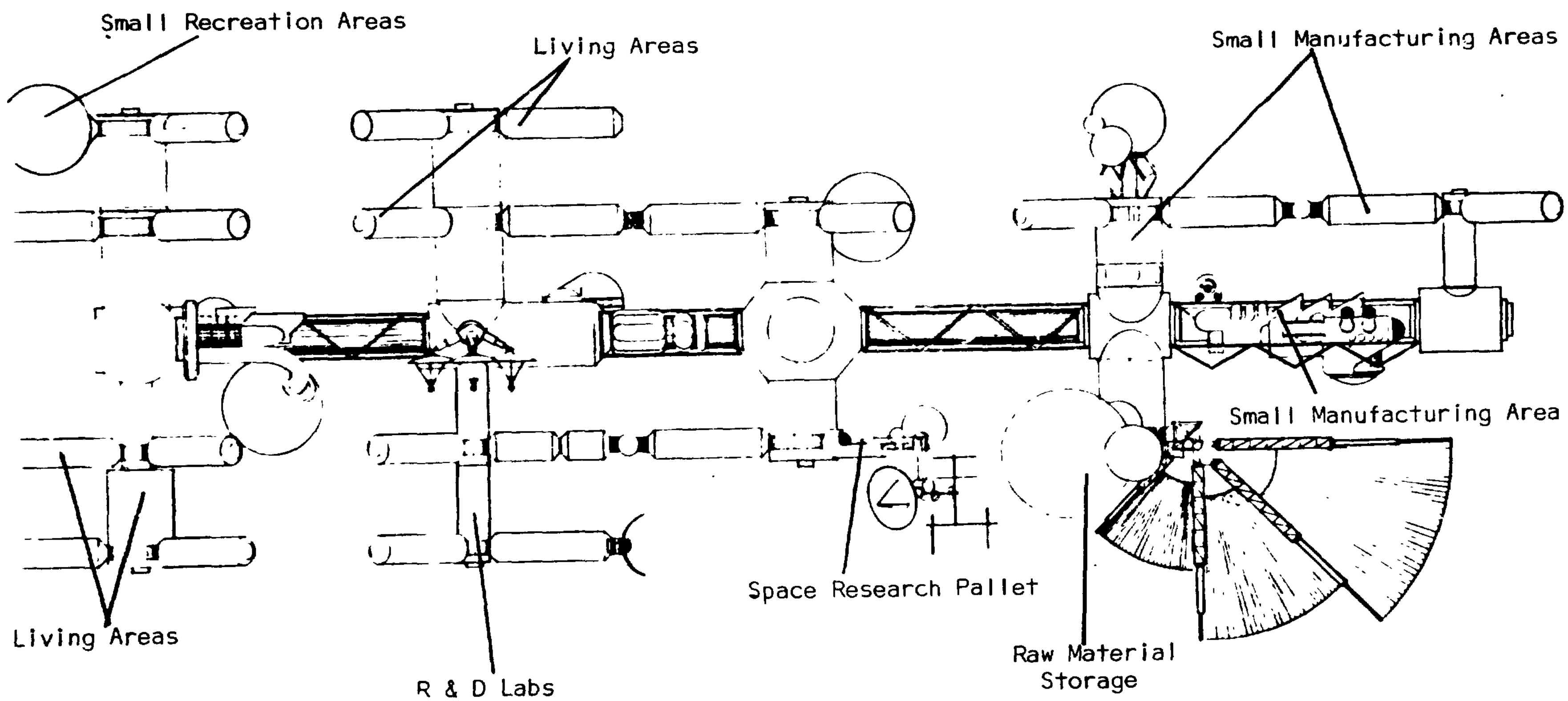


FIGURE 18



FIRST BRANCH COMPLETED (Approx. 100 man S.S.)

FIGURE 18a

even when the outer limits of the size requirements are unknown.

The future expansion of a facility is a prime concern of architects, builders, and owners. Early in a project the decision must be made for the additional provisions required for potential expansion and portions of the budget allocated for its use. In many cases, it means each system has to be oversized throughout its length to allow for the increased demands which might be experienced should the expansion occur. If the building does not expand, which is often the case, those systems and additional resources are not maximized, resulting in a loss in investment. With the provisional adapter, this is not the case.

As an example, let us examine the growth cycle of the power systems. With the first core module, the solar power generator is located central to the specialized modules and directly connected to the core module. Bussing and conduit within the core are designed to accommodate the loads throughout the entire branch of four cores. With the next major expansion, the station may double, quadruple, or more; the core bussing and conduit are not adequate for this configuration.

At mid-point of the core module branch is placed a provisional adapter; wired, bussed, and conduited to accommodate the required load the solar power generator is capable of producing for the major axis.

As the package of four cores is doubled or more, the solar power generator is relocated from the end of the first branch of core modules to the axial connector of the provisional adapter, wired directly to the adapter's bussing and distribution system, and continues its delivery of power, only now to 2 to 4 times the

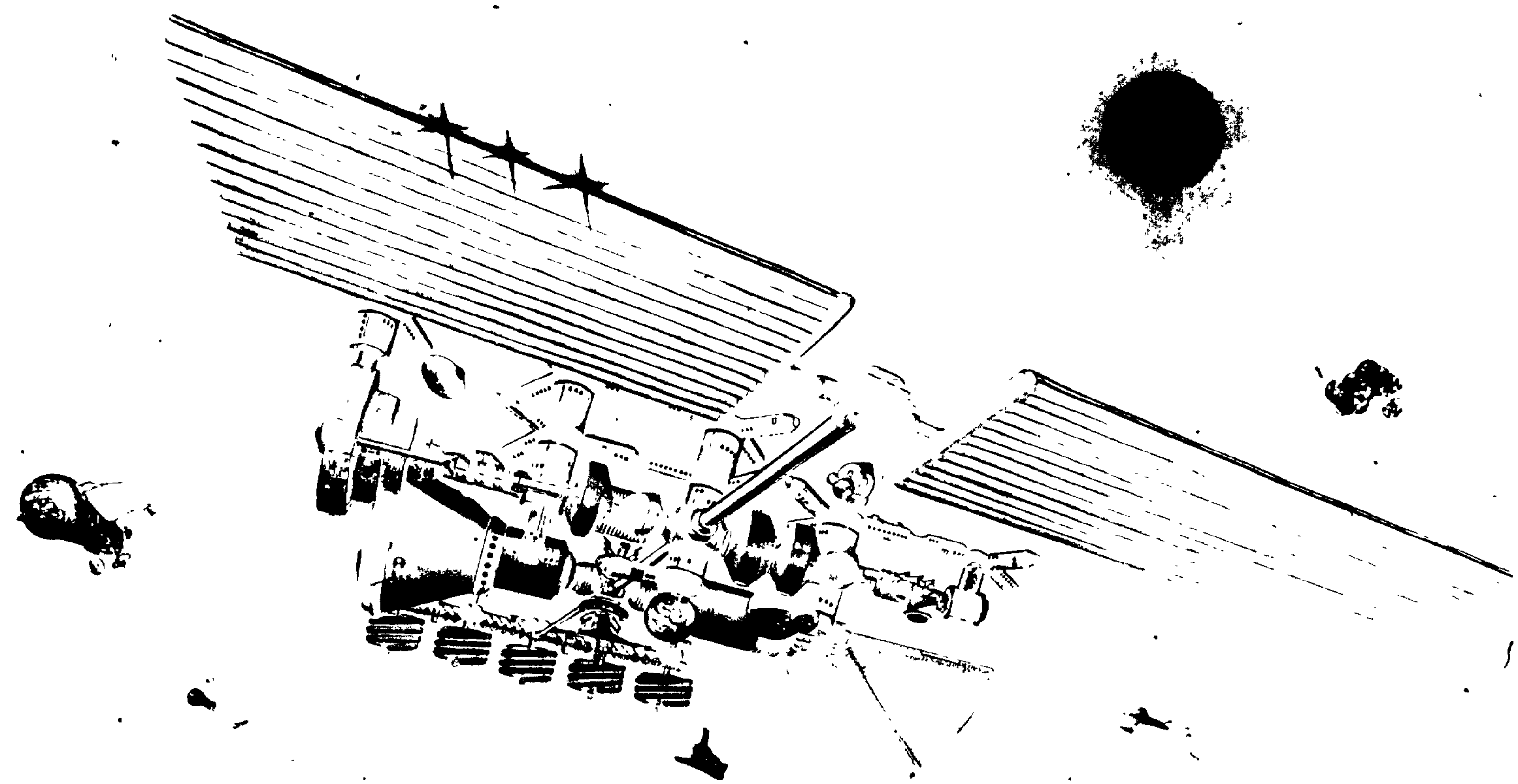


FIGURE 19

previous units. (Figure 19)

The original solar panels are sized to power about half the requirements of the completed axis; when the half way point is reached the next size provisional adapter is connected and additional solar panels are attached to the original solar power generation equipment.

In summary, with this system minimal sized wiring is used throughout and not oversized through the entire length to accommodate possible expansion; heavier bussing and wiring is retained within the provisional adapter, minimizing the distances and amounts of materials used, and conduit is prefurnished to accommodate future wiring needs, if required. Resource utilization is maximized.

During the last 22 months we have collected, categorized, and accumulated an extensive data base relative to materials, building systems, and engineering practices. We have analyzed the data collected and in view of the goals set earlier within the project have identified a set of problems we felt were pertinent to habitation of space by man.

The initial probe into these considerations was conducted by addressing a series of questions:

1. How to prepare this specific environment for the support of life in a productive manner?

2. What political structure would be best for this particular community?

3. Will the political structure manage the station or will each interest manage themselves?

4. How will it be paid for?

5. How does it function? What are its interrelationships?

6. If manufacturing occurs, who will be the market?

7. How will raw material be obtained, and from where?

8. Will research and development (R&D) be established as an industry; possibly renting space to other interests or nations?

Having posed these questions, the next step was to determine in more specific terms, both the magnitude and the elemental composition of the program, and map out, visually, its interrelationships. A preliminary listing of possible needs was established (see Figure 20) based on proposed activities, habitat needs, economical considerations, etc., and plotted with a listing of facilities which could formally meet those needs. The resulting matrix (see Figure 21), when evaluated, identified common use elements, affinities, and potential adjacenties. Figure 22 represents, in a diagrammatic format, a visualization of this programmatic study. (NOTE: Figure 22 is not a design or a proposed design, simply a study tool.)

The elements which are included in the scheme are:

1. Transportation (Space Port);

2. Agricultural Activities;

3. Manufacturing Activities;

4. R & D (Agricultural, Manufacturing, and Pure Research); and

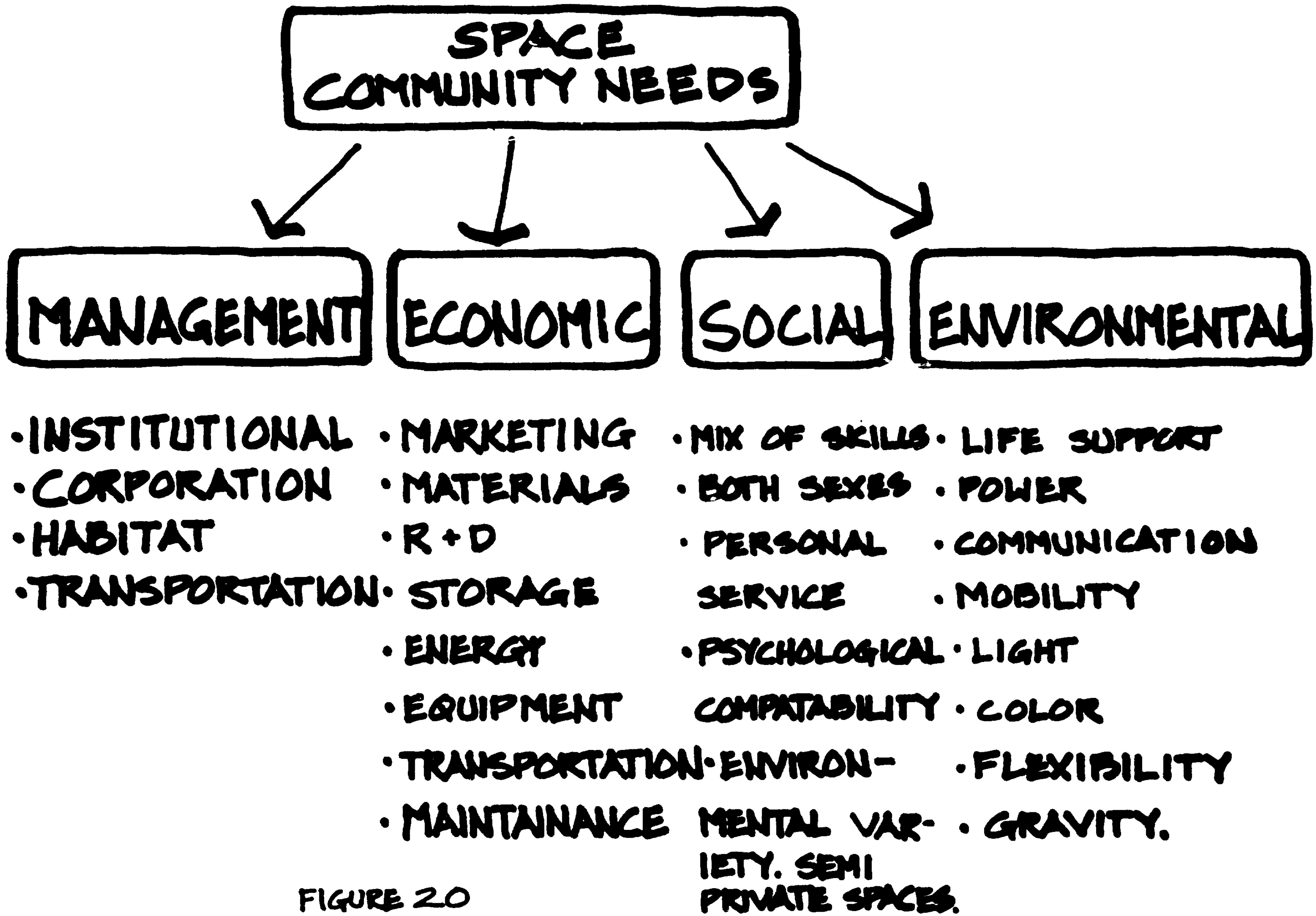

SPACE COMMUNITY NEEDS
MANAGEMENT
ECONOMIC
SOCIAL
ENVIRONMENTAL
• INSTITUTIONAL
• CORPORATION
• HABITAT
• TRANSPORTATION
• MARKETING
• MATERIALS
• R + D
• STORAGE
• ENERGY
• EQUIPMENT
• TRANSPORTATION
• MAINTAINANCE
• MIX OF SKILLS
• BOTH SEXES
• PERSONAL SERVICE
• PSYCHOLOGICAL COMPATABILITY
• ENVIRON-MENTAL VARIETY. SEMI PRIVATE SPACES.
• LIFE SUPPORT
• POWER
• COMMUNICATION
• MOBILITY
• LIGHT
• COLOR
• FLEXIBILITY
• GRAVITY.

FIGURE 20


SUBFACILITIES
FACILITIES
TOURISM
ENGINEERING
SPACE PORT
AGRICULTURE

FIGURE 21

COMPONENT FACILITIES RELATIONSHIPS

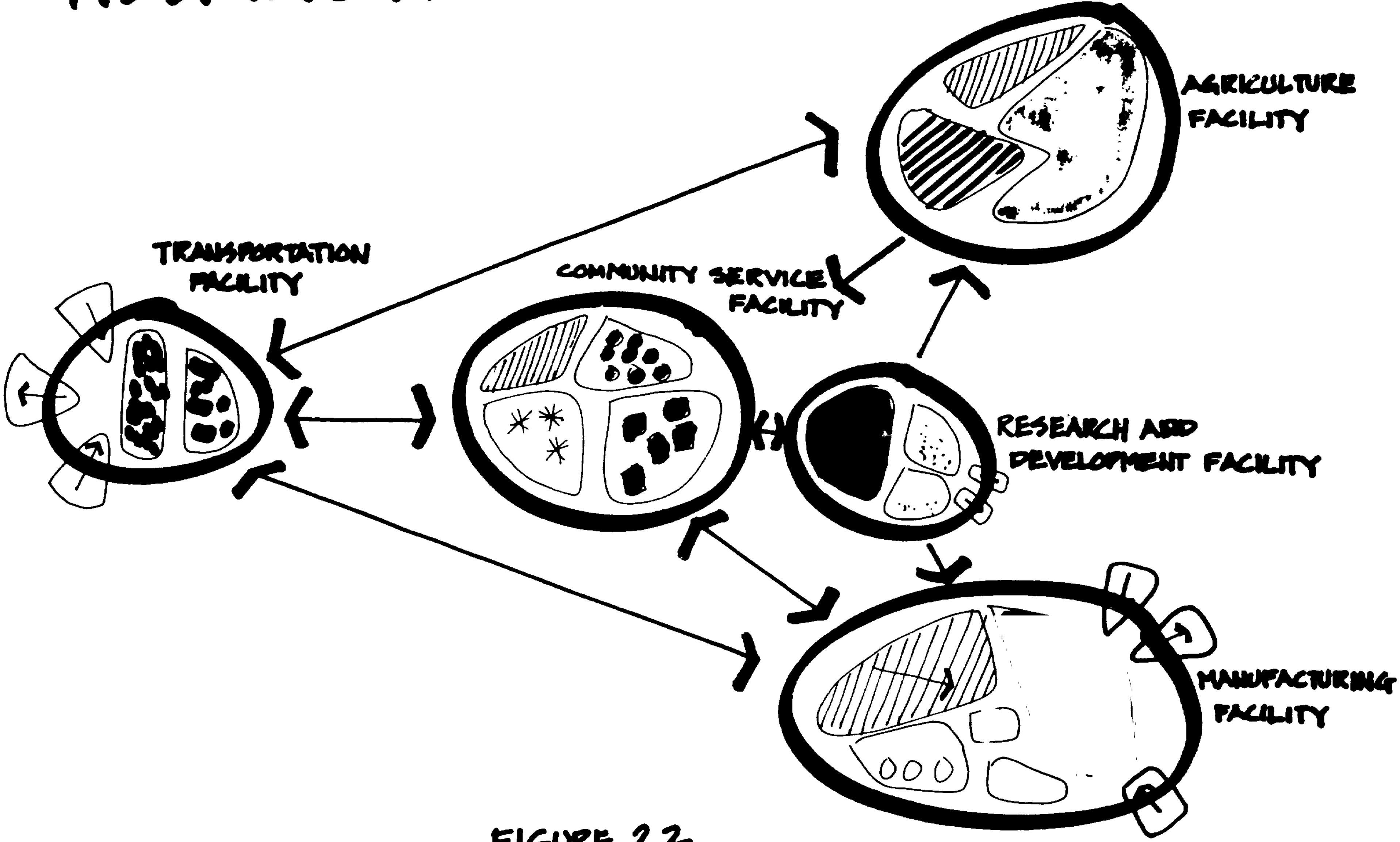


FIGURE 22

PRELIMINARY STUDY OF STRUCTURAL SYSTEMS

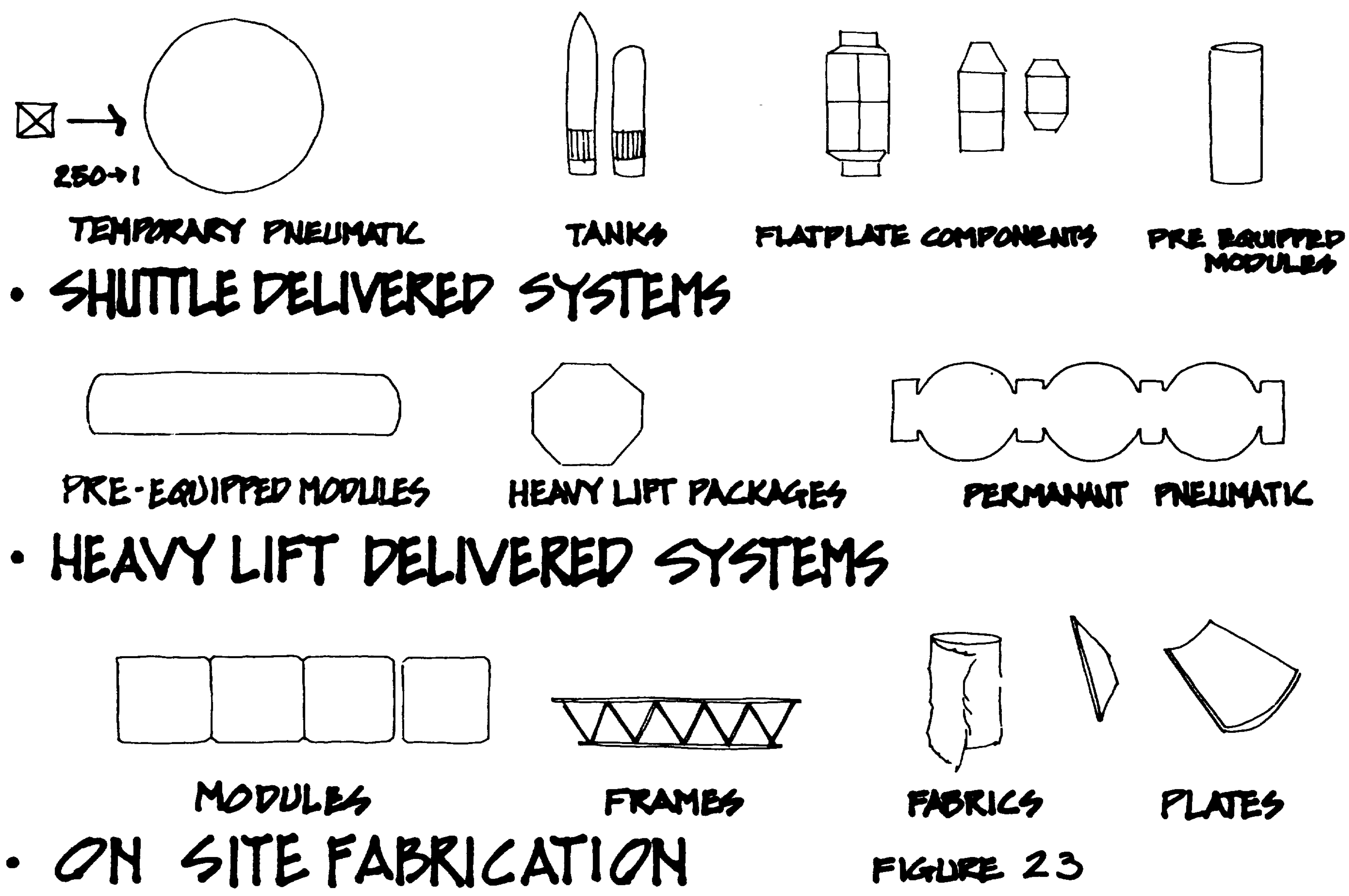


FIGURE 23

5. Community Services (internal maintenance, housing, recreation, health facilities, etc.).

In configuring the basic units, major consideration was given to:

