3 GENESIS II ADVANCED LUNAR OUTPOST DESIGN

3.1 SITE SELECTION

The purpose of site selection is to provide a geologically and geographically rich environment. Additionally, the surface features should be able to sustain roadways between the launch facilities, habitat, and surface operations. The Apollo 15 site contains features that range from flat expanses to cratered areas, from low hills to higher ridge areas. Hadley Rille, a sinuous geologic feature, also exists in this area. It suggests the presence of the lunar lava tube which is a volcanic lava channel beneath the lunar surface.

*Genesis II* will make use of the anticipated existence of a lunar lava tube. Precursor survey missions will define an optimal location for penetrating the roof of the lava tube. An anticipated collapsed section will allow egress from not only the surface portion of the base, but through the opening as well.

The site provides smoother areas for the construction of the launch and landing facilities, and protected areas in which the nuclear power plant can

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**Figure 3.1-2.** A lunar map, including all of the Apollo landing sites.

**Figure 3.1-1.** Apollo 15 site.

**Figure 3.1-3.** Apollo 15 site – Approach to Genesis II base location.
be built. Near the base nucleus, the solar array field can be erected, protected from launch pad debris and clear of shadow-producing obstructions.

3.2 BASE SITE SELECTION

The Genesis II zoning is divided into three categories: industrial, hazard, and inhabited. These were selected as a result of the base and mission operations detailed for Genesis II.

The area included in the hazard zone is the nuclear power production facility. It's location will be no less than 1 kilometer away from the habitation and laboratory area. Located in the industrial zone are the launch and landing pads and the mining facility. The launch and landing facilities have been placed at the northern-most location of the base. This location provides for landings from eastern and westerly directions, and helps reduce the hazards from exhaust blasts or launch and landing failures. The distance between the launch area and the habitation area is approximately 3 kilometers, and between the habitation and the mining facilities is 1.25 kilometers. Lastly, the manned zone will contain the far-side astronomical observatory, the solar power field, and the habitation and laboratory facilities. This area is more centrally located in Genesis II.

3.3 MASTER PLAN

The Genesis II base is designed in a linear fashion on a north-south axis, with the components consisting of the launch and landing facilities, solar power array field, mining facility, habitat and laboratory facilities, nuclear power generator, and a far-side astronomical observatory. The linear design provides safety for the base by prohibiting space vehicles from flying directly overhead. There will be transportation channels connecting these areas, observing the necessary safe distances between them. These distances are determined from the zoning requirements established due to the nature of the various activities occurring at the sites.

The zoning divisions are the result of an increased awareness of what effects will be produced by the living and working facilities on the Moon. This is an attempt to prevent damage, either intentional or unintentional, which may result. The effort is international in scope, with the International Lunar Environmental Protection Authority (ILEPA) being created from the Environmental Protection Agency model on Earth (Schroeder, 1990). It addresses the effects which will occur on the lunar surface, its subsurface, near surface and on-orbit environs. Suggested zones for a lunar base are:

- hazard zone (including nuclear power stations, bio-hazard areas, genetic engineering facilities and any activities that would be designated as extremely dangerous to humans or the lunar environment),
- industrial zone (mining operations, launch and landing, or other surface operations),
- inhabited zone (habitation areas, laboratories or frequently occupied pressure facilities),
- wilderness (areas to be saved from exploration, yet accessible),
- parks (those areas designated as historically, geologically, or scientifically significant).

3.4 CONSTRUCTION SEQUENCING

In order to understand the sequencing process, the components comprising Genesis II are as follows: on the surface of the Moon will be the assembly facility and protection truss-work. Below the surface, within the lava tube cavern, will be the truss-work, two space station-derived modules, an extravehicular activity (EVA) module, and two inflated structures.
Fig. 3.3-1  The Genesis II Base Master Plan—launch and landing facilities located to the right, habitation/laboratory areas near center, power facility to left, mining below (Note: North is to the left).
Figure 3.4-1. Emplacement phase: Equipment being landed for the construction of the base.

Figure 3.4-2. With the assembly facility in place, the hole is sintered into the roof of the lava tube.

Figure 3.4-3. Integration phase: A crane lowers pieces of the space frame into the lava tube.

