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Special Design Project Issue

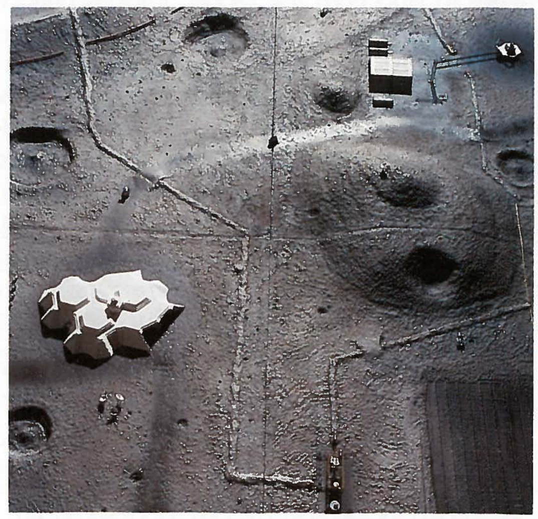
SICSA OUTREACH

Sasakawa International Center for Space Architecture

Project LEAP

SICSA pursues research and design studies for permanent lunar settlements. One such study, ***Project LEAP* (Lunar Ecosystem and Architectural Prototype)** produced staged growth concepts for a manned base to support lunar mining and industrial processing operations. The project was undertaken in cooperation with the ***Advanced Programs Office*** and ***Solar System Exploration Division*** at the ***NASA-Johnson Space Center.***

The primary purpose assumed for this lunar development is to produce oxygen for rocket propellant and for Space Station/lunar base consumption. The plan provides for growth from an initial six-person crew occupancy to an advanced facility for thirty occupants. The physical plant is scaled to house more than one hundred people if necessary. Evolutionary growth stages are planned to utilize lunar materials as fully as possible, with self-sufficiency as a goal.



Lunar Base Model - Photo By Jim Olive

Initiated in Fall, 1985, Project LEAP involved faculty and students in the College's ***Experimental Architecture*** graduate program. Technical and financial support were provided by the NASA-Johnson Space Center Advanced Programs Office. The project's main pupose was to create a reference lunar base development and staging plan to support follow-on research and design studies by SICSA and other organizations. The project identified requirements and recommended concepts for peer review and evaluation.

Project LEAP Study Objectives

- Identify evolutionary site development and facility requirements.
- Identify candidate site development and construction options.
- Propose site layout and habitat design/growth concepts.
- Survey requirements to achieve a high level of self-sufficiency.

A Publication of the University of Houston's College of Architecture

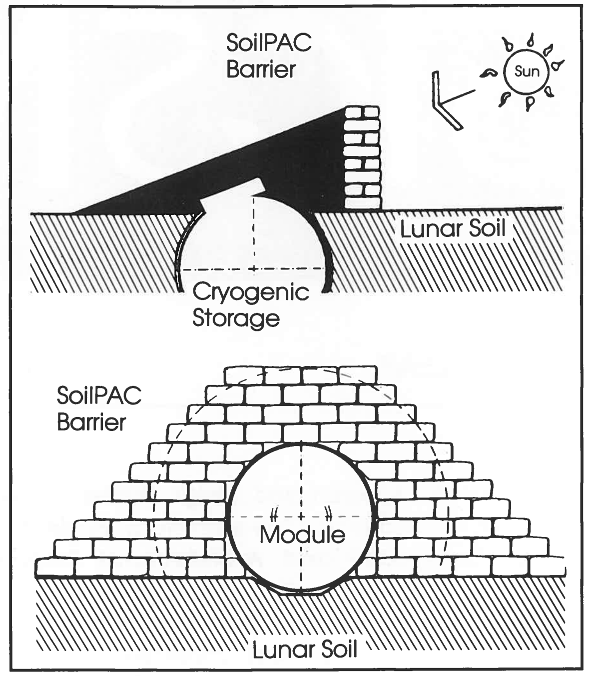
Key Objectives and Issues

The ***National Commission on Space,*** appointed by President Reagan, proposed that a permanent settlement be established on the Moon by the year 2005 and a manned mission to Mars be undertaken by 2015. Accordingly, Project LEAP was conceived with both goals in mind. The development can provide consumable resources to be used in support of International Space Station and orbital transfer vehicle operations. It can also serve as a scientific research station and staging base for manned missions to Mars, its satellite Phobos, and other planetary bodies.