1. Obvious, easy access to the internal system by external traffic;

2. Minimization of internal traffic in type, volume, and distance;

3. Reduction of cross traffic;

4. The close relationship with external traffic access to the manufacturing facility, for shipment to Earth and other orbits of manufactured products, and for direct unloading of raw material;

5. The need for immediate access to the community services by the external transportation crews;

6. The need for proximity of the housing and the areas for work with its corresponding requirements for people transportation (internal) systems;

7. The desirability of R&D being proximal to both the agricultural and manufacturing activities' centers; and

8. The internal transportation needs for bulk items (cargo, manufactured material, etc.) and people.

A synthesis of these considerations appear in the following (see Figure 22).

1. The transportation facilities with its people and cargo transportation systems, refeuling capacity, maintenance units, cargo warehousing, etc.;

2. The community service facility with housing, recreation, food service, health care, temporary housing, etc.;

3. The agriculture facility (top) with plant and animal production areas, and its related activities areas;

4. The R&D facility (center) with air locks for direct E.V.A.;

5. The manufacturing facility (bottom). Secondary docking ports are located in this facility to facilitate the movement of material either too bulky or unsuitable for movement through the station.

STRUCTURAL SYSTEMS

With a basic understanding of what might be included and a general idea of the magnitude of the facilities needed, a systematic review of the shuttle delivered structure systems was conducted to determine which system or combination of systems might be used to embody these facilities. Considered were those systems previously studied by this project as well as some that N.A.S.A. has subsequently investigated. (See Figure 23.)

The various systems were studied first by use; next by what they were best suited for; and last by method of delivery.

Considered were:

1. Pneumatics
2. Plates
3. Frames
4. Cores
5. Modules

TEMPORARY SYSTEM

- REUSABLE SYSTEM: COULD BE DOCKED THROUGH OUT STATION

POSSIBLE USES

- CONSTRUCTION SHELTER
- STORAGE

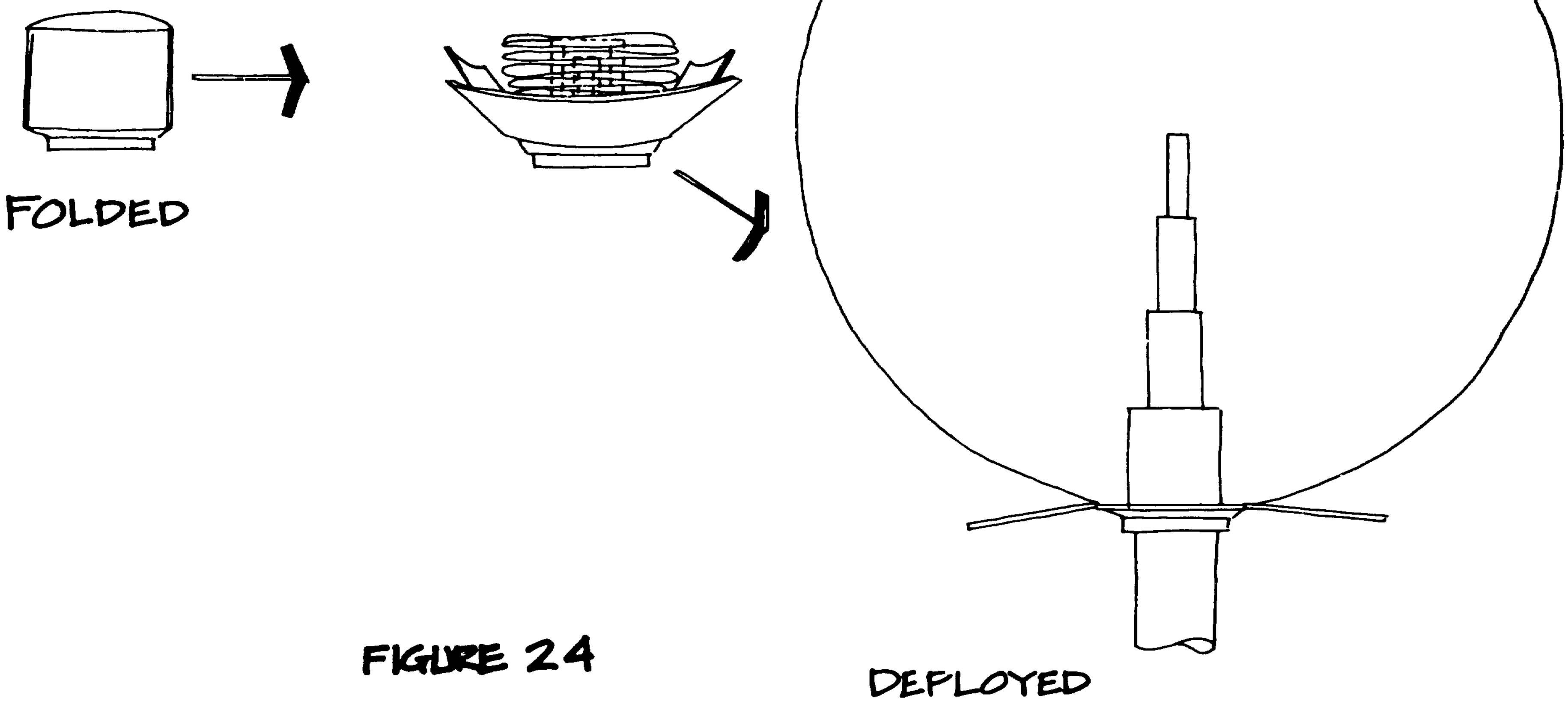


FIGURE 24

SHUTTLE EXTERNAL TANKS SYSTEMS POSSIBILITIES

- USED AS STORAGE SPACE
- REMODLED FOR SPECIFIC USE
- LIVING FACILITIES
- WORKSHOPS
- LABS, ECT.
- RECYCLE ALUMINUM FOR MANUFACTURE OF OTHER PRODUCTS.

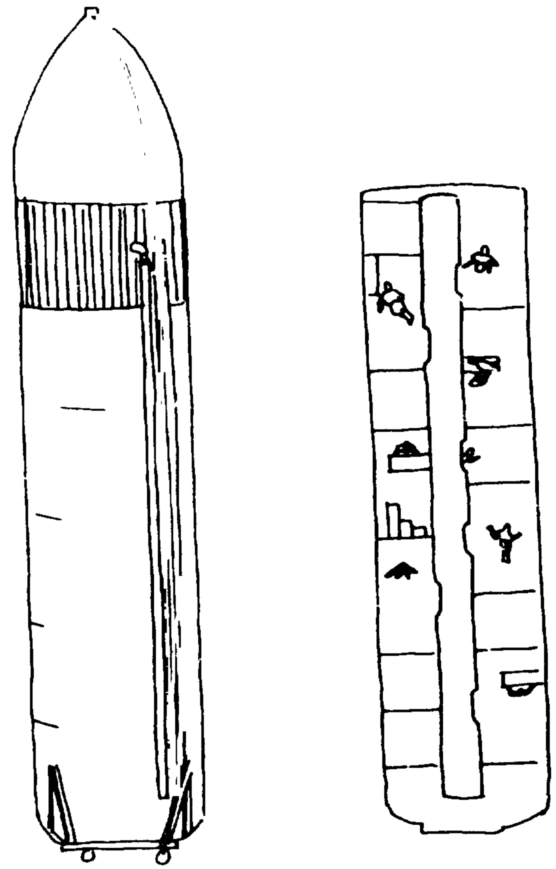
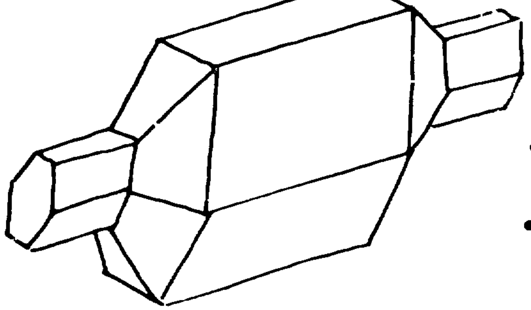


FIGURE 25

PLATE SYSTEM POSSIBILITIES

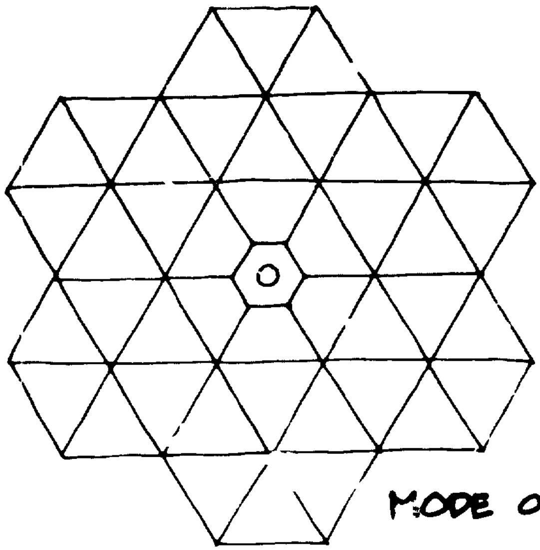
FLAT:

MODULAR EXPANSION
(SLOW VOLUMETRIC GROWTH)



POSSIBLE USE:

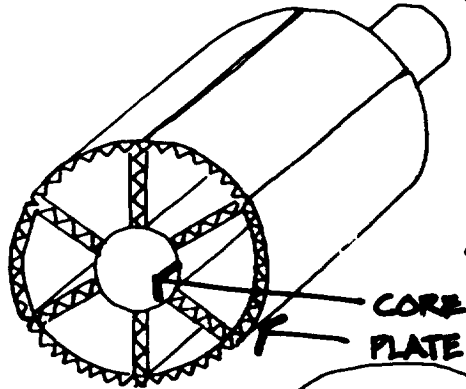
- COVER SHORT SPAN EXTERIOR WALL AREAS
- INTERIOR PLATFORMS



MODE OF EXPANSION

CURVED:

CYLINDRICAL EXPANSION
(FAST VOLUMETRIC GROWTH)



POSSIBLE USE:

- COVER LONG SPAN EXTERIOR WALL AREAS
- CIRCULATION TUBES

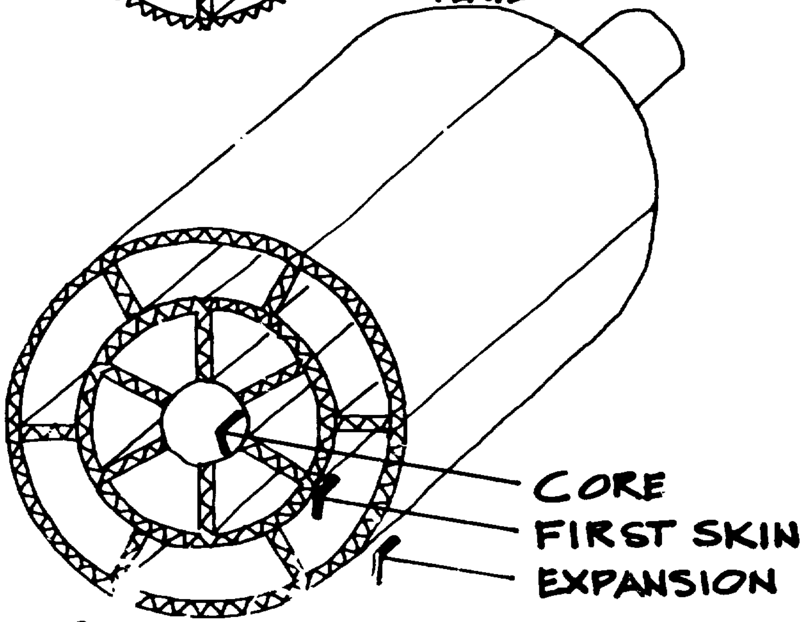


FIGURE 26

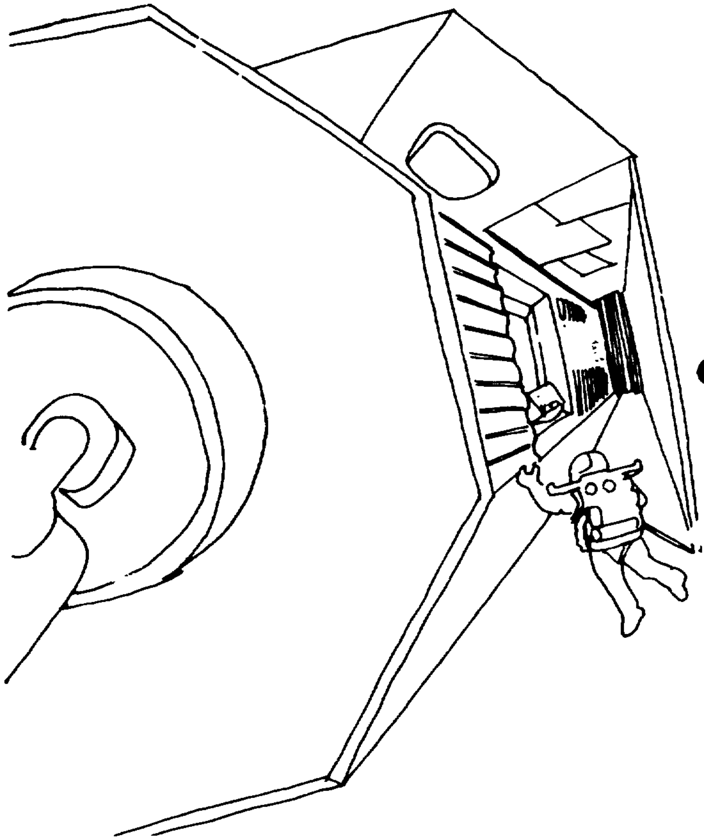
MODULAR SYSTEMS

SHUTTLE, HEAVY LIFT DELIVERED

CAN MODULE

POSSIBLE USES.

- DATA COLLECTING LAB
- LOGISTICS

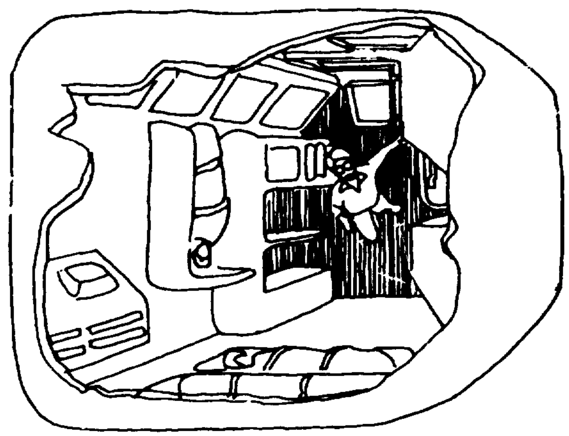


CORE MODULE

POSSIBLE USE:

- LIFE SUPPORT
- CIRCULATION TUNNEL
- EARTH FABRICATED EQUIPMENT.

ON SITE FABRICATION



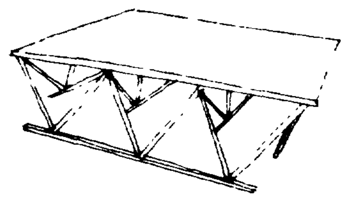
INTERIOR MODULE

POSSIBLE USE:

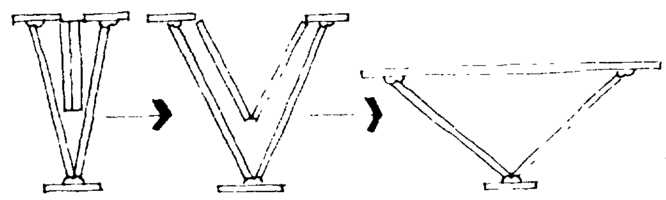
- SLEEPING
- HYGENE
- EATING
- RECREATION

FIGURE 27

FRAME SYSTEMS



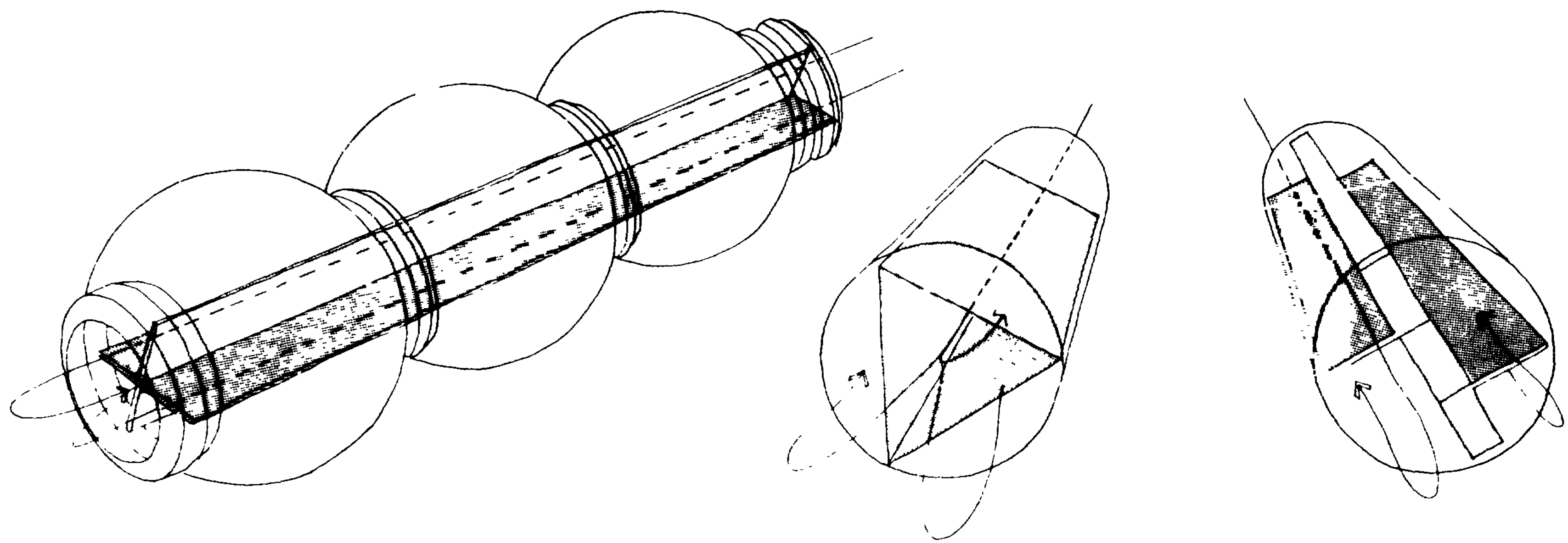
PRE-ASSEMBLED



DEPLOYABLE

POSSIBLE USE

- STRUCTURAL MEMBERS (beams)
- ANNTENA SUPPORTS (columns)
- WORKING PLATFORMS (spaceframes)
- INTERNAL WALL STRUCTURES



POSSIBLE INTERNAL CONFIGURATIONS

FIGURE 28

6. Shuttle Tanks

Some of the more pertinent considerations are listed here (see Figures 24 through 28):

1. PNEUMATICS: A reusable system consisting of a folded pneumatic membrane which may be shuttle delivered. Upon deployment it may be used as a construction shelter for the station or storage space; wherever a low pressure pneumatic could be utilized. The expanded/folded ratio is quite significant.