Figure 3.4-4. A Shuttle-C module is lowered into position through the hole in the lava tube's roof.
Connecting the surface to the base below will be a Shuttle-C derived module. At its initial operating configuration, *Genesis II* will see the assembly facility module moved to the mining area of the base, and in its place will be two logistics modules and an additional EVA module. Centered over the Shuttle-C module, and used as a connection point for the logistics and EVA units, will be an interconnect node.

The precursor missions to the lunar surface will have determined the optimal site, and robotic missions will bring the necessary equipment for site preparation (grading, leveling, bulldozing, lifting, and sintering). At that time as well, the module used as the assembly facility, fully out-fitted, will be landed. Once that equipment has arrived on the Moon, manned missions will begin the base construction sequencing.

The first task is the placement of the assembly facility and the erection of the radiation protection truss-work, with accompanying regolith covering. The crew members will proceed to cut through the roof of the lunar lava tube to access the cavity below. The process of cutting through the roof of the lava tube begins with a long rod, the length of which will be greater than that of the roof thickness. This rod is attached to a sintering vehicle. The rod is heated to 1400 degrees Celsius, and will melt through the lunar surface to the lava tube cavern below. This is repeated in a circular fashion creating a perforation. Small explosive charges will dislodge the center section. It is anticipated this section will drop to the cavern below and then is cleared away. Once the entrance to the lava tube is open, the crew must complete a clean-up process, removing rocks, regolith, and any additional debris which will impede construction. After site preparation, and the securing of any anticipated lava tube roof weaknesses, the truss-work will be lowered in through the opening to the floor below. A crane will be necessary to complete the truss construction, although it can be a smaller version.

The truss-work will be the supporting structure for the EVA module and the space-station modules, which will "hang" above the ground surface of the lava tube. Once they are secured, the Shuttle-C module can be lowered into position, connecting to the top section of the common module, and connected at the surface by the interconnect node. Inflation of the soft modules can commence, with construction of their interiors occurring as the logistics and EVA modules are delivered and set into position.

When all the components have been delivered, placed into position and secured, the actual interior configuring will commence. At the same time, any further clearing away of debris from the lava tube cavern will occur.
Fig. 3.5-1 The Modular Construction Component System. This is the basis of the interior configuration, based on a grid system measurement of 1.2 meters.
3.5 MODULAR PANEL AND RACK DESIGNS: A KIT OF PARTS

The design of this lunar base has been based on a system of modularity. Modular components utilize an easy system of emplacement and resupply. The pieces are sized to be transported through the hatches and be moved about the base from the logistics module on the surface. To address these requirements, a baseline measurement was determined. For the needs of the lunar base, both in transporting items, and responding to human anthropometrics, 1.2 meters was chosen. This corresponds with the human reach and the body position while in 1/6th gravity. Wherever possible, sizing of the pieces were designed within the 1.2 meter requirement, or a multiple thereof.

As in Space Station Freedom, a rack system has been chosen for the base. Not only does the rack system allow easy movement of items, making rearranging spaces easy, it also allows interchangeability in items, allowing the ability switch around racks in the base. This also allows interchangeability when replacement is needed for things such as logistics, or if a rack should become damaged or inoperable.

The racks themselves will vary in height and width but will conform to the 1.2 meter system or its derivative. Connector variations allow wall systems to interconnect in any number of possible combinations. This reinforces the crew's ability to reconfigure personal spaces, as well as easily reconfigure areas as the base expands. Wall panels are designed with ease of maintenance in mind. Color will be easily applied to a surface either by manufacturing or by inserts, or simply with velcro-applied textural combinations.

3.6 PHASE I: EMPLACEMENT PHASE

The Emplacement Phase is the first manned mission phase. After the machinery necessary to prepare the site is landed, crew members will accompany the Assembly Facility to its proper location. This facility consists of a fully-outfitted pressure vessel, 13.6 meters long by 4.5 meters in diameter, constructed like the space station module model. The four crew members will oversee the base construction, on a mission rotation of approximately two weeks.