The high costs of transporting equipment, people and supplies to and from the Moon impose critical planning requirements and limitations:

- The size and weight of all systems and components must be compatible with launch vehicle constraints. The availability of heavy lift launch vehicles (HLLVs) is assumed.
- A high level of self-sufficiency which optimizes use of lunar materials should be realized at the earliest possible development stage.
- The mature development should support mining and material processing operations of sufficient throughput to offer cost/value-effective yields.
- Health and safety measures must be provided to extend crew duty cycles to practical limits and minimize personnel rotation transport costs.

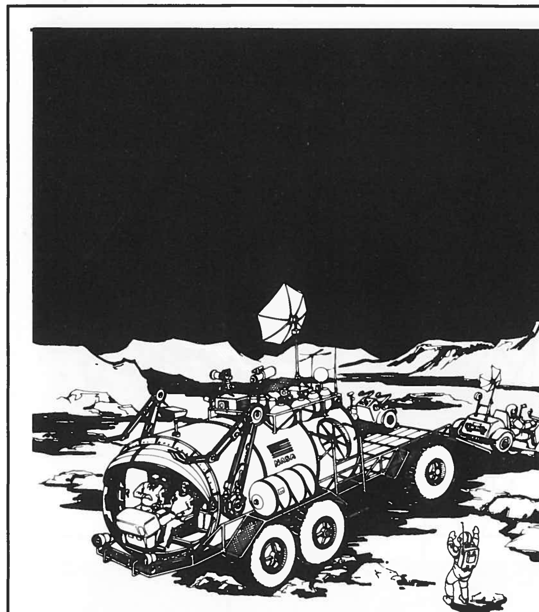
The Moon has no radiation-absorbing atmosphere nor magnetic field to deflect radiation transport of cosmic ray nuclei. Therefore, means are required to minimize crew exposure to radiation hazards, particularly during periods of extravehicular activity (EVA). The maximum permissible annual radiation dose set for occupational radiation workers is 5 rem. A typical upper meter of lunar surface receives an annual radiation dose equivalent to 30 rem during times of solar minimum, and as much as 1,000 rem during periods of high solar activity which occur approximately every 11 years. Accordingly, EVA time is estimated to be limited to approximately 10 hours per 24 hour interval during two-week-long lunar days of solar minimum activity. Protective shielding may be required over the habitats to avoid radiation hazards during intravehicular activity (IVA) periods.



SoilPAC Shielding Concept

A ***Soil Particle Acquisition and Containment (SoilPAC)*** concept is proposed for radiation, micrometeorite and thermal shielding:

- Lunar soil (regolith) is collected in bags and stacked over habitats and storage tanks to form a protective barrier.
- The SoilPAC bags control the fine lunar dust which will otherwise disperse as an abrasive contaminant if piled up in an uncontained manner.
- Approximately 3.5 meters of densely packed soil (700 grams/cm^2) will limit annual radiation exposure to an estimated 5 rem during solar maximum.
- The soil barrier will protect pressurized vessels from penetrations by high velocity micrometeorites.
- The soil barrier will insulate covered areas from surface temperature extremes which can range from $+200^{\circ}$ F to -200° F.



Geologic Traverse Vehicle - Drawing by Li Hua

Surface Exploration Phase

Surface exploration of the lunar terrain commences with the arrival of manned mobile explorer vehicles equipped to support scientific excursions. One approach uses a ***Geologic Traverse Vehicle (GTV)*** with a crew of up to six people, which tows or stows two rover vehicles. The GTV has a short range excursion capability. The rovers could extend the range by 50 kilometers or more between rechargings or refuelings. GTV capablities include:

- Consumable supplies, temporary shelters, and communication systems for short and extended excursions.
- Spare pressure suits, critical parts and servicing tools to respond to malfunctions and emergencies.
- Scientific equipment for collecting, analyzing and transmitting data from soil samples and process experiments.

Site Selection Considerations

Availability of abundant and accessible lunar resources is essential to project feasibility. Apollo mission surveys indicate that lunar regolith contains as much as 40 percent oxygen in some locations. Lunar maria sites are known to also contain large quantities of silicon, aluminum, iron, titanium, magnesium and other materials for potential base construction and orbital applications.

Capabilities to collect and process these resources in a cost and labor-efficient manner are also of great importance to reduce dependence upon Earth-supplied consumables and construction materials.