2. TANKS: External tanks of the shuttle craft may be used as storage space as is; remodeled for living facilities, labs, work shops, manufacturing stations; and later, after useful life is exceeded, they may be recycled for their aluminum.

3. FLAT PLATES: Flat Plates and their possibilities were discussed earlier in detail. A variation of this system is curved plates which result in cylindrical spaces.

4. MODULARS: Modular units, preassembled on Earth and moved into space as either can-type modular units or as core units for other growth, afford equipment and systems which may not be manufactured at this point in space. As an example: the can-type module may be used to transport packaged units into space and back at a reasonable cost, or be prepared for specialized research such as O-G Crystal manufacturing, etc. The modules may be lifted in the shuttle craft, heavy lift, or manufactured on site in space.

5. FRAMES: One complete system discussed earlier, would be a modulated pneumatic

supported by an expanding frame system.

Further modification of the basic frame systems lend themselves to additional use. One possible use, platform subdividers, is shown in Figure 28. The space within the units themselves are sub-divided into sections which allows assembly line production techniques to occur in a well defined and confined space. Raw materials arrive at one point and are processed through the system to a state of finish and then exit either opposite or adjacent to the entry.

INTERIORS

The architectural study of the interiors is in the early problem seeking stage. Fundamental questions are being sought and answered systematically to build a data base from which conclusions relative to the construction of functional spaces may be drawn.

The architectural features of the interiors will be a significant contribution to basic habitat design. These solutions will apply in nearly any O.G. space station and will serve as examples of isolated environmental situations.

Some of the questions addressed to date are:

1. How are structural shells subdivided into livable, functional spaces?

2. How does a person circulate through these subdivided spaces?

3. What accommodations and considerations are effected by O-G.?

The solutions had to be further defined by a set of considerations specific to the nature of the "space" environment. Consequently, a further set of parameters was established:

1. Minimize the sense of confinement. Starting with a limited environment maximize its use without extra-vehicular activity.

2. Simplify the effort required to move within the space.

3. Simplify the effort required to mount and service equipment.

4. Minimize the potential psychological friction which could develop among the people as they live and interact within this environment.

5. Help the environment not to produce tensions.

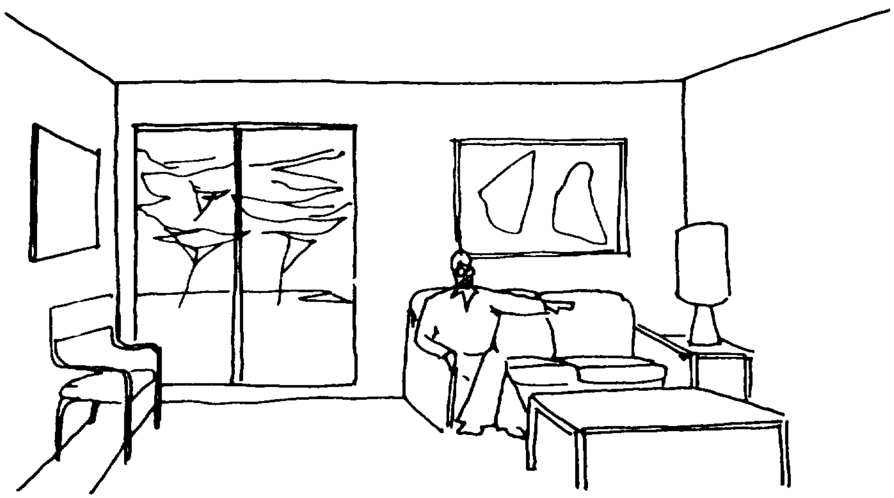
Through the use of careful structuring, adjacent spaces may be defined but left open enough to be included visually into the particular area occupied by a given person.

Variation may be created in both internal configuration as well as differing area sizes to enhance the feeling of variety and present options to movement routes.

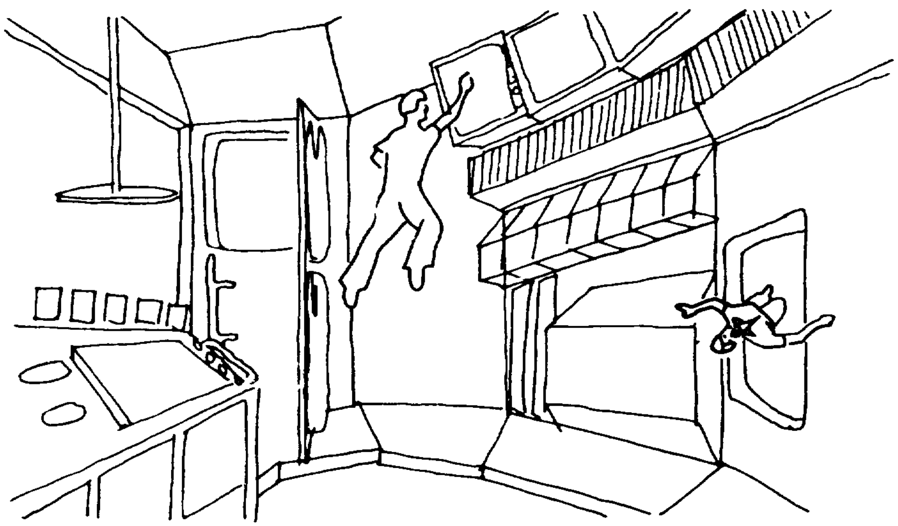
Some areas will be formalized into public spaces while others will be clearly designated as private, creating the sense of home. Each space will be designed with visual clues which orient the user to its purpose and assist the person in subconsciously understanding what is expected in terms of his own actions. The resulting spaces allow the person to feel comfortable upon entry.

A system will be established to orient the people to their relative position within the station. On Earth one has up-down, as well as the points of the compass. This study will deal with exploitation of "0" G environment and is concerned with the

VISION AND USE



EARTH - THE SURFACES THAT ARE MOST OFTEN USED ARE THE ONES WE SEE. VISION EXTENDS FROM SLIGHTLY ABOVE EYE-LEVEL TO OUR FEET, AND THE SURFACES WE USE MOST ARE THE LOWER WALLS AND FLOOR. THE CEILING IS NOT DIRECTLY USED AND IS ONLY PERCEIVED VISUALLY.



ZERO-G ROOMS WILL HAVE FLOORS AND WALLS YET NO CEILING. WHEN USING ONE FLOOR, THE OTHER FLOOR (LIKE AN EARTH CEILING) IS MOSTLY IGNORED. THIS IS PSYCHOLOGICALLY ACCEPTABLE WHILE STILL UTILIZING THE FULL FUNCTIONAL POTENTIAL OF ZERO-G SPACE.

FIGURE 29

architectural arrangements suited to accommodate man's needs - in this special situation. In the station perhaps a color system combined with formal use of space may be established to suggest orientation. Maximum flexibility of panel location will be considered, allowing reconfiguration with a minimum of effort. This will enhance the potential for variations and change.

On Earth, a defined living area is unconciously and automatically divided by a person entering the space into the three elements of walls, floor and ceiling. Further useful division normally occurs from eye-level downward, rarely considering use of space above the physical reach or visual range of the person. The ceiling becomes a non-useable element. In space, all surfaces become boundaries and may be defined as simply surfaces subject to full use by the people and classified as a "wall", "floor", or "ceiling" depending upon the orientation of the person at any given time. (See Figure 29.)

All surfaces may be used. How to use them and maintain smooth uncluttered orientation and safety while maximizing their use will be studied in detail.

Interconnection may be accomplished through the simple device of punching a hole into the divider plate between two spaces, or connecting remote areas with tubes or tunnels (halls). These tubes may be either internal or external (pressurized).

Transportation through these connectors could be self-propulsion (hand grips) or mechanical (lift belts or vehicles).

CYLINDRICAL STRUCTURES

The configuration studied was the cylinder. A review of the structural systems suggested that one form or another of the cylinder

SPLIT LEVEL

COULD ALSO ALTERNATE IN THIRDS OR HALVES INSTEAD OF QUARTERS. COULD ALSO BE HELICAL WITH EACH SUCCESSIVE LEVEL HIGHER THAN THE LAST.

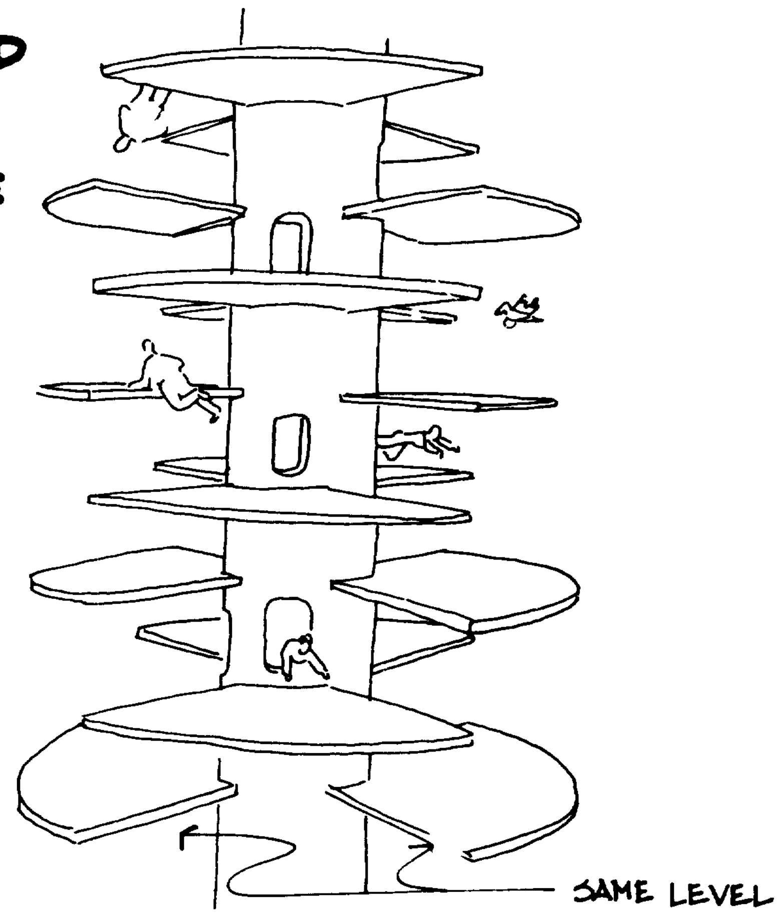


FIGURE 30

presented not only an efficient area to surface ratio, but an efficient interior to work with.

Three major ways have been considered in subdividing and using the cylinder:

1. Split-level affords the opportunity of acquiring visually large spaces within a limited area. A person's mind tends to include, within its own "personal" space, the adjacent area which may be viewed uninterrupted. The effect is enhanced by the suggestion of space existing beyond the divider: "around the corner" so to speak. (Figure 30.)

   This particular arrangement presents two more positive features:

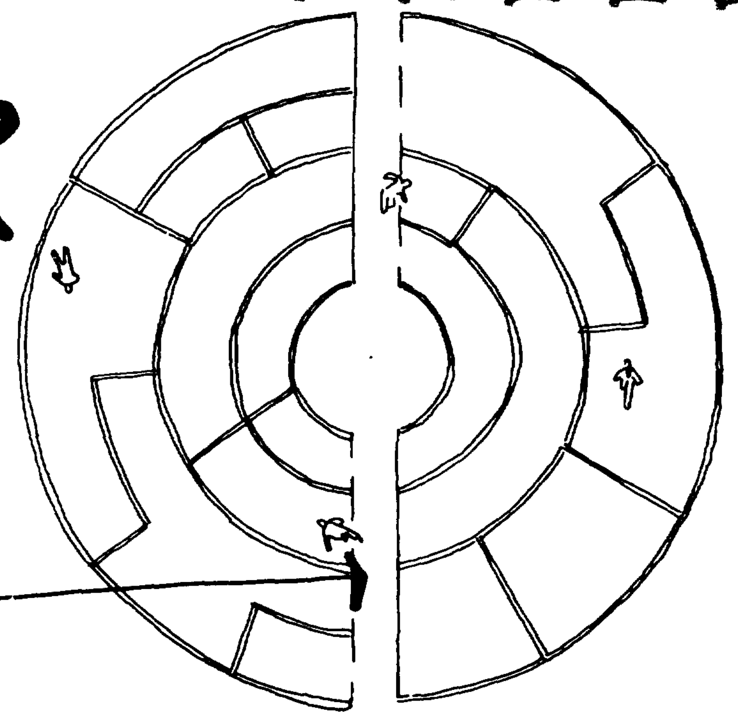
   1. The flexibility to create new spaces, or reconfigure with the minimum of effort by simply moving, adjusting, adding or totally removing any given panel.

   2. The option of the person to choose from a variety of possible circulation routes, each being different depending upon need or choice.

2. The curved wall system does not allow this flexibility or complete option of circulation, but does afford a variety of adjoining spaces which could range from very small "private" rooms to large open halls; each distinctly articulated with six "walls" (Figure 27). Circulation would be through a major tube with branch "halls' leading to the individual spaces.

3. Concentric tubes afford similar capabilities with some notable differences; all "walls" would be flat surfaces,

CURVED FLOOR



- CURVED FLOOR SURFACES MAKE ORIENTATION WITHIN SPACECRAFT EASIER.
- MOVEMENT FROM CORE TO OUTER LEVELS THROUGH SECONDARY CIRCULATION TUBES.
- MOST MOVEMENT BECOMES HORIZONTAL.

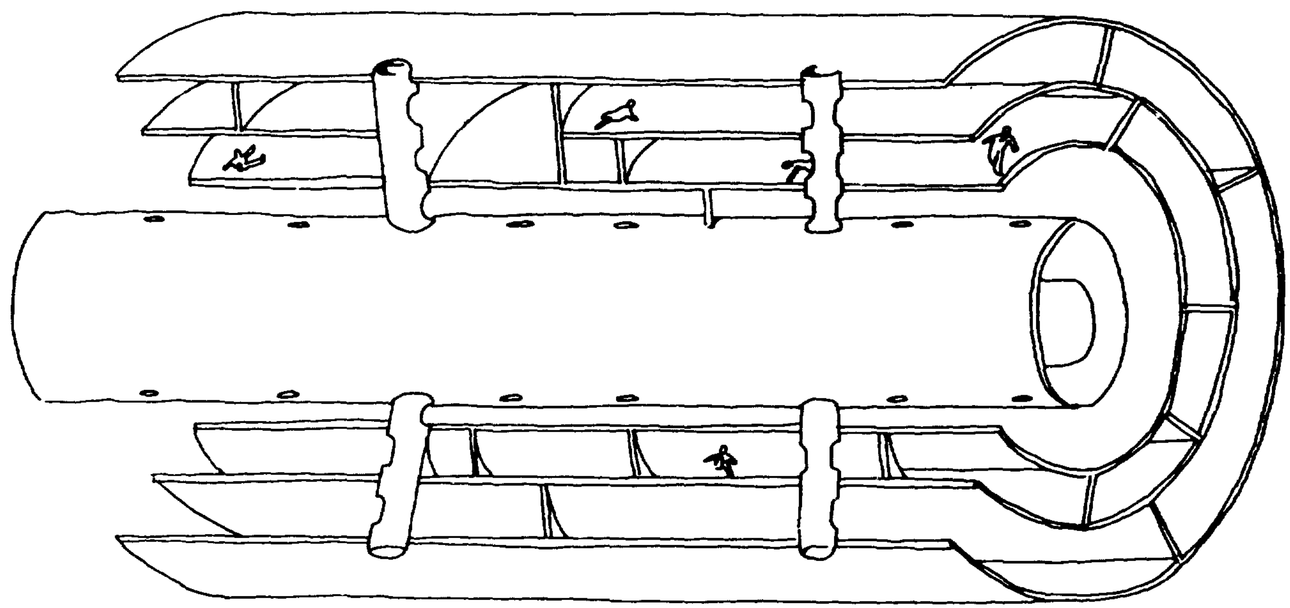


FIGURE 31

CONCENTRIC TUBES

- 120,000 □' FLOOR SPACE
- 40,000 □' IN THE CORE
- 80,000 □' IN OUTER TUBES
- PLUS ANY PARTITIONS

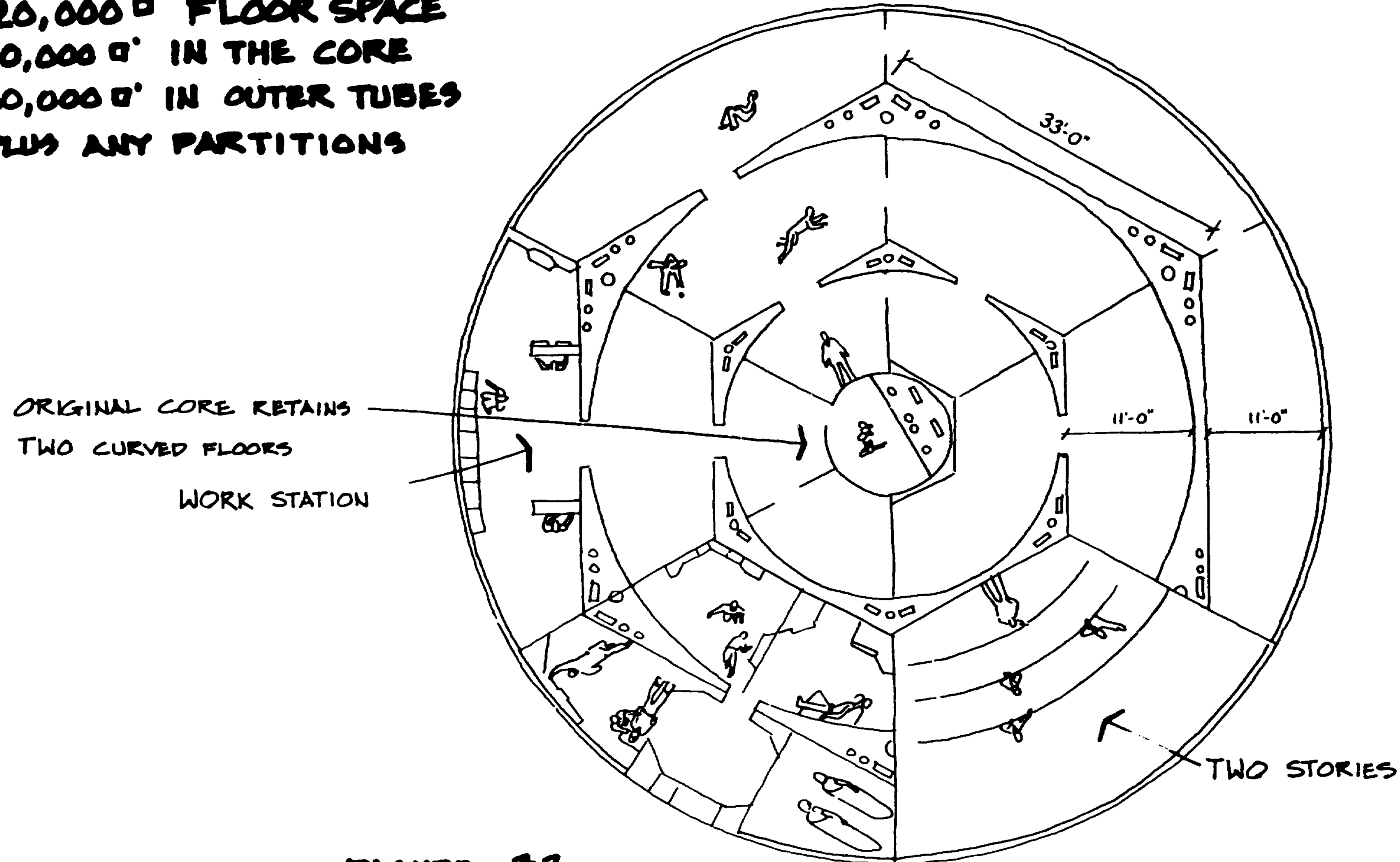


FIGURE 32

PADDLEWHEEL

- INTERESTING SPACES AND FEELING OF SPATIAL EXPANSION IS PLEASING
- CREATES LARGE OPEN FLOOR SPACES THAT CAN BE PARTITIONED EASILY.