The Assembly Facility contains all life support necessities. It consists of an EVA (extravehicular activity) and pressure suit chamber, sleeping quarters, galley and wardroom, and hygiene facility. Within the modular rack system will be a "safe-haven" rack where medical supplies will be housed. Exercise performance will be minimal given the shorter mission durations.

This facility will be reconfigured when extended missions are performed, and a greater number of crew quarters are necessary. Once additional components for the base have been landed and brought to the site, the crew will begin the Integration Phase. The reconfiguring of the Assembly Facility will begin only after full crew support exists in other areas of the base. The final destination for the Assembly Facility will be adjacent to the mining field.

3.7 PHASE II: INTEGRATION PHASE

This phase of base construction is a reconfiguration phase. The base is expanding, yet is not mature, with all sections functioning. Integration will see the delivery of the balance of the base components, an increase in the size of the crew, and final construction of the surrounding surface facilities.
3.7.1 SURFACE LEVEL 1

Included on the surface of the base will be the temporary Assembly Facility, an interconnect node, EVA chamber and logistics module. It is during this phase that the actual lava tube roof penetration will occur. A description of the process is found in Section 3.4 Construction Sequencing. All these structures will be protected underneath truss-work incorporating a regolith infill system. This system provides for a double layer of Kevlar with expansion space between. Regolith is then introduced between the layers and fills to reach a width of .5 meters. The truss-work is enveloped in this protective covering, allowing the logistics module and Assembly Facility to be removed and replenished.

3.7.2 SHUTTLE-C CYLINDER

This structure will be dedicated for stowage and translation core activities. The vertical movement will occur in the central portion of the 4.5 meter diameter. Around the perimeter, in a typical stowage level, eight modular racks can be installed. The translation core will permit mobility of the racks between levels and into the inflatable sections of the base.

3.7.3 LAVA TUBE LEVEL 5

During the Integration Phase of construction, the base has expanded to support seven crew members. With a portion of the crew support facilities on the surface, the balance will be housed within the lava tube.

Within the Crew Support Module, there will be a limited exercise facility, a full hygiene facility, the mission operation's workstations and the health maintenance facility. This will be a module which will see some reconfiguration as the base matures. The Habitation Module has a number of combined activities. There will be galley, wardroom, passive and active recreation areas, pressure suit stowage, and wardroom stowage.

An EVA module will be connected to the habitation module, and it will provide additional suit stowage as well as access to the interior of the lava tube through the airlock.

As mention before, reconfiguration of the two larger modules will occur. Remaining will be the health maintenance facility and hygiene facility. Mission operations remain unchanged as well. The limited exercise facility will move into the inflatable crew support area. The space available will be dedicated to health maintenance stowage and general stowage for the mission operations sector.
The habitation module sees the greatest reconfiguration. It will house pressure suit stowage chambers and maintenance workstations for the suits.

3.8 PHASE III: INITIAL OPERATING CONFIGURATION

The initial operating configuration (IOC) will house eleven crew members. All of the components will be in place and functioning.

3.8.1 DESIGN ORGANIZATION

The overall image and organization of the Genesis II base is that of the separation of work and living. This is accomplished through an established set of criteria: safety, habitability/human factors/environment-behavior considerations, using advanced near-term technology, and replaceability/modularity. The safety factor, a crucial element in the designing of a lunar base, is achieved through situating safe-havens throughout the base. A safe-haven is a modular rack supplied with all the necessary equipment needed to neutralize an injury or hazardous situation. Dual egress, a vitally important element in the safety of the crew, is located at the top of the base on the surface of the Moon and below where the roof collapsed. Habitability is derived by allowing the crew the ability to change or adjust anything undesirable to fit their needs. Using advanced near-term technology will give credibility to Genesis II in that it can be built without having to wait until the technology is developed. The kit of parts modular design allows replaceability and modularity. By giving the crew the opportunity to change anything undesirable, it will relieve possible stress. These criteria are used throughout the entire five levels of the base.

The first level contains one of the two EVA modules which contains the suit stowage, maintenance, and airlocks. There are also logistic modules which can be attached and removed from the base as needed.

The Shuttle-C module (level 2), which is the spine connecting the top and the bottom parts of the base, is the vertical translation core and the main area for stowage (see Figure 3.8.1-1). The modular replaceable racks can be easily held here until needed.