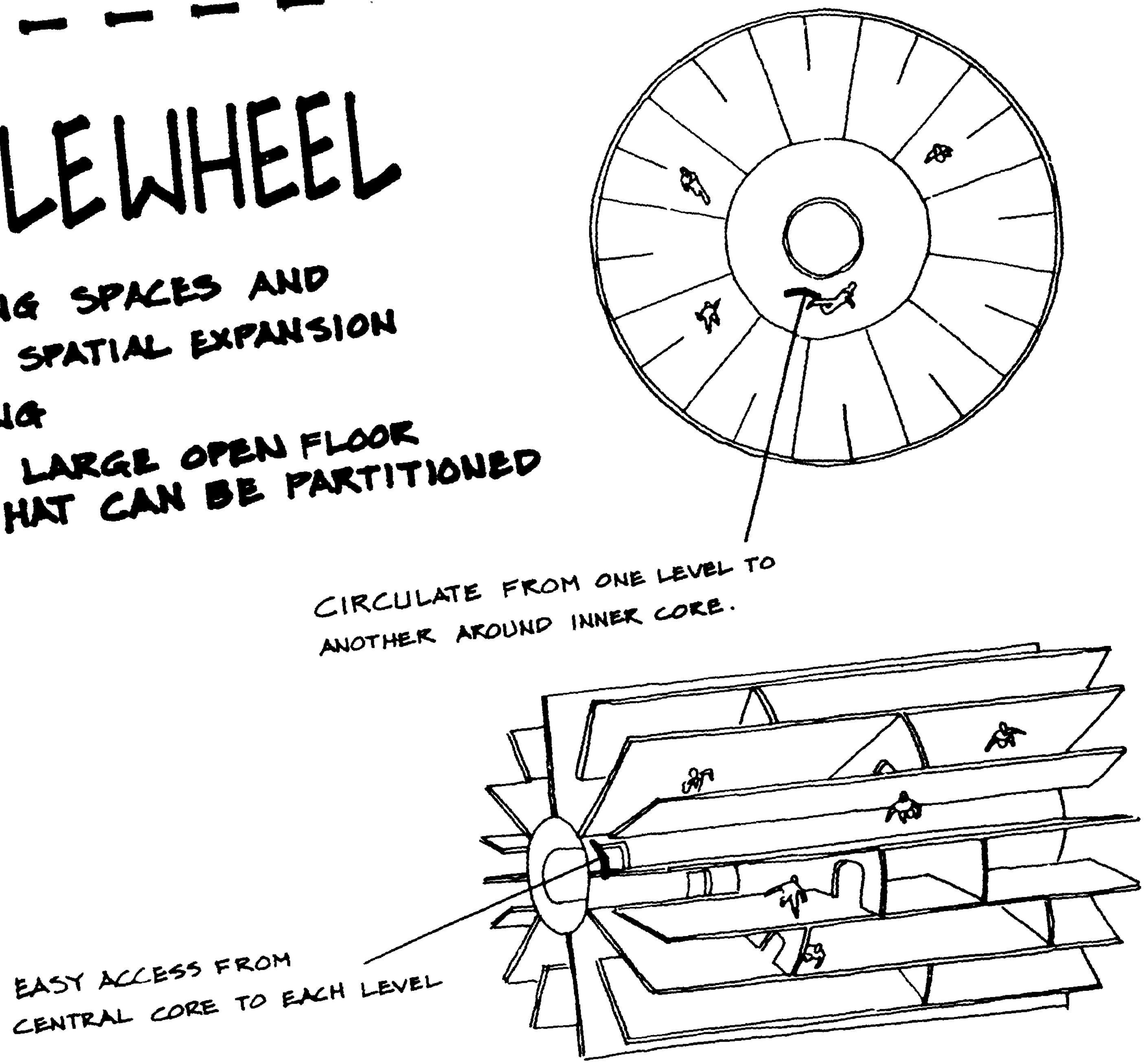


FIGURE 33

and the variety of intermix between the rooms, circulation spaces, and adjacent spaces is increased. (Figure 28.)

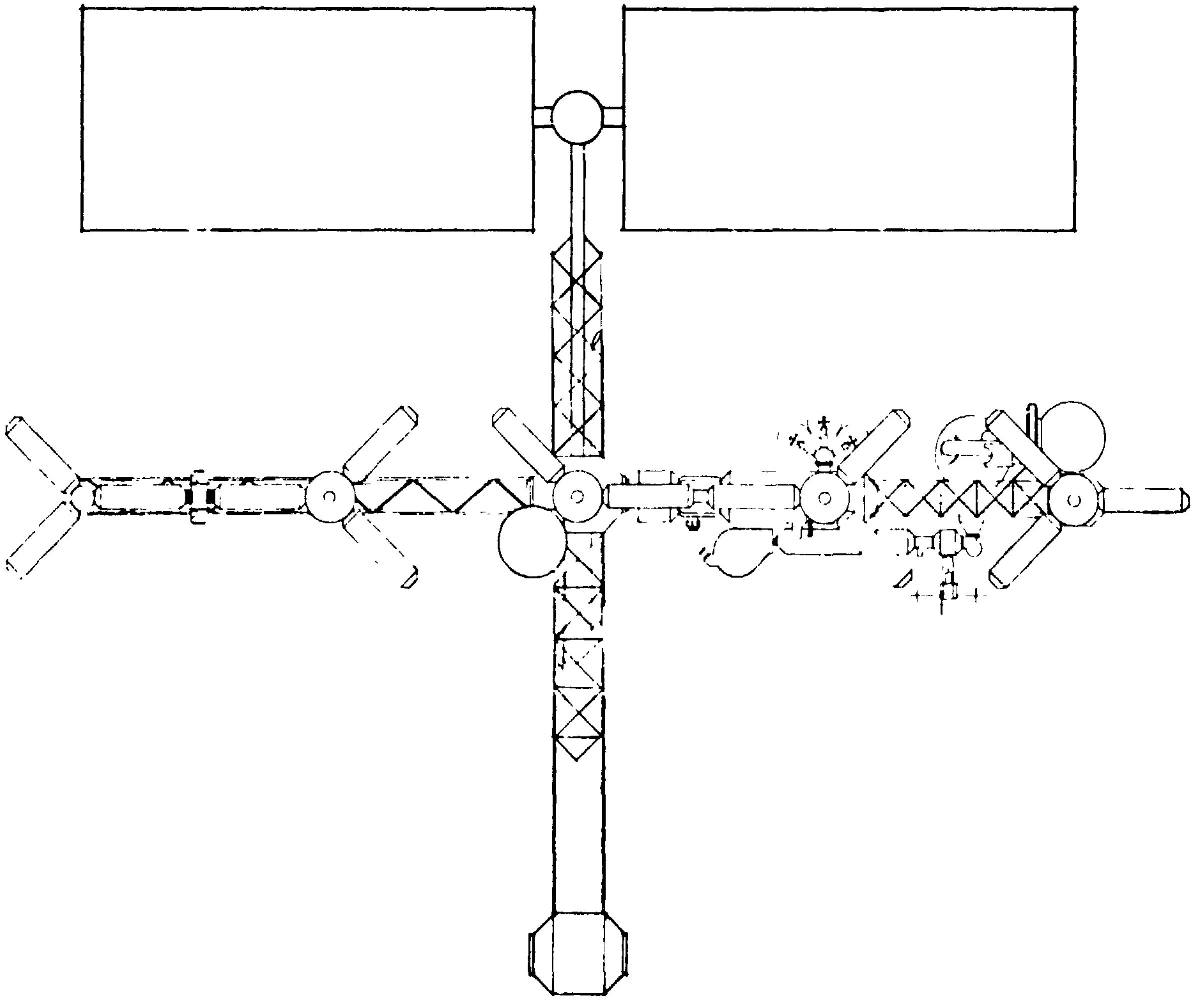
4. The paddle wheel allows public as well as semi-private space. Unlike the split-level, major circulation would be limited to tunnels. Orientation within this configuration is possibly the best since all walls lead to the center of the cylinder. (Figure 29.)

Through a series of four progress reports, coupled with personal presentations, we have reported on our progress and reviewed for consideration, our conclusions. As previously stated, the scope of this project encompassed the design of a space community as opposed to a mere space station designed to support a small number of personnel. To meet these larger urban criteria, we have designed a facility to house 500 individuals with a growth capability without limits. At this time we would like for you to join us, jump ahead in the design sequence, and explore the feasibility of an initial, hypothetical, space city which is based on the solutions discussed in this and the previous four reports.

It would not be adequate to undertake a study of this nature without carrying out a solution to its extreme. The solutions and designs which we propose are the extremes of the available technology. We would not undertake to design a 40 story building and then present to the client drawings of only the lobby and a typical floor. Nor would we attempt to promote a multiacre office complex by providing only information about Phase One, when in fact, multiple phasing lasting perhaps 15 years must be considered in and overview.

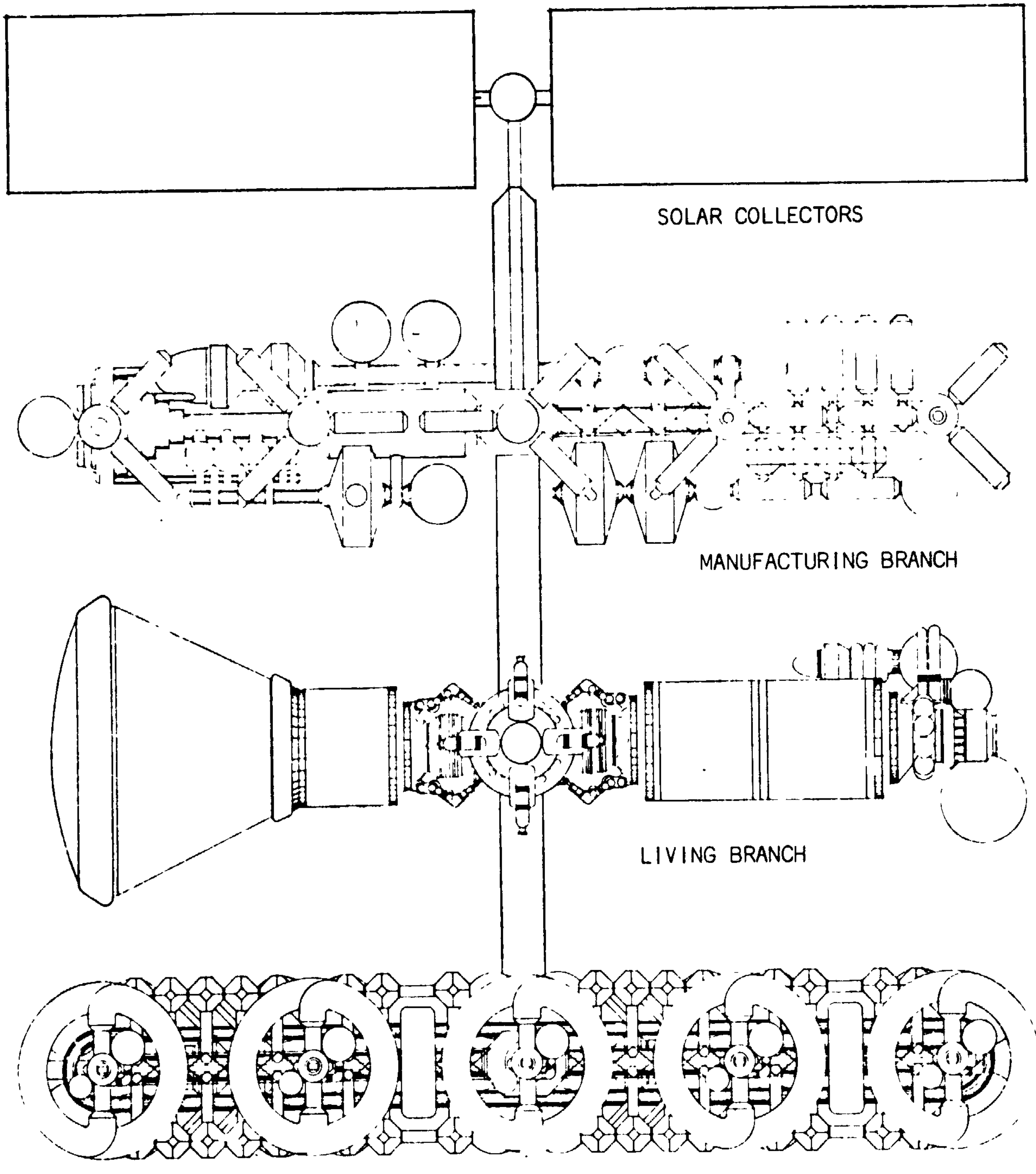
For the purposes of this report, we are presenting not simply a solution, but a solution in four parts. These phases, encompassing perhaps a decade, embody our conclusions about what a space community can become. This facility is composed of three branches, each highly sophisticated, each following another in a progression which will ultimately determine the final solution to our configuration. Phase One, the initial branch of the facility is a further developed version of the 100 man space station previously discussed in the growth story. (Figures 18 & 18a.) To make the transition from that configuration to the newly developing community, an axis change and an additional adapter is required. (Figure 34.) This initial phase appears as the branch noted as manufacturing branch. (Figures 35 & 36.) After this wing is completed, work will begin on Phase II which will be the permanent living areas, hospital, administrative offices and recreation cone. When this branch is completed, Phase III will encompass the relocation of personnel from temporary to permanent living quarters and the re-outfitting of the initial branch as a pure manufacturing/research and development section of the station. Phase IV will be the construction of a third branch which will house the farm for food production processing and storage and a final step in self-sufficiency for the space community.

Experimental architectural forms delineated in these designs define only one scheme, one exterior design configuration. They are meaningful only to the extent to which they provide a vehicle to explain interior environments. They are an expression of the architectural principals embodied within them. The exterior skins which have been designed are reflections of the architectural spaces contained within.



SPACE STATION SHOWING THIRD AXIS CHANGE

FIGURE 34



PLAN VIEW OF SPACE COMMUNITY

FIGURE 35

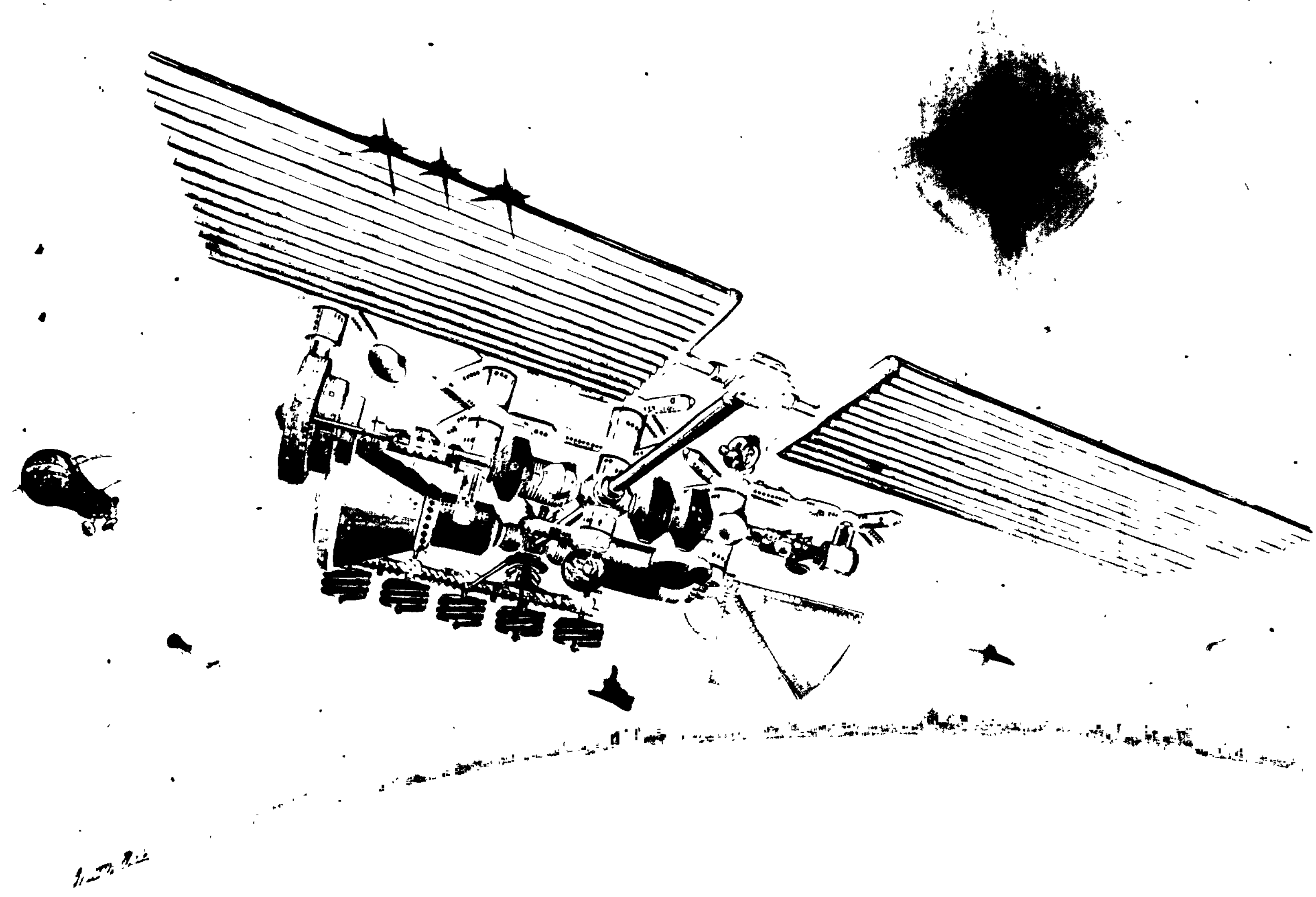


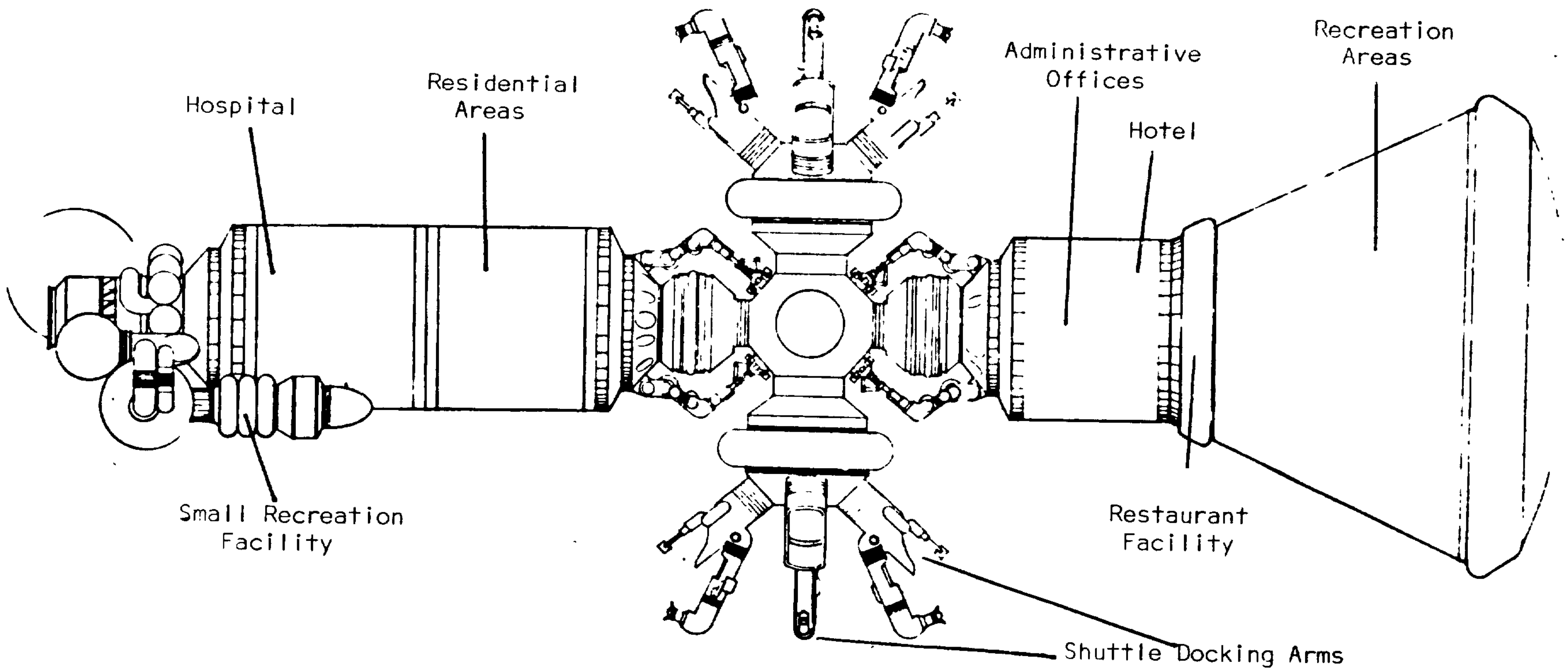
FIGURE 36

SPACEPORT

Introduction to the space station occurs at one of the 8 landing docks, designed to accommodate shuttle craft in their present configuration. (Figure 37.) After debarkation of passengers and off-loading of carry-on supplies, the pod areas are used to refuel and resupply the shuttle craft with expendable material needed for the return trip to Earth. The newly arrived passengers will proceed directly to the receiving lobby for orientation and familiarization. It is anticipated that zero-G environment adaptation will pose one of the greatest problems to incoming personnel. New arrivals will remain at this orientation area for varying periods of time, depending on their individual adaptation rates. After familiarization with their new environment and after demonstrating rudimentary capabilities of coping with zero-G, new arrivals will then be introduced to the urban systems which form the station. Personnel proficiency is expected to progress at a rapid rate in their coping with zero-G.