The habitability inflatable is physically separated from the rest of the base, attached only through a connection node and an emergency hatch. It faces the entrance to the lava tube creating good views to the moonscape.
Figure 3.8.1-2. A section of the base, including the Shuttle-C module which connects the elements in the lava tube with the lunar surface.
Figure 3.8.1-3. Shown on the left is the plan of the lower floor of the habitation inflatable, showing the galley, wardroom, exercise, limited hygiene facility, and a number of recreation areas. On the right, the laboratory inflatable is shown, including a general laboratory and a number of specialized laboratories.
Figure 3.8.1-4. The interaction of areas on the lower level of the inflatables connected by circulation through the Shuttle-C central core.
Figure 3.8.1-5. Shown on the left is the upper floor of the habitation inflatable which includes crew quarters, personal hygiene and a small library. Shown on the right, the laboratory inflatable includes the biotron and several contemplation areas.
Figure 3.8.1-6. The left side of this axonometric shows the many variations in the crew quarters including single and double crew quarters and a possible larger single crew quarters for the mission commander. The right side shows the interaction between the contemplation areas and the biotron.
Fig. 3.8.1-7. Initial Operating Configuration Level 5 at the base of the luna-tube.
Being almost totally isolated allows the crew to not only leave work mentally but physically as well. It is important to be able to get away and to go "home."

On the other side of the Shuttle-C modules is the laboratory inflatable. Here most of the scientific work will be done. This appendage faces into the lava tube thus allowing views to the lit interior.

Below this three modules are hung from the space frame. Medical and mission operations make up one 4.5 meter by 13.6 meter modules. An identical module holds suit stowage and maintenance. Attached to that is a 4.5 meter by 7 meter module containing the EVA chamber (see Figure 3.8.1-6).

Equipment, vehicles, and experiments will be stored inside of the lava tube. This will protect them from the harmful radiation and the irritation dustiness of regolith.

3.8.2 ENTRY AND LOGISTICS FACILITY

Because it is essential to have dual egress, there will be two entries located in the base. The main EVA chamber is situated on the surface of the moon, acting as the front door. Most of the activities will be occurring on the surface of the moon thus the need to have an entrance on top. The secondary entrance, or back door, is located in the lava tube. Because a lot of the outside equipment will be stored inside the lava tube it is important that it be easily and efficiently reached.

Both of the EVA chambers will be in modules 4.5 meters by 8 meters. They will contain an airlock, suit stowage (two suits), and a maintenance facility. The top module is covered with regolith for protection against the harsh lack of environment of the moon.

The logistics facilities are modules 4.5 meters by 13.6 meters and are located on the surface of the moon. They flank either side of the EVA module and are attached to a connection node. Regolith also covers the module for protection but allows them to be removed (i.e. one side is open). These facilities are temporary in that when emptied they will return to earth and be replaced by new ones (see Figure 3.8.1-1 on p. 31). The modules are sent with modular rack full of new supplies and equipment and are returned with the racks that aren't needed.

3.8.3 STOWAGE

Most of the stowage is located in the Shuttle-C module which also acts as the translation between the modules at the top of the base and the inflatables below, in the lava tube. Surrounding the vertical translation core are modular racks meant solely for stowage. It acts as a weigh station between the logistic modules and the habitat elements.

3.8.4 CREW SUPPORT FACILITY

The Crew Support Facility, on the lower floor of the Habitat Inflatable (level 4), is where the crew will be spending most of their time. This is the crew's home, containing all the personal areas for day to day life. The inflatable contains both public and private areas and will service all needs of the crew.

3.8.4.1 Galley

The galley is what we refer to as the kitchen here on Earth. It is designed to be a facility for food preparation for the entire crew of 11. Included in the area are cooking and eating utensil stowage, food stowage, refrigeration units, cleaning facilities, and cooking facilities. Both convection ovens and microwave ovens will be used as well as a standard range top type cooking surface.

As in all other areas, the equipment and stowage in the galley area will use standard sized racks. Some of the racks, such as those containing sinks, refrigeration, or ovens will be more specialized than most standard racks, but will use the same overall dimensions and mechanical line inputs.
As an aid in preparing food, a movable working surface is included in the design. The surface is attached to a swinging, extending arm which allows the work area to be placed in a wide range of areas throughout the galley area. This feature will come in handy when cooking is being done for the entire crew at once, since a large amount of counter space will be required.