CORRIDOR SYSTEM

Mobility within the space station will be one of fluid human motion. A system of corridors interlinking every area of the station will provide rapid, direct connections. This movement in 3 space will be one of the most exhilirating aspects of life within the station. Varied textures and lighting will enhance the experiences of the tubes, while windows will provide free-floating pedestrians breathtaking views of deep space, pleasantly contrasted with the confines of the tube. (Figure 38.) The configuration of the tube is an oval which has been flattened on one side. (Figure 39.) Locomotion occurs on the two side walls. Central definition is accomplished by a tubular rubber rail,skylab fashion,which acts as a hand-hold for stopping, turning or changing direction in this space, approximately eight feet in height



LIVING BRANCH

FIGURE 37

CUTAWAY OF TRANSPORTATION TUBE

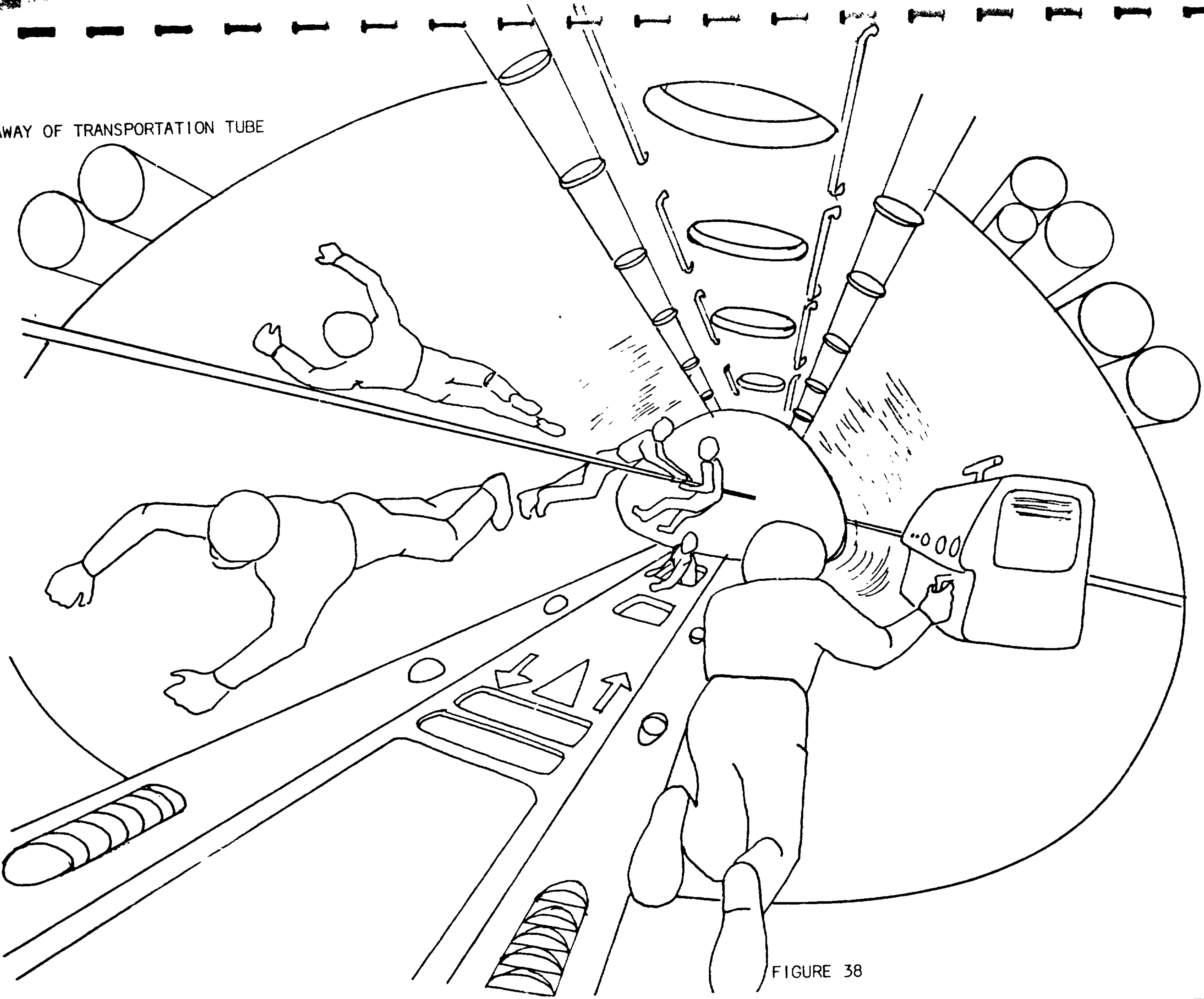


FIGURE 38

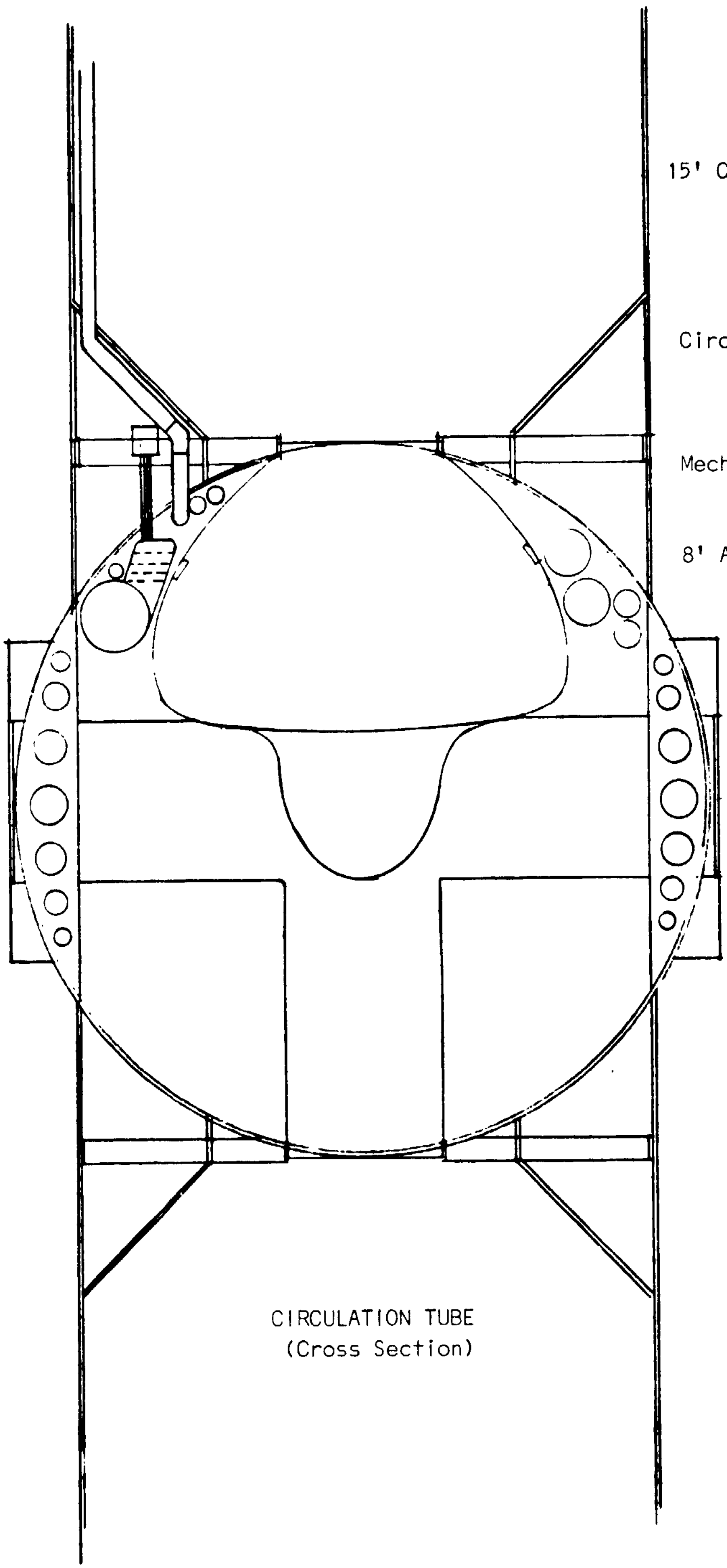

15' Core Module
Circulation Tube
Mechanical Space
8' Access Tube
15' Core Module
CIRCULATION TUBE
(Cross Section)

FIGURE 39

by eleven feet wide. This center rail may be removed for the movement of large equipment through the tube. Exits are located in the flattened bottom portion of the tube. This floor, or neutral area, is provided with a depressed "feeder" area which allows egress from the tube system. (Figure 40.) To travel the tubes is to move in 3 space. It is to experience all of the attributes of underwater movement free of the associated problems. The human body becomes the vehicle. Muscular power as the motive force provides forward impetus theoretically capable of limitless speed. Movement becomes an experience rather than merely a mundane relocation. Body action may be controlled to such a degree that man's oldest dream, that of free flight, may be realized.

An additional aspect of the tubes is the supply systems. Primary utility systems and power bussing is accomplished by direct link through the tubes, and provides power hook-ups to all interfacing modules. (Figure 39.) The tubes additionally perform a structural function, connecting station components. (Figure 41.) The lower half of the tube is used for shops, storage, mechanical, or office space. Interior walls consist of a foam laminate providing tactile restraint capabilities while also insuring a modicum of safety and pleasantness of texture. This texture will be one of a myriad of foam nodules. These tiny projections will enable persons in transit to literally "dig in" to the wall with his hands in order to propel themselves forward or to slow down or stop. This will eliminate the need for hand holds or similar mechanical appliances. Upper and lower areas of the tube are designated as stopping or slowing areas. These areas while being utilized as rest stations or turnarounds may also be used as places of personal contact between crew members or areas to simply stop and view the station

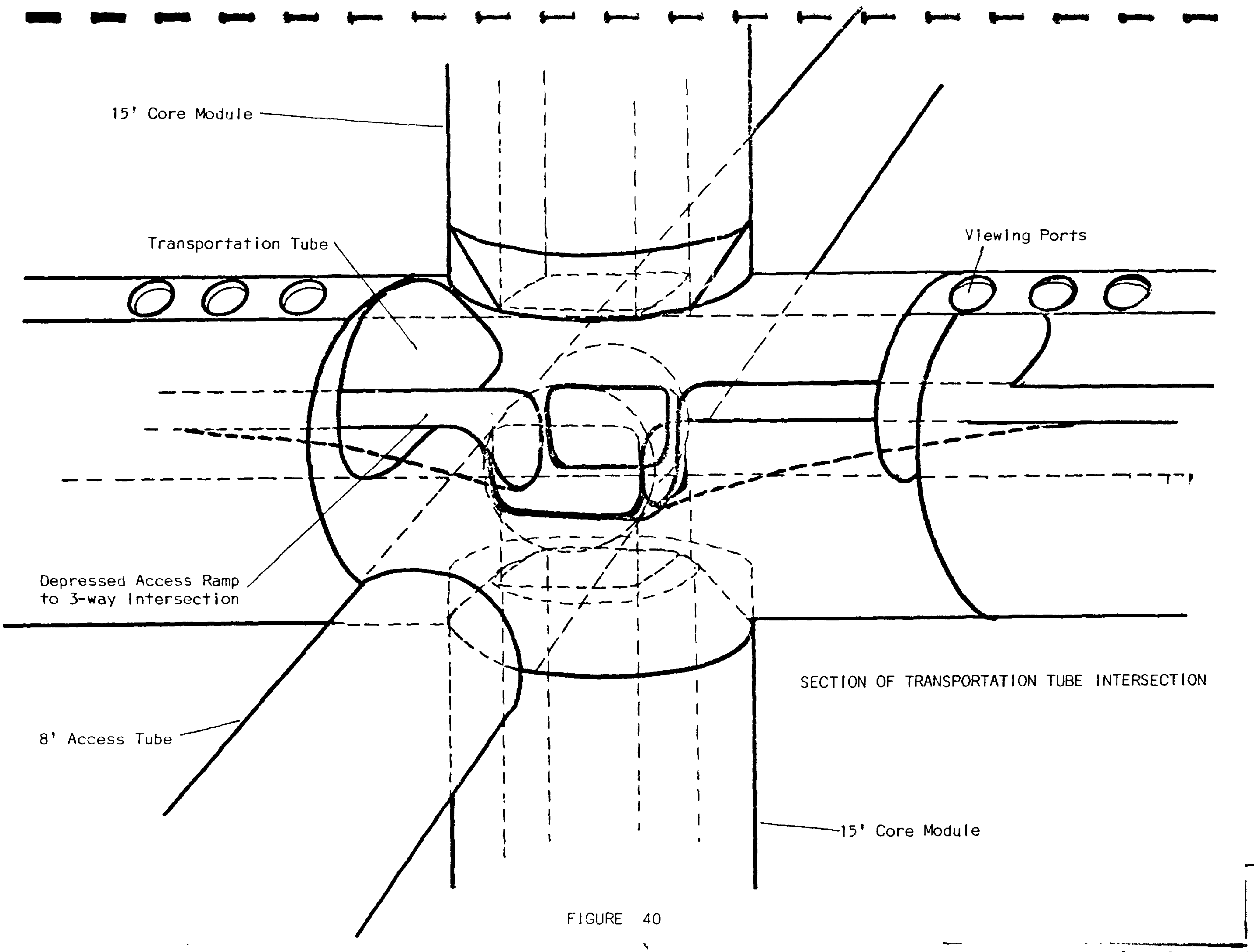
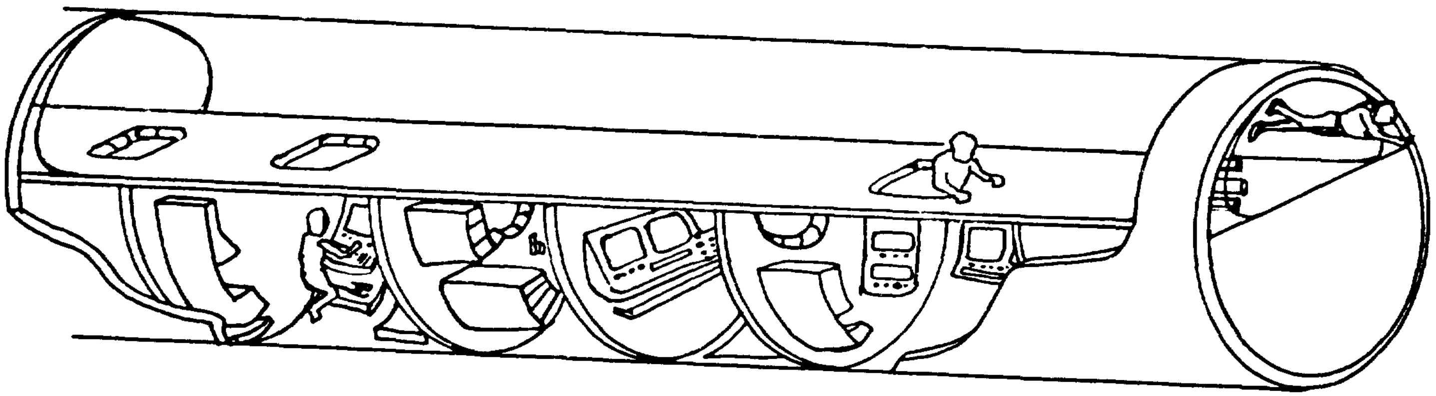

15' Core Module
Transportation Tube
Viewing Ports
Depressed Access Ramp
to 3-way Intersection
8' Access Tube
SECTION OF TRANSPORTATION TUBE INTERSECTION
15' Core Module

FIGURE 40



CONNECTOR TUBE: CUTAWAY VIEW

FIGURE 41

exterior and deep space. Right and left perimeters are designated as high speed areas for optimum circulation.

Carry on luggage or packages may be attached to a conveyor system contained with the walls. By programming a final destination, personnel may be left unencumbered for zero-G movement through the tubes. A pneumatic system of material transfer is located in the side walls providing a computerized method of transporting objects of 1 cubic foot or less.

HOSPITAL/CLINIC

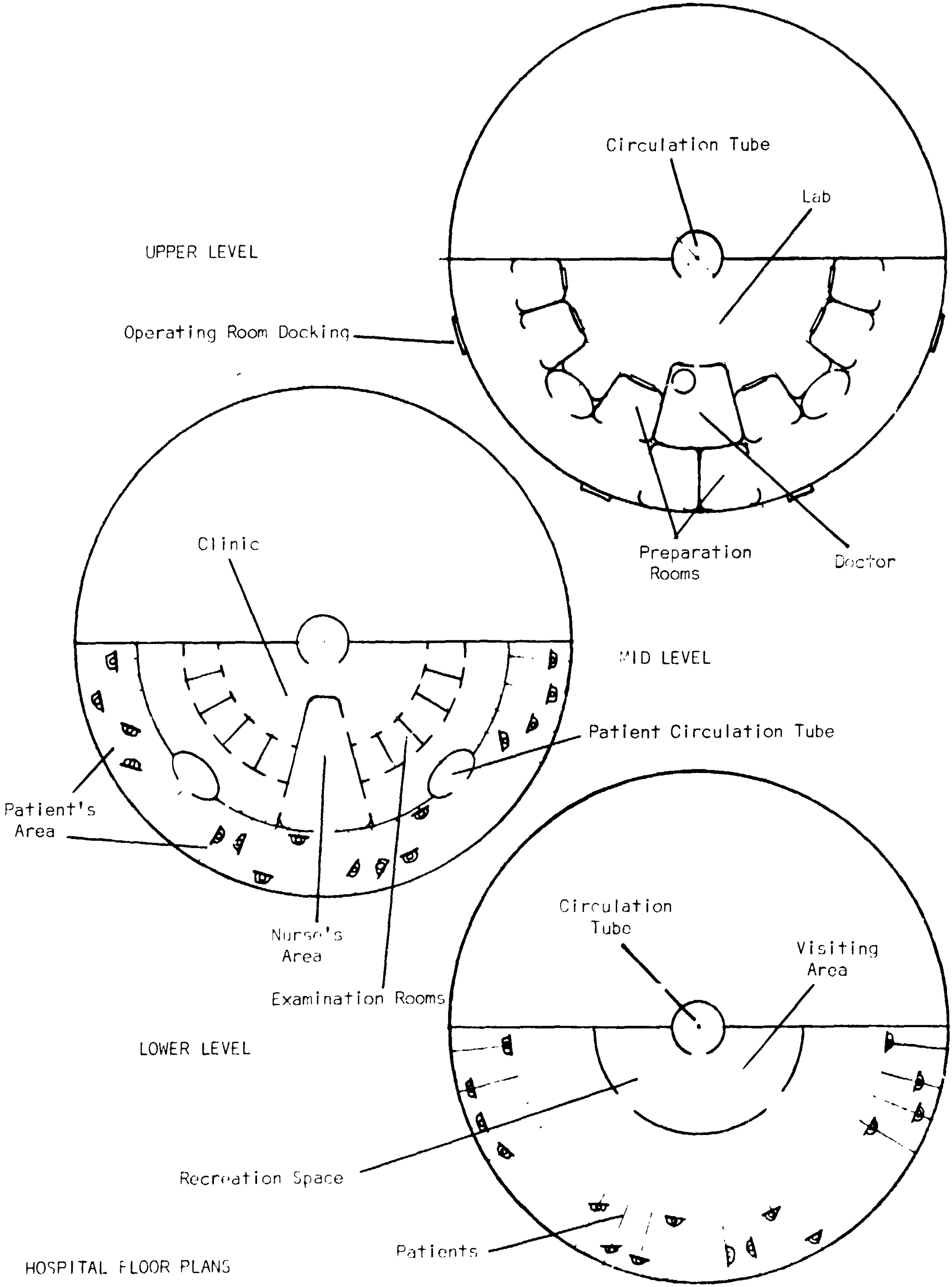
After travel by personnel tubes from the orientation center, we enter the living wing of the station.

At the extreme end of the living wing is a three tiered hospital/clinic section. (Figures 42 & 43.) Walls and floors, as with other parts of the station, are utilized relative to the user's orientation. A wall may become a floor or vice versa. Lighting within this area as within residential areas is evenly distributed between the surfaces, so as to provide uniform illumination regardless of user orientation. The hospital functions as an ambulatory clinic for cadre as well as a specialized emergency facility for personnel working in free space or orbits near the station.

A staff of three on call doctors augmented with physicians extenders provide the medical assistance for up to 32 continuous inpatients as well as 90 outpatients per "day" within the ambulatory care clinic.

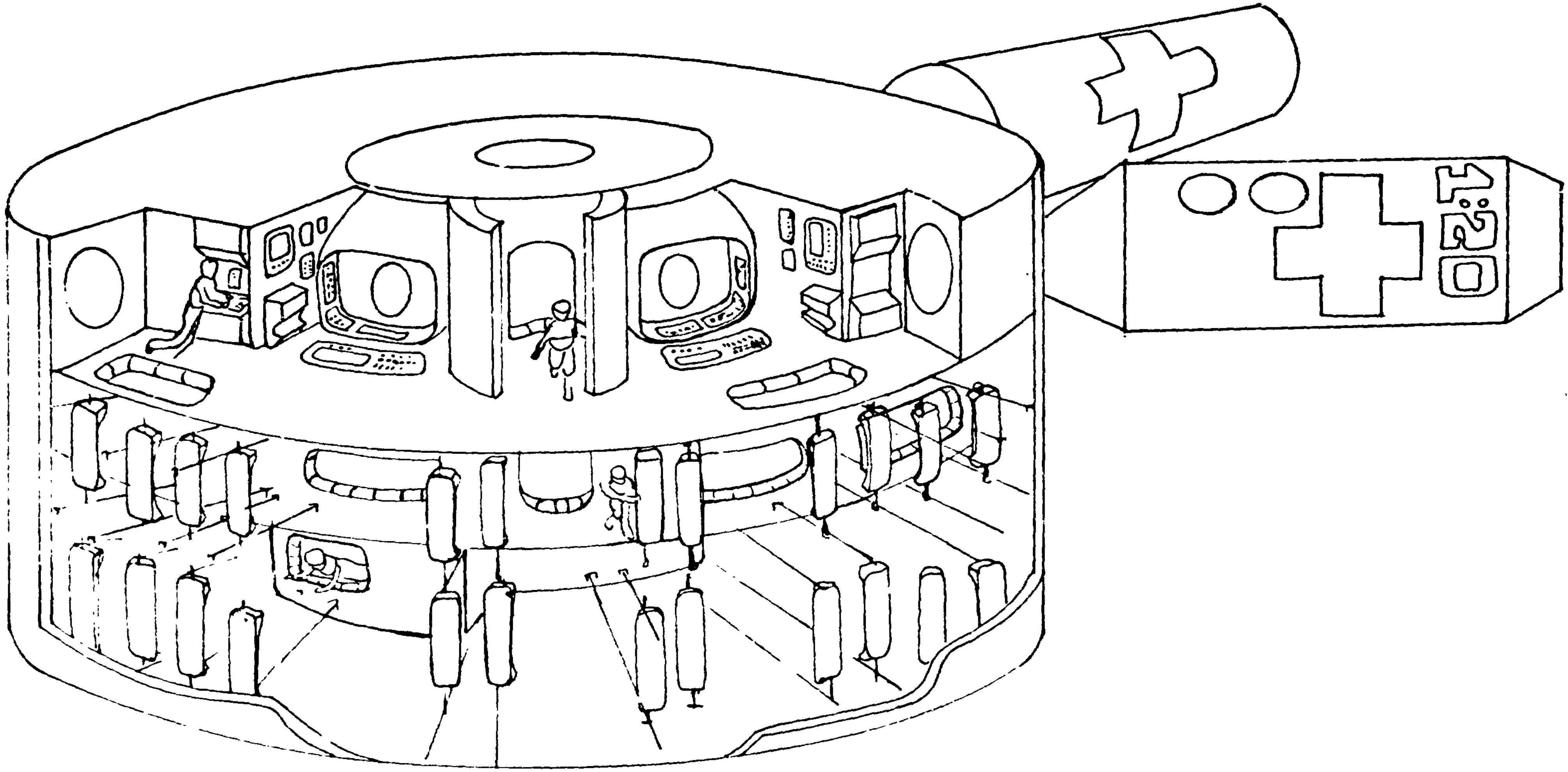
Support facilities of X-ray, clinical lab, medical records, food service, etc., may be arranged directly adjacent to the clinics the emergency room, surgery, and inpatient facilities in 3 space.

At zero-G, movement of patients will cease



HOSPITAL FLOOR PLANS

FIGURE 42



HOSPITAL-CLINIC FACILITY: CUTAWAY VIEW

FIGURE 43

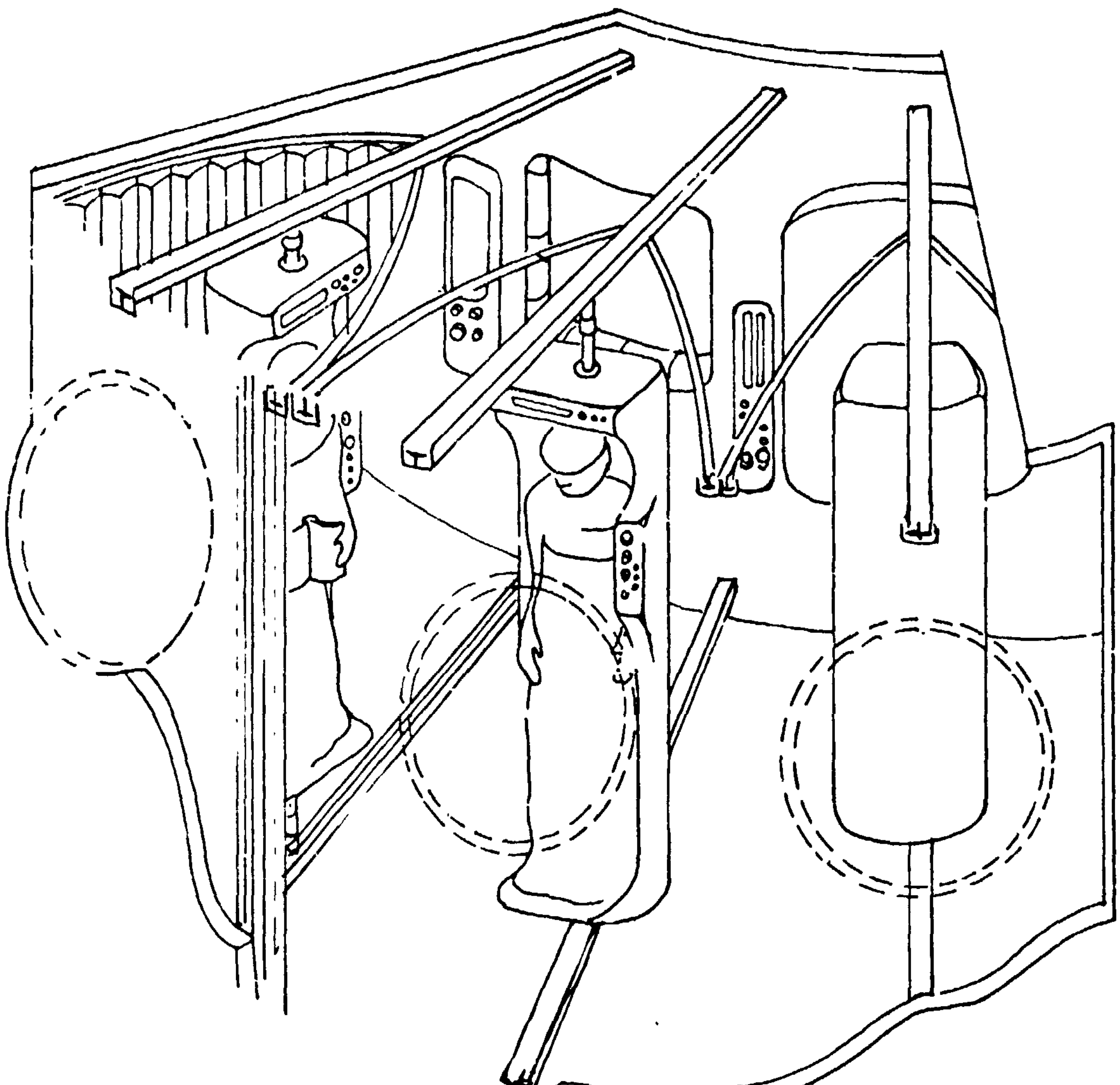
to be a problem. The patient, in bed, may be guided from area to area smoothly, effortlessly, and efficiently, with the minimum of personnel.

Surgery and emergency treatment will have new dimensions, solving some problems while presenting others; blood as an example, and other fluids will have to be continuously vacumn removed or be expected to ultimately cover all surfaces. Patients requiring invasive techniques or closing procedures may be positioned directly in front of the physician at eye level, close up and any angle desired. With the ability to use hard vacumn, the operative environments may approach germ-free states.

Inpatients are admitted into a step-down treatment system which concentrates man-power and specialized equipment into a intensive care unit (ICU) with the remaining beds split approximately 10% progressive care (a bit less than intensive) and 90% extended care (for patients requiring some medical attention, but not as a matter of life).

Patients admitted to the ICU are placed into a fixed medical container (Medcan), a softly padded fiberglassed shell approximately 22 inches wide and eight feet long. (Figure 44.) Molded into the shell are immediate monitoring devices, med gasses, and cabinets which contain the patient's unit doses of medication, records and personal items. The entire shell is computer linked to the central data bank for instantanious continuous update of the patient's records, as well as assistance to the medical personnel.

The patient is restrained into the shell via a light containing net stretched across the front; the position of the shell allows constant eye contact between



HOSPITAL BED (Detail)

FIGURE 44

the patient and the staff. As the patient's condition improves, his shell is removed from its fixed holders and floated to the next level of care. Here, as in the extended care units, the shell is placed, not on a fixed point but on tracks which allow the patient to move the medcan along their length. The tracks start against the inboard bulkhead and extend to the outboard wall, terminating next to a porthole. The patient, by simply moving along the track, can create his own space, include or exclude the rest of the ward and the other patients. The medcan, in this configuration, may also be rotated about its longitudinal axis allowing additional choice of visual configuration by the patient. Complete privacy is afforded with collapsible by-valve shutters fitted to a semi-circular track about the outboard end of the medcan track.

Outpatients are treated within a health maintenance organization (H.M.O.) system allowing preventative medicine and maximum use of paramedical personnel.

The overall physical arrangement is based on easy entry by the patient combined with minimum distances for med personnel to travel from activity area to activity area. Unimpeded movement, except as required, is inhanced in zero-G 3 space.

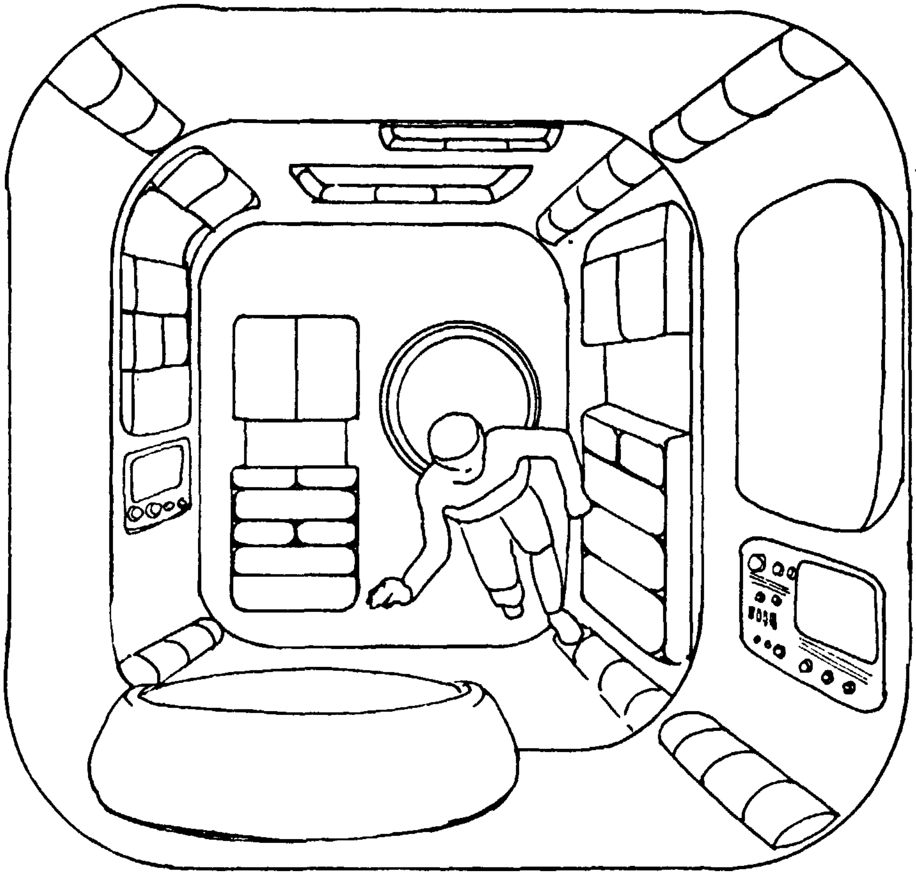
In passing from this area let us momentarily look into the O.R.'s. The O.R.'s are contained in shuttle delivered modules attached to the med core unit. Each is self contained and has a variety of interesting items fully practical only in zero-G; operating tables which move on gimbals allowing placement of the patient in any position desired; physician stations at right angles to the table allowing a surgeon to work straight-in and close-up rather than bent over; and free floating magnetically controlled light with unlimited position possibilities, to mention a few. The rooms are double airlocked and may be totally vented after each procedure, filled with sterilizing gases, then returned to normal air, or may be converted to a hyperberic chamber for expecially virilant gangrene amputations, or debreedment. The med-complex is efficient, compact and open to the patient.

RESIDENTIAL AREA

The residential area is a ring of living units surrounding the central corridor and administrative areas. Windows allow exterior views of the station. Sleeping coves share adjacent living areas dormitory fashion. (Figure 45.) These coves are designed as personal spaces capable of personalization. This area, like an apartment, is provided with a key insuring its occupant privacy; a place to be alone with himself. The flexibility of the living area design is such that a multiple configuration of living units is available for persons living together or persons with children. Colors and interior accoutrements may be selected by the residents, including personal possessions which may be secured in special zero-G display/storage areas of the space.

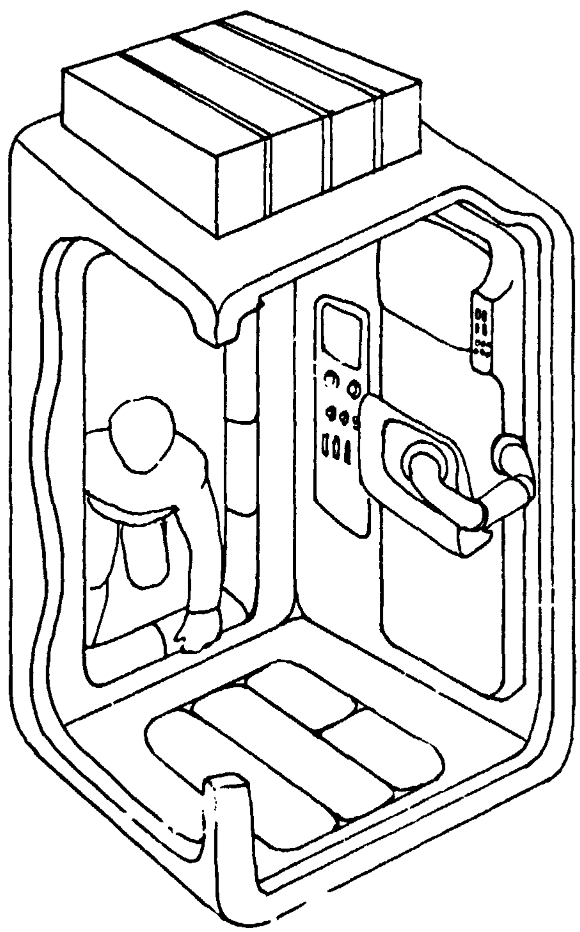
OFFICE AREA

Existing as a 30' diameter core within the residential section, the administration area, in turn, surrounds the transportation tube leading to the hospital. Office decks are laid in pie-shaped segments arranged much like a spiral staircase around the central transportation tube. Half-space increments lend a sense of infinite space to this arrangement. There seems always to be something beyond the adjacent spaces. Floors become ground planes working in both directions. Every plane is functional as a work area allowing optimum utilization of space for equipment. The administrative



ENTERTAINMENT AREA

TYPICAL LIVING AREA



SLEEPING

FIGURE 45

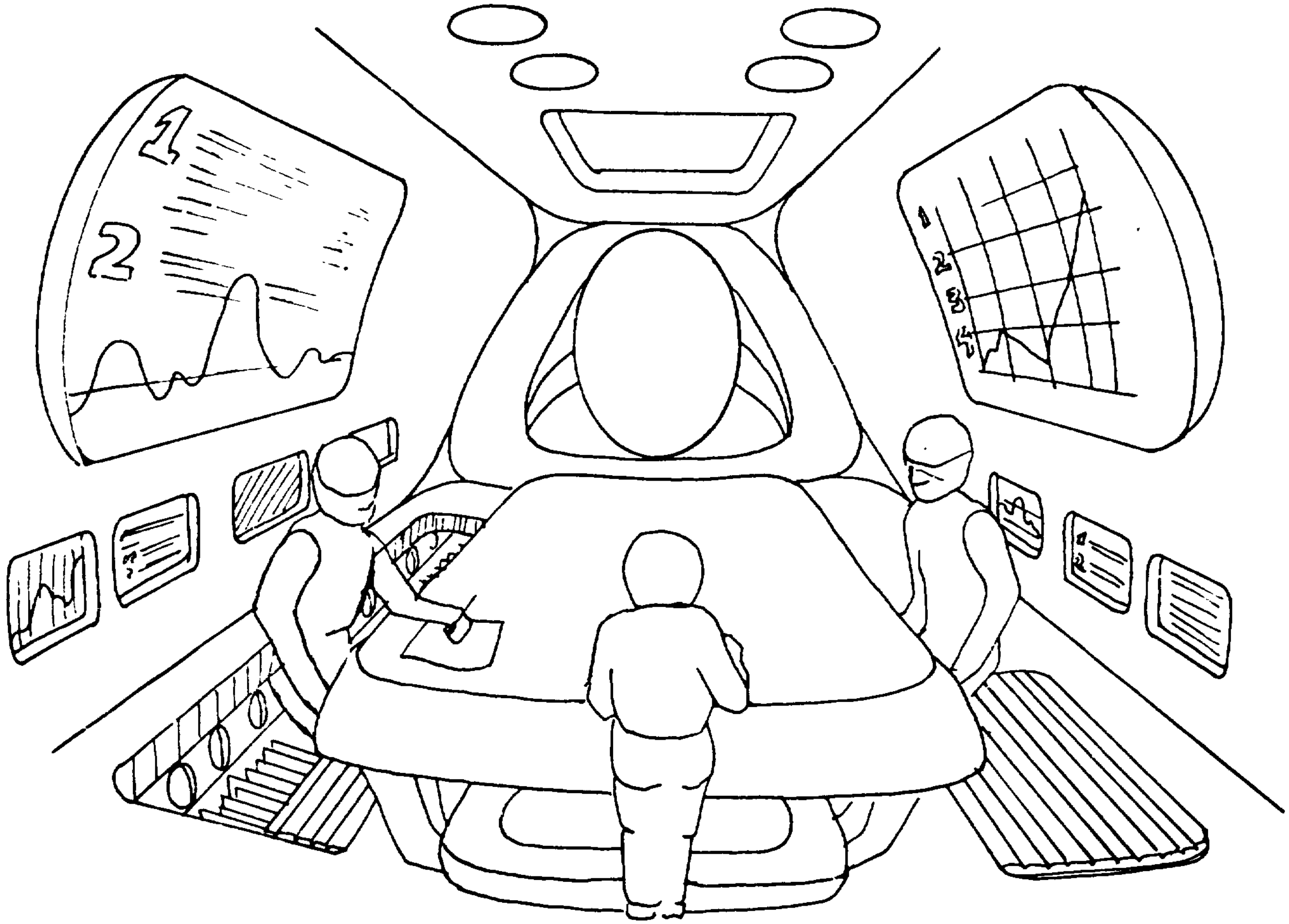
area offers a mixture of spaces: A library, accounting services offices, security sections, legal facilities, laundry and small business offices are located in this section, adjacent to the central tube system, providing these services directly to the station and its inhabitants.