3.8.4.2 Wardroom and Dining

The wardroom/dining area is adjacent to the galley. The wardroom normally functions as a dining area for the crew, but is also a place to gather the entire group for meetings, communications with the Earth, and any other event requiring a large number of people to gather.

The seating in the wardroom is provided around three movable tables. The tables, which are round, will normally be in a triangular configuration, but can be rearranged to any suitable placement. In the event of a large group meeting, a triangular shaped working surface can be lowered from the ceiling to cover all three of the tables, making it one large table.

Three viewing screens are arranged such that any of the crew members can see at least one of the screens no matter where they are sitting. The screens will be used for conferences, casual viewing of television, and will be tied into the base informational systems.

3.8.4.3 Group Recreation

The group recreation area, located in a few areas on the first floor of the habitat, is dedicated to the well being of the crew. Group recreation is divided into three separate entities: the hobby room, the game room, and the audio/visual room.

The hobby room is a space dedicated to activities the crew may pursue for relaxation. This could include any number of activities, including but not limited to: model building, plant growth, puzzles, and drawing. With the variation of activities which will be taking place in this space, it will need to be flexible. Included in the space is a large amount of stowage, work surfaces, and a large video screen.

The game room is another recreation area for the relaxation of the crew. The space is designed to accommodate up to seven crew members in any game like activity. This could include board games, dice games, cards, etc. The space is flexible in design and can easily be reconfigured to accommodate other activities.

The audio/visual entertainment room is a place for the crew to gather and either watch television or listen to music. Comfortable, easily movable
seating is provided for the crew to gather around the large video screen included in the area. The space is open to many of the other recreational spaces included on the floor so crew members can communicate between the spaces.

3.8.4.4 Exercise Facility

The exercise facility is an important space in the habitat. Because of the lessened gravity, their will be a degradation of the crew members’ bodies over time. Not only will their muscles weaken in the lessened gravity, causing cardiovascular problems, but calcium will also leach from their systems, causing problems upon returning to Earth. By providing an exercise area, many of the health problems the crew may experience could be avoided. The exercise area includes exercise bikes, treadmills, a resistance machine, a rower, a stair climber, and a punching bag. All of the exercise equipment will be run through a computer management system. This system will connect to monitors or virtual reality units which allow the user to view stimulating scenes while they exercise. The system will also monitor the users vital signs which will be accessible from the medical center in the base.

3.8.5 CREW QUARTERS

The upper floor of the habitation inflatable (level 3) is a more private area dedicated to personal activities. The floor contains the 11 crew quarters, a multi-unit personal hygiene facility, a laundry facility, and a library. Access to the second floor is gained by bounding platforms located in the middle of the first floor. The opening in the upper floor not only allows passage on the platforms, but allows a view from floor to floor.

3.8.5.1 Personal Crew Quarters

The crew will spend more time in their quarters than any other single area in the base. This will be not only a place to sleep, but a place of retreat. Being confined to the base as they are, they will often desire to get away from others and have time to themselves. The crew quarters will need to accommodate functions such as studying and personal recreation as well as changing and sleeping.

The crew quarters, like all other areas, are designed with flexibility in mind. Part of the function of the crew quarters is to be an experimental testbed. Both double rooms and single rooms are included to test how the crew reacts to the different arrangements. If an arrangement is found unsuitable,
the walls and interior elements are modular and can easily take on a
different form. The double rooms also allow married couples to stay
together in the base.

Included in the crew quarters are a bed, a desk, stowage, and entertain-
ment items. The beds in the crew quarters are often arranged so the bed of
one quarter is placed over a bed of another quarter, with each bed being
accessed from only its respective quarter. This arrangement saves space,
allowing the crew more floor area in each quarter. Stowage for clothing and
other accessories is provided in modular racks. The desk unit is also a
modular unit which can be used for any number of personal activities. The
room will include a small portable computer unit which can be used for
games, telecommunications, and will double function as a television which
can be placed anywhere in the room. Also included in each room is a
window which will look out into the lava tube. The windows will help
provide a place for the crew to contemplate and relax.