ADMINISTRATIVE CONFERENCE ROOMS

Between the Administrative section and the main circulation tunnel are banks of conference rooms. At this juncture, in a radically tapering area of the station, the super structure of the space complex is visible through large domed oval-shaped windows. (Figure 46.) These pre-shaped areas afford one of the most impressive views of the exterior of the facility. Within this space, the highly technical aspects of the facility are apparent. Against a back drop of deep space the lattice work of the station's structure must evoke profound emotional responses from those who view it.

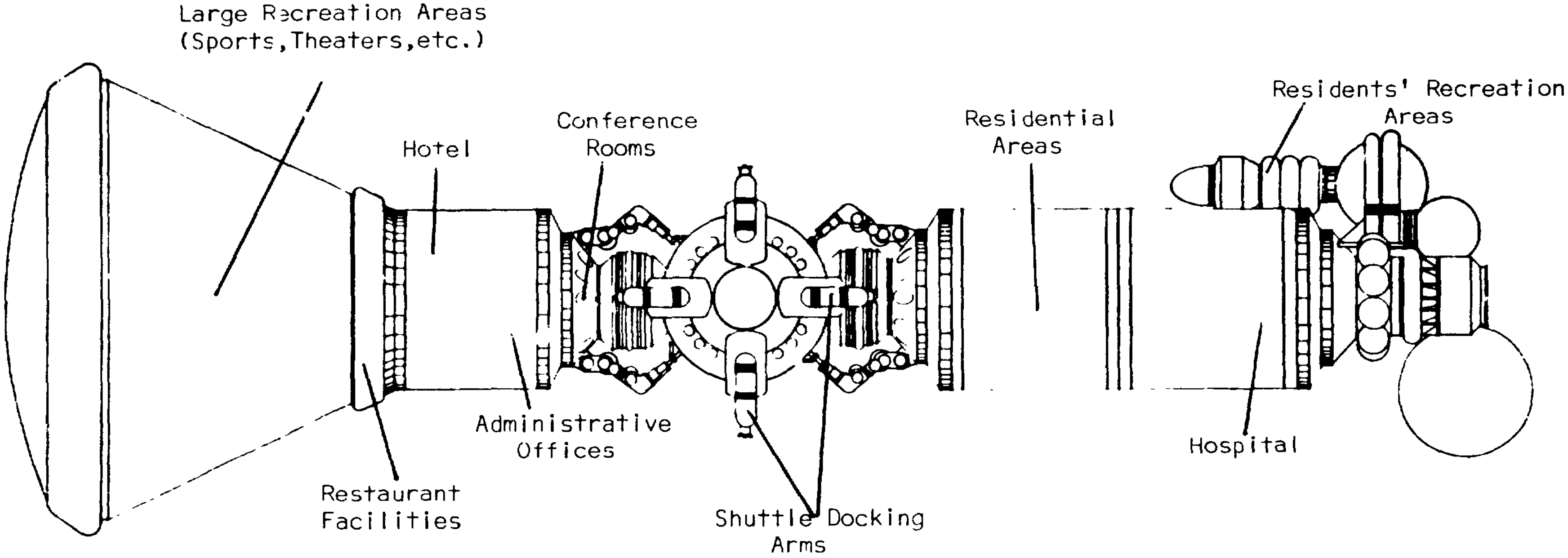
HOTEL

Across the circulation tunnel is the hotel and recreation area (Figure 47): This wing of the station is also provided with conference facilities; these for use by hotel guests and special functions. Hotel administrative areas providing required services are located within the interior thirty foot corridor of this wing. Adjacent to this grouping is the hotel lobby. The outer skin of this eight foot core houses hotel rooms similar in configuration to the residential area. Rooms are pie-shaped 8' across x 10' deep and 11' long. (Figure 45.) All surfaces are utilized for seating or entertainment. Lighting is similar to that within the residential spaces and serves to aid in orientation. Furnishings are merely constraints, except for a table configuration with constraints for the legs.



CONFERENCE ROOM

FIGURE 46



LIVING BRANCH (top view)

FIGURE 47

DINING AREA

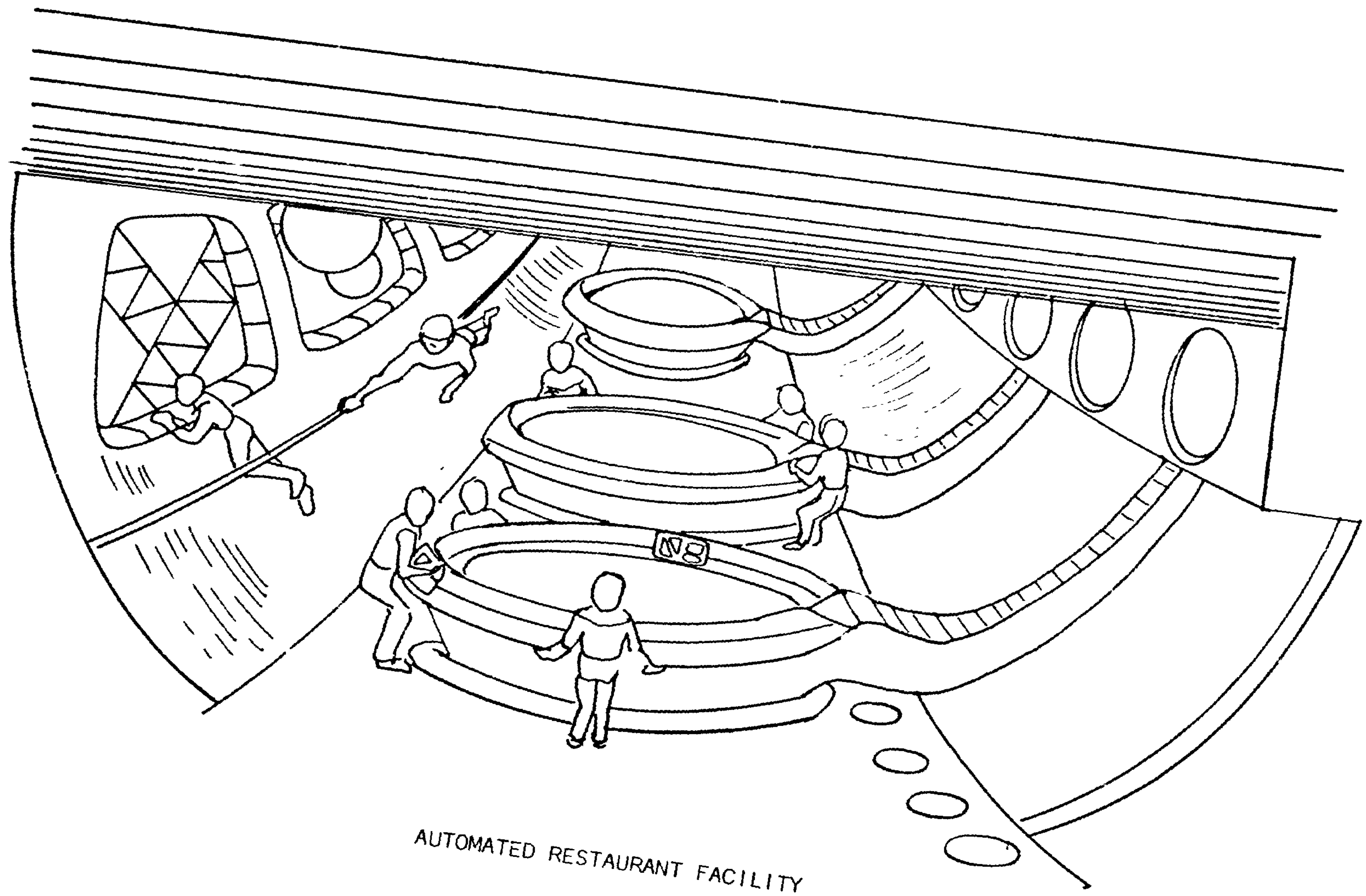
Beyond the hotel is the restaurant area to be utilized by cadre and visitors alike. Expected use of this space by personnel is to be twice each day. (Figure 48.) Designed as a ring, this space affords views out of the spacecraft as well as upward into the recreation cone. Food service is as specialized as the station itself. Due to the difficulties of moving and serving in zero-G, food will be delivered to individual tables seating small numbers of people by a conveyor system which rings the dining facility. (Figure 49.) Tilted magnetized surfaces will facilitate dining and provide restraint for food containers and utensils. Patrons will be constrained by softly padded floors with counter sunk leg restraints providing stability and orientation.

RECREATION CONE

As the largest open volume space in the station, the cone's small end measures 90 feet in diameter. Two hundred feet in length the widest diameter of the cone is 230 feet. (Figures 50 & 51.) This area houses active recreation facilities such as tracks for jogging, theaters and large assembly facilities. An amusement park contained within a 10' triangular space frame will provide incredible new experiences in zero-G context. This space frame will act as a transportation system within the cone. Modular courts for ball games work within this frame and are accessible through it. The large dish-shaped end configuration will be utilized with photographic projectors featuring halographic projections endowing the recreation center with sureal movement and life.

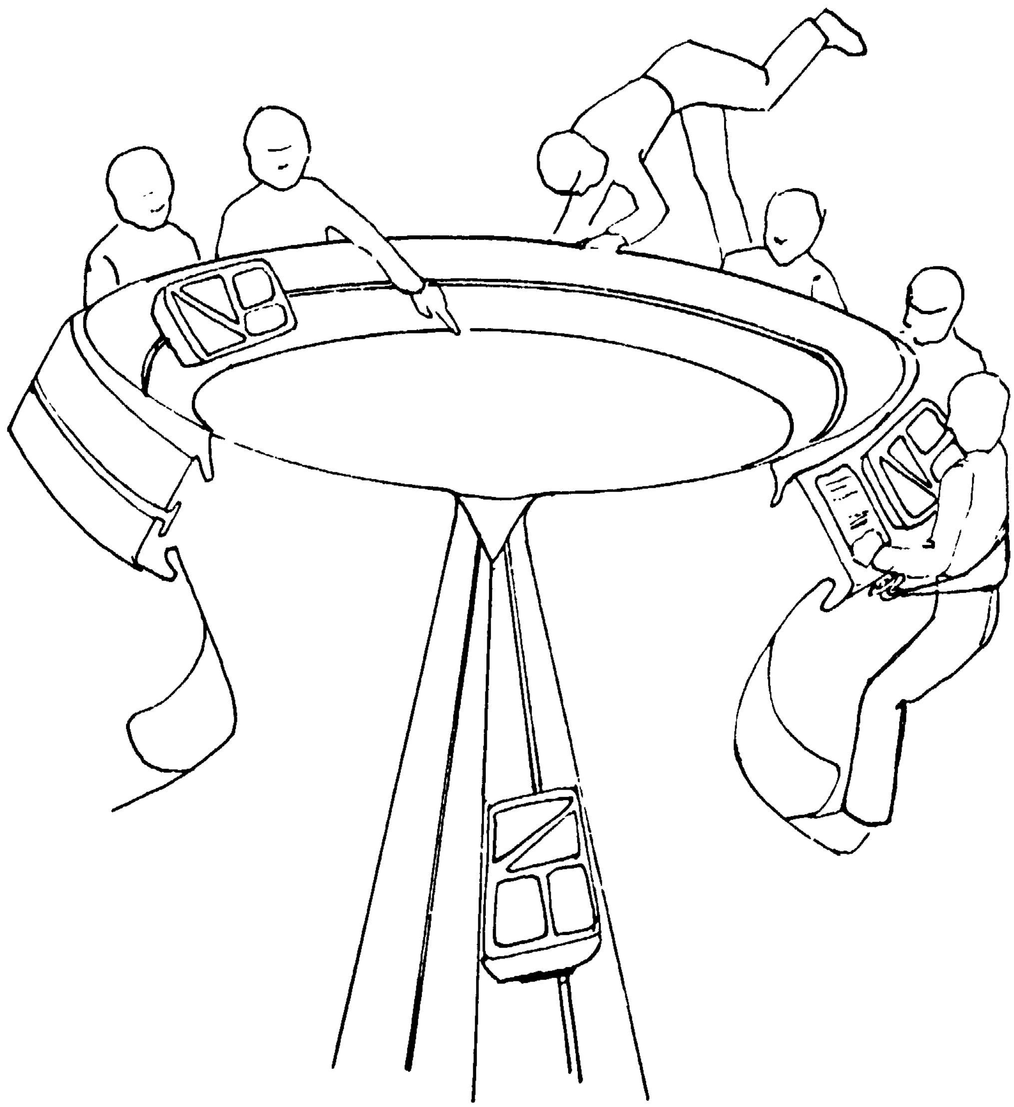
INDUSTRIAL AREA

Moving laterally through the main circulation corridor, we enter the heavy industrial, research, and development areas. (Figures 52 & 53.) Industrial receiving



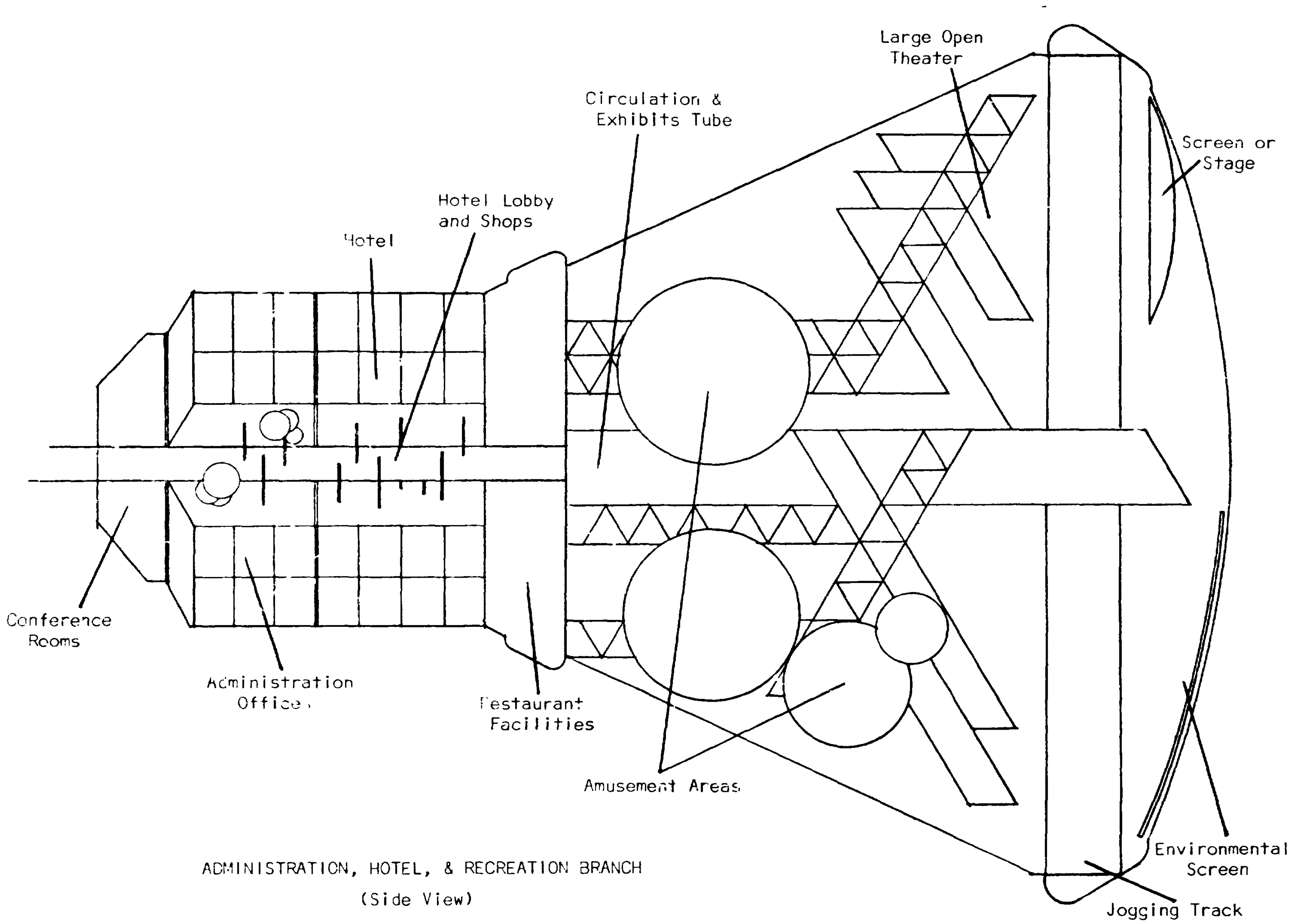
AUTOMATED RESTAURANT FACILITY

FIGURE 48



AUTOMATED DINING FACILITIES

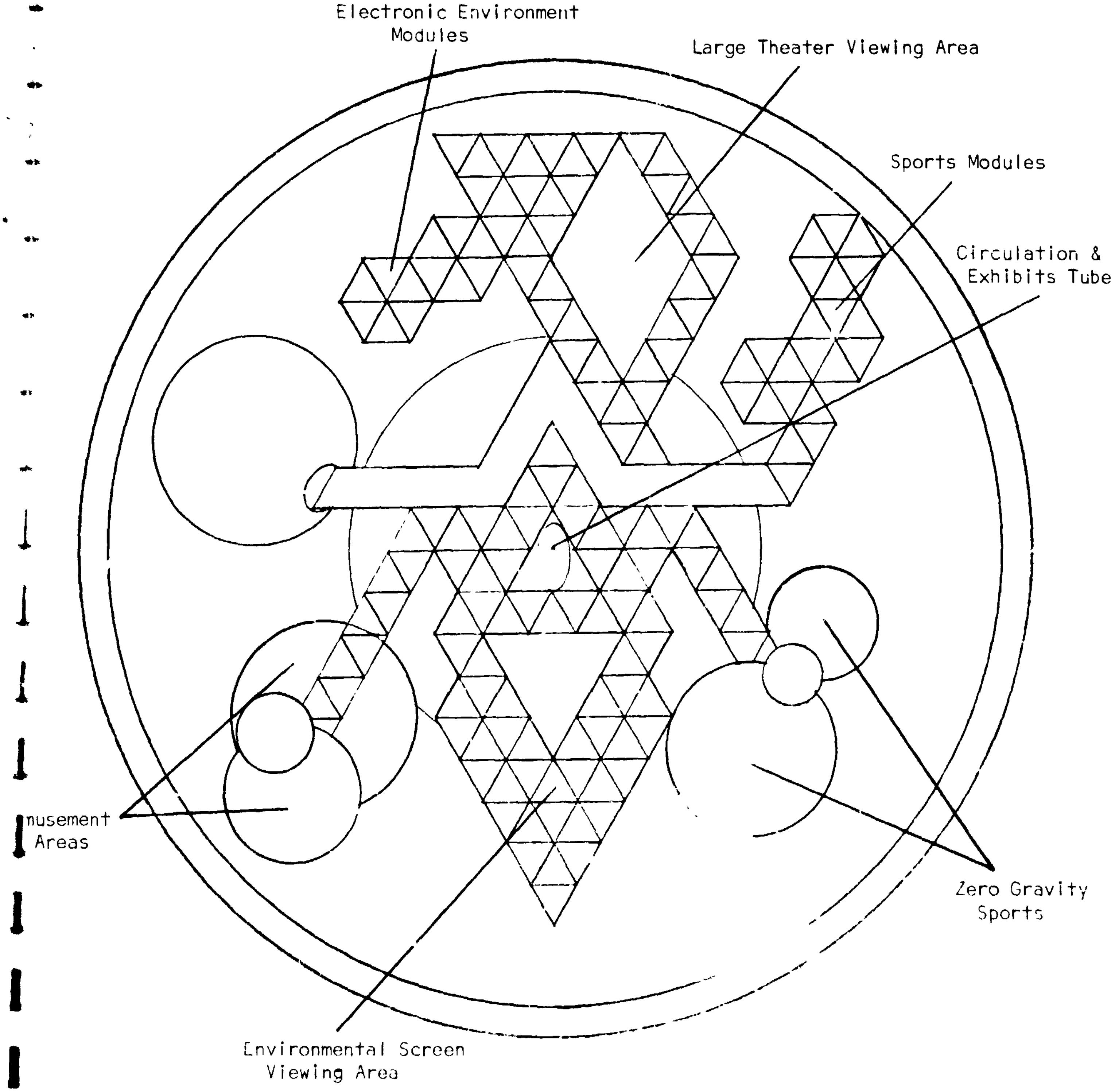
FIGURE 49



ADMINISTRATION, HOTEL, & RECREATION BRANCH

(Side View)

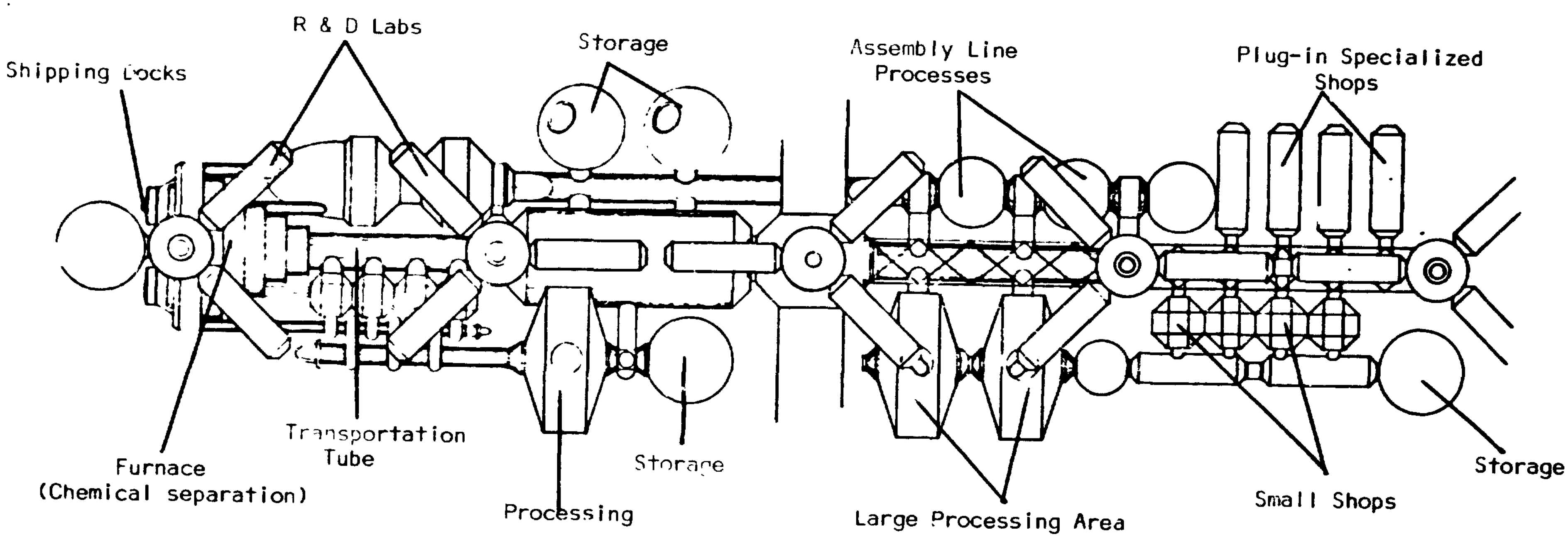
FIGURE 50



RECREATION AREA

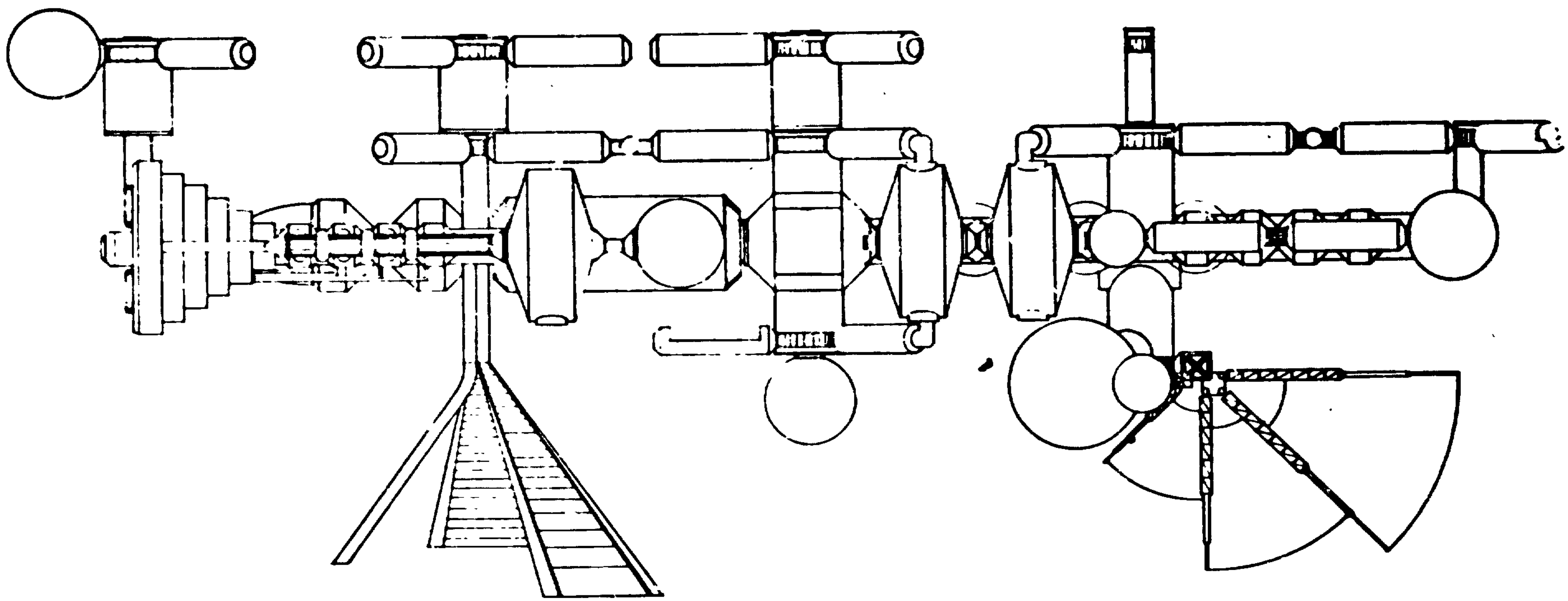
(End View)

FIGURE 51



MANUFACTURING BRANCH

FIGURE 52



MANUFACTURING BRANCH
(Side View)

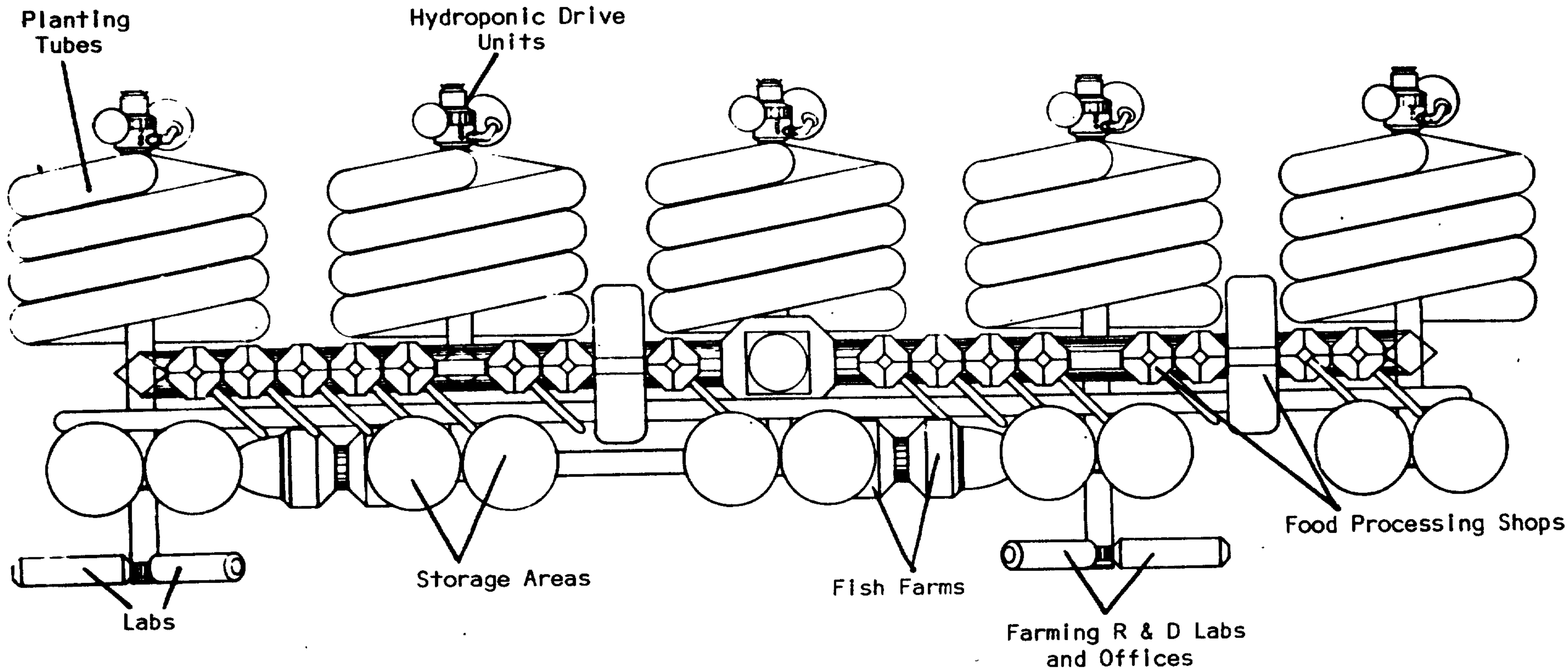
FIGURE 53

areas are located at the furthermost extremity of this wing. Figure 16 shows a space freighter off-loading raw materials at the receiving area. These materials will be used as raw products for the manufacturing plants which will enable the space station to become virtually self-sufficient. Materials such as aluminum, titanium and other third generation metallics will be processed and converted to structural elements, beans, ribs, etc., which will enable the station, in much the same way as a living organism, to reproduce itself, growing from within constantly adding, adapting, enlarging at a rate determined by internal manufacturing capabilities rather than earth dependence. This interdependence of growth as related to capability is expected to produce a comradery among the cadre. Heavy manufacturing will be carried out by automated or manned systems as the need exists. This area of the station will literally hum with life and motion. As a self-contained manufacturing complex it will digest raw materials and turn-out completed components and structural elements, it will be automation's finest hour.

At core junctures, small, highly sophisticated industry will receive raw materials and components through a dispersal system from the receiving area. These small industrial shops will carry out such diverse functions as electronic component fabrication and assembly in contaminate free "clean room" environments, zero-G crystal growth and medical research with conformance to tolerances and criteria not possible in an earth side environment. It is here, also, that routine maintenance of station electronics will take place. These research and development modules are to be shuttle-delivered complete and intact, ready for use. It is expected also that these facilities will embody University extension services in various capacities limited only by man's imagination as to their adaptability to particular scientific disciplines. As in other areas of the station, pneumatic storage areas are utilized for bulk containerization of materials.

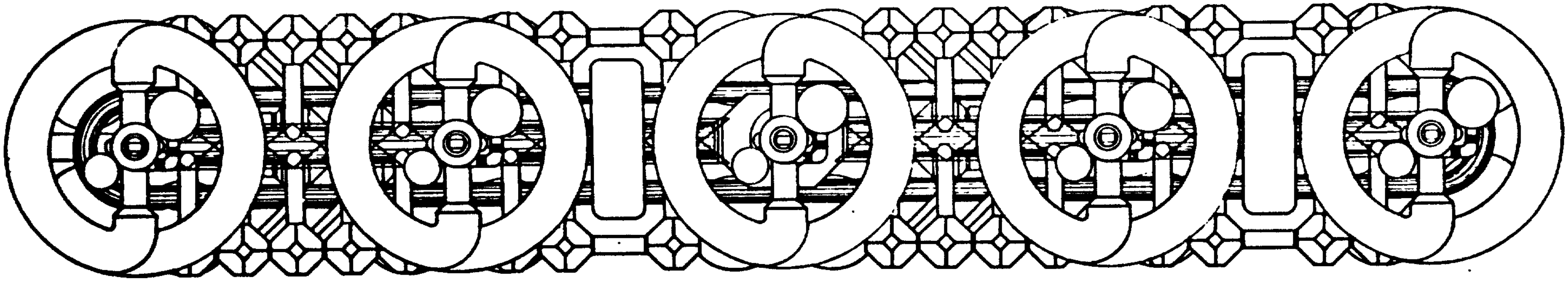
FARM

The final wing of the facility to be discussed is that of the Farm. (Figure 54.) It is anticipated that ultimately the station must become self-sufficient if it is to be a viable community. Self-production of essential food stuffs will help offset a "balance of trade" with earth side markets. Internal supply of these commodities will be a major step toward self-sufficiency and self-reliance. The growing areas of the farms are designed as a series of concentric spirals or springs. (Figure 55.) Growing areas within these spiral tubes occupy the full 360^o wall cross section. Initial configurations provide approximately one-half million square feet of plantings. Harvesting these high-yield crops, such as soy beans, barley, oats, wheat, leafy green vegetables and sucrose producers such as beets will be accomplished by scouring the inside of the tubes with mechanical blades and vacuum transfer of the material directly to storage areas adjacent. (Figure 56.) These pneumatic vessels will store crops in natural, refrigerated or freeze-dried states as required. During growing seasons, which may be of constant duration due to artificial light sources, nutrients are forced into a fibre matrix containing planted seeds. A central light source will cause the plants to grow toward the center of the spiral tubes. Fish will be raised in this area in the elongated continuous tube forming the structural element of the lower level. Fish will provide meat, eggs and sources of protein, as well as a research medium. It is expected that Agricultural extension services and branch university forms will



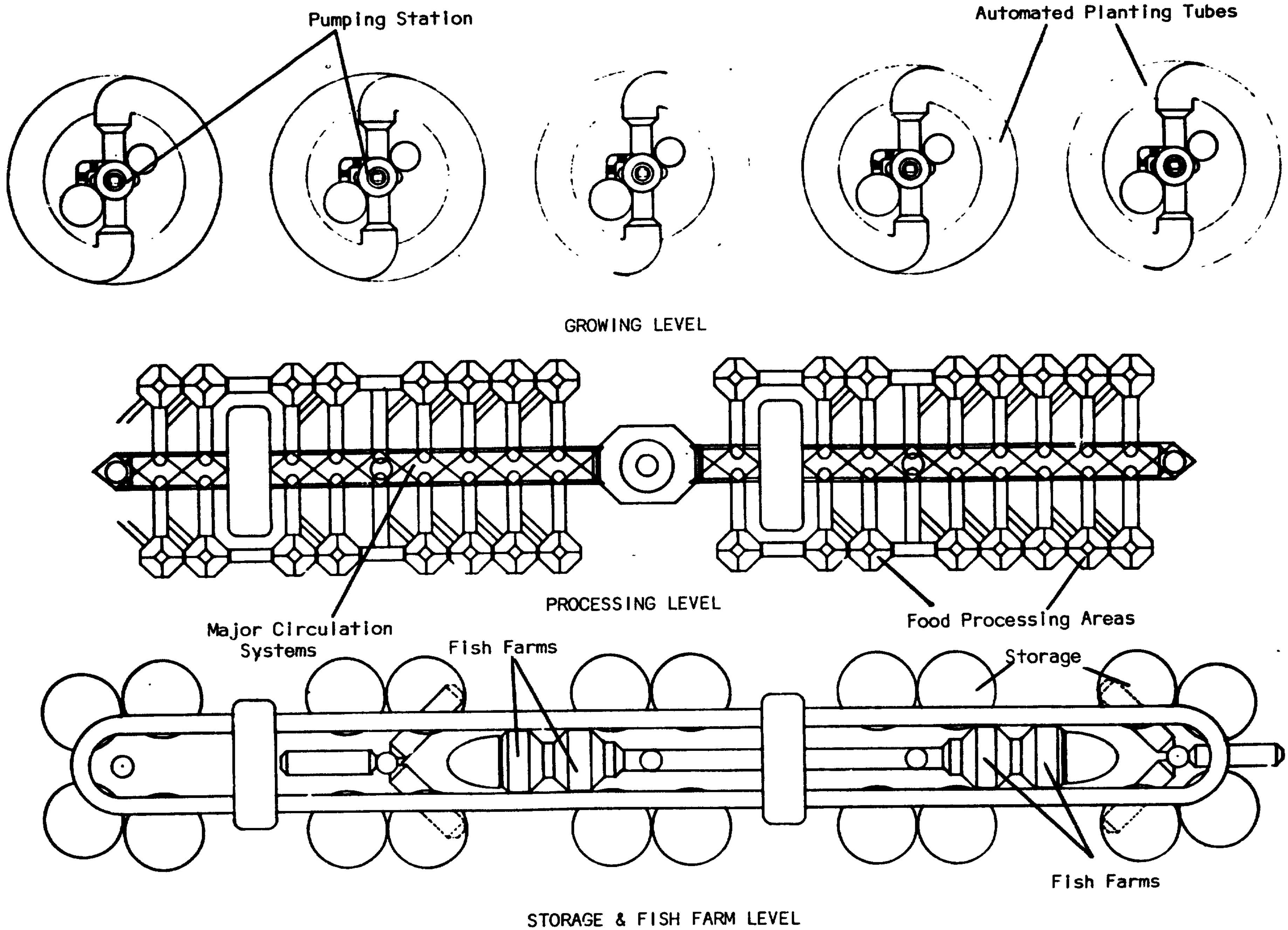
FARM BRANCH (SIDE VIEW)

FIGURE 54



FARM BRANCH (Top View)

FIGURE 55



FARM: TOP VIEWS

FIGURE 56

make extensive use of these facilities.

We were charged at the inception of this project with an in-depth investigation into the needs and design of an orbiting space station with growth capabilities. A product of two years of study, this report defines and quantifies the key areas of consideration toward this end. While we have formulated viable solutions to those problems considered, there are still other facits within the scope of our work which must be meticulously researched.

Man is in space and he is in space to stay. It is his last frontier and opportunity to realize his maximum potentials. Conquering space is to conquer infinite frontiers. To achieve this it will require a totally coordinated multi-disciplinary approach. The architect has a distinct role in that approach. We feel that our work represents the beginning of the architect's involvement in this search for the new frontiers. This study raised more questions than it gave answers, it is the continuance of this kind of work which will bring our solutions closer to reality.

> "Make no little plans; they have no magic to stir men's blood, and probably themselves will not be realized; make big plans, aim high in hope and work, remembering that a noble logical diagram, once recorded, will never die, but long after we are gone will be a living thing, asserting itself with ever growing insistency."
>
> Daniel Burnham