3.8.5.2 Personal Hygiene Facility

The base includes a number of personal hygiene facilities located on
almost every floor. The main hygiene facility is located on the upper floor
of the habitat inflatable. This location will service the crew mainly in the
morning and the evening when the crew is showering and cleaning. The
facility is split into four sections, three hygiene facilities, and a laundry
facility.

The hygiene area is designed to provide showering, washing, and toilet
facilities for the entire crew. The three hygiene facilities include two
showers, two toilets, and three sinks. The first unit in the facility contains
a shower unit and a sink. The other two units share one shower unit, and
each contains a sink and toilet. The shower unit is designed to be entered
from either of the two units, with a sliding door closing the shower off from
the other unit so privacy is assured.

3.8.5.3 Laundry Facility

The laundry facility, included in the personal hygiene area on the
upper floor of the habitat inflatable, will serve all of the crew member’s
cloths washing needs. The area includes two washers and two dryers. A
small amount of stowage is also included for keeping of washing supplies.
Small working platforms pull out of the washer dryer racks to provide a
surface for folding cloths and other needs.
3.8.5.4 Library

The library area is located on the upper floor of the habitation inflatable and can be seen from the first floor through the vertical circulation opening in the floor. The area is meant to be a retreat for the crew, and includes book racks, aquariums, and comfortable, couch-like furniture. The library also includes two windows which look out towards the opening in the lava tube. This will make the library a pleasant place to go for relaxing and contemplating.

3.8.6 RESEARCH LABORATORIES

The research laboratories are located on the first floor of the laboratory inflatable (level 4). The space is designed to allow as much openness as possible. As one would enter the facility, a window would be seen as a focal point between the bounding platforms terminating the central translation path. The space opens up in the center allowing for a meeting place where daily activities can be discussed. Running along the perimeter of the inflatable, the laboratories are located (see Figure 3.8.1-2).

There are six specific scientific functions that occur here: microbiology, biochemistry, experimental mining and construction, astronomy, environmental-behavior monitoring of the crew and habitat, and experimental waste recycling. In addition to these functions there is a general laboratory, a small cafe, and a half hygiene facility located on this floor (see Figure 3.8.1-2).

The aforementioned functions each have their own private work area. Here all the special equipment needed for each function is stored. All the shared equipment and most of the work space is located in the general laboratory. The specialized areas contain full sized and half sized modular racks. This is to allow as much space to be open as possible. Psychologically, the crew will be able to see and here each other most of the time. The areas can be isolated by pulling an accordion like curtain around the space. The cafe, being situated in the center, is designed to be a place where the crew can congregate comfortably during breaks without having to track all the way to the habitation inflatable in order to get a snack. The window that is located between the bounding platforms has a view into the lava tube. Here activities (experiments and maintenance) can be monitored. Since the lava tube will be illuminated the view should actually be quite stimulating (see Figure 3.8.6-3).

Figure 3.8.5.4-1. A view of the library area, which will be a place of contemplation for the crew.

Figure 3.8.6-1. A view of the general labs shows the openness created by the half racks, the window terminating the main translation path through the laboratory inflatable.
3.8.7 BIOTRON

The biotron is located on the second floor of the laboratory inflatable. It is a plant growth experimentation facility. There will be expandable and contractible high density plant growing racks and a plant experimentation laboratory. Wheat, lettuce, carrots, soybeans, tomatoes, and cucumbers are just some of the plants that will be grown. Although most of the food consumed will be brought from earth, this experimental "garden" will supplement it. This facility is not only designed to experiment with biotrons but it is also meant to be a place where the crew can go to relieve stress.

The psychological benefits from the laboratory are plenty. For example, the crew has the opportunity to care for living organisms not unlike that of taking care of one's family. They also have the chance to cook with their own "home" grown food.

3.8.8 QUIET/CONTEMPLATION AREAS

Also located on the second floor of the laboratory inflatable is an area dedicated to reviving the inner self-a contemplation area. Being in close proximity to the pleasant scent of growing plants will stimulate the olfactory senses while the sight is activated and soothed by the architectural elements in this area (see Figure 3.8.1-5).

The contemplation area is divided into three distinctly different spaces: the reading room, the biotron conservatory, and the chapel. Each space is large enough for just a few people in order to keep it as intimate as possible. As one bounds up from the work area below, plant life is immediately seen. To the left is the reading room. Here "real" books and couches are available in order to just get away and relax. Terminating the space is a window surrounded by colorful stained glass for viewing into the lava tube (see Figure 3.8.8-1).

To the right is the biotron conservatory. This space designed to be in the center, is formed by a trellis with vines winding around it. The seating curves around the periphery making the space circular. In the center is a reflecting pond holding experimental fish and plant life. One must walk through the space to reach the chapel (see Figure 3.8.8-2).

The chapel is a place that one can go to practice his/her belief in a private and personal setting. Since the crew will be an international one, there will be many religions practiced. In order not to favor any one faith the chapel is decorated only symbolically with plants, an alter, and stained glass. Again, there is only room for a few crew members as to keep the space as private as possible (see Figure 3.8.8-3).
3.8.9 MISSION CONTROL AND SPECIALIZED FACILITIES

This portion of *Genesis II* will oversee the base operations, surveillance all base functions, both internal and surface, and will allow the monitoring of the crew and their life support systems.

3.8.9.1 Mission Control

Mission and base operations will be housed within the lava tube. Additional communications stations will be located within the base. The purpose of the major workstations will be to monitor inter- and intra- base activities, any telerobotic activity on the lunar surface, the mining facility, power stations and launch facility (see Figure 3.8.9.1-1). The workstation itself is designed to fit within the modular system. The anthropometrics of the human body in 1/6th gravity has been considered in the placement of the monitor screens and controls. Additionally, the chair used at the workstation will address the altered body position (see Figure 3.8.9.1-2). It has been determined that three major workstations will suffice in overseeing the base functioning, and the supporting communications stations will provide any backup system necessary.
3.8.9.2 Health Maintenance Facility

This area of the base will provide health care and emergency medical aid. The core of this facility is the patient restraint table and supporting diagnostic equipment (see Figure 3.8.9.2-1). The table is especially designed to provide a wide range of movement, not only for the equipment but for the physician or medical personnel. All instrumentation is clearly visible, and accessibility to the necessary supplies is easy (see Figure 3.8.9.2-2). The equipment placed into the medical facility follows guidelines set by NASA and the proposed Space Station Freedom health maintenance facility (HMF) NASA-JSC Medical Sciences Space Station Working Group and the University of Houston College of Architecture/SICSA (SICSA, 1989).

3.8.9.3 Maintenance Work Area, Suit Stowage, and EVA Chamber

An entire common module has been dedicated to the stowage and maintaining of the pressure suits. Eight of the suits will be housed in this module along with six workstations. These six, in banks of three each, will allow the astronauts to lay out an entire suit for maintenance (see Figure 3.8.9.3-1). This module is adjacent to the EVA chamber and additional suits will be located there as well. The maintenance module is placed beneath
the main translation path in the event of an emergency. For the day to day activities, the health maintenance facility and mission operations will not be in the way of traffic.

3.8.10 CONSTRUCTION TECHNOLOGY

The design of this lunar base includes many technical details. Although the architectural considerations of the base were concentrated on, some thought was given to the technical issues. These include: the space frame, the inflatables, hatches and connectors, and radiation shielding.

3.8.10.1 Space Frame

The space frame is a major element in the construction of the base. The frame is made of aluminum tubing, much like that of the proposed Space Station Freedom. It forms a platform measuring 13 meters wide, and 29 meters long. Basically, the space frame holds all of the bases structural elements in place, acting as a carrying system. It is needed due to the expected unevenness of the interior of the lava tube. The SSF modules can simply be hung from the frame, and the inflatables will have a flat, sturdy platform on which to rest.

The vertical trusses of the frame will use the tubing to form a square column, which is one meter square, and approximately six meters tall. The columns will include diagonal bracing and will rest on an adjustable footing. The horizontal elements of the frame are triangular trusses, measuring one meter across a side. These trusses also use triangulation in their construction.

Construction of the space frame is a relatively simple process. All of the trusses will be transported to the lunar surface preassembled. The entire space frame is comprised of three different sized trusses. These pieces will be lowered down through the opening created in the roof of the lava tube. The pieces will then easily connect together, forming a sturdy platform on which to build the base.

Figure 3.8.10.1-1. The space frame under construction.

Figure 3.8.10.2-1. A wall section through the inflatable, including sections through both floor levels, and through a window in the wall.
3.8.10.2 Inflatable Construction

The habitation and laboratory modules in the base are constructed using inflatables. The structures are comprised of two membranes, one inside the other, which are based on the material Kevlar. Structural foam is inflated into the space between the two membranes, raising the structure to its final shape, and rigidizing to a hard form.

The internal framing of the inflatables uses lightweight trusses and panels. The base of the inflatable is formed by a rigid aluminum plate which folds for transport to the lunar surface. The base will then have an interior floor system which is raised up to allow space under floor for systems distribution.

The second floor system includes aluminum trusses which lie on the grid system with a depth of approximately 30 centimeters. These are supported by columns which fit on the grid system. The floor is then covered by 1.2 meter square panels which are made of a lightweight honeycomb material.

3.8.10.3 Hatch/Connector Designs

The hatches which connect all of the elements in the base are much like those proposed for Space Station Freedom. Their will be two basic hatch designs for the base, one for vertical translation, which has an opening of 1.25 meters square, and one for horizontal translation, which has an opening of 1.25 meters by 2 meters.

The connector is a collar, 2.5 meters in diameter, on the end of a SSF module, or attached to an inflatable. The collar includes alignment guides for attaching two connectors, securing devices which lock two connectors together, and a number of pass-throughs for the mechanical systems.

3.8.10.4 Radiation Shielding

The majority of the base will not need shielding for radiation or micrometeoroids since it lies under the lunar surface. The elements which are on the surface, however, will need this protection. To provide the needed protection, a space frame based system was used to hold regolith.

A space frame, 50 centimeters in depth, is used to form a frame with the shape of a half octagon. The interior of this frame is covered with aluminum panels. The outer portion of the frame is covered with Kevlar 149. Regolith is then dumped into the space in between these layers.

This protection not only stops radiation and micrometeoroids, but also has other benefits. Since it is the logistics modules which are on the surface, they will need to be removed and replaced. Using this system the replacement of logistics modules is very easy. Another benefit is that access to the modules is still possible since there is a large standoff between the protective structure and the modules.

3.8.11 FURNITURE AND EQUIPMENT

The furniture throughout the habitat is designed to fit the body in 1/6th gravity. It will be adjustable in order to accommodate the 5% female to the 95% male. It also will be able to be easily moved and stored. All of the furniture has rounded corners for safety reasons (see Figure 3.8.11-1 as well as Figures 3.8.4.2-1 on p. 39, 3.8.4.3-1 on p. 40, and 3.8.9.1-2 on p. 44).

3.8.12 LIGHTING

The lighting throughout the base will incorporate as much natural lighting as possible. By using fiber optics and piping it into the habitat both inside and out. Artificial lighting will supplement the natural and be used in emergencies.

The fixtures used are: ceiling application (45/45/90 degrees), corner application, track, and adjustable workstation task lighting. All will be easily adjusted and assembled (see Figure 3.8.12-1).
easily adjusted and assembled (see Figure 3.8.12-1).

3.8.13 SUMMARY OF INITIAL OPERATION CONFIGURATION

There are four main elements incorporated into **Genesis II**: safety, habitability/human factors/environment-behavior considerations, using advanced near term technology, and replaceability/modularity. By using these criteria, **Genesis II** won't just be a place for experimenting but a place where the astronauts can live comfortably.

3.9 EXPANSION

Future expansion of the base can be accomplished in a multitude of ways. Adding more inflatables width wise is an option to consider. However this would cut down on the space allowed for circulation. It can also grow into the lava tube extending deeper inside with another topside entrance. Here the lava tube is utilized while at the same time allowing enough room to circulate large equipment. Expansion could also be located on lunar surface however it would then have to be covered with regolith for protection thus creating more construction time being exposed to the moon's hostile environment (see Figure 3.9-1).