A location on the far side of the Moon presents radio interference-free access to the solar system for astronomy and other scientific purposes.

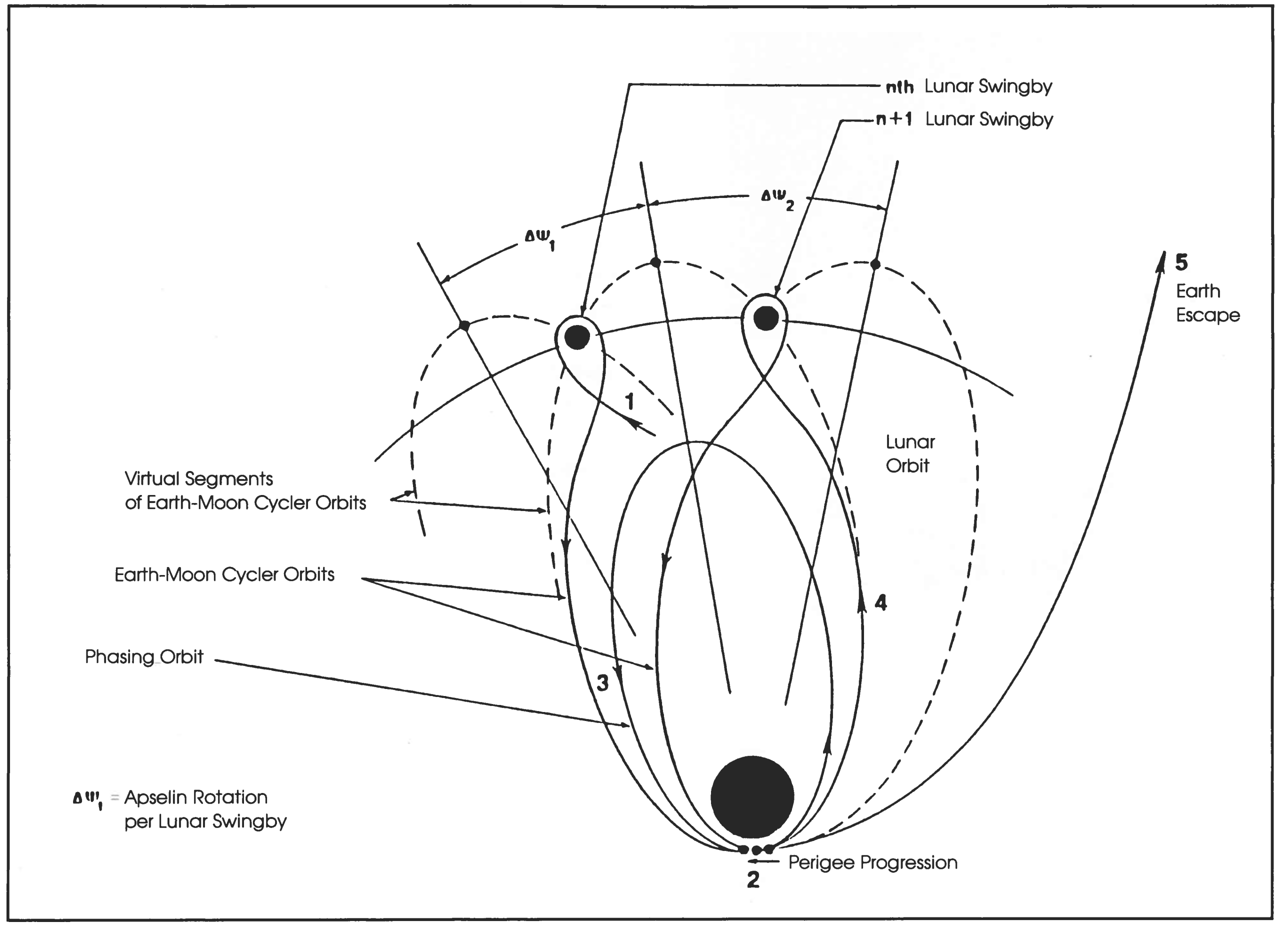
Lunar base site selection must take operational considerations as well as resources into account. Equatorial locations at 33° E longitude offer optimal placement of mass drivers to launch to Lagrangian Point 2 with minimum dispersion. However, the two-week-long diurnal cycles will require large solar energy storage provisions and/or continuous energy generation.

An equatorial base on the near side offers direct line-of-site with Earth for ease of communication and psychological benefits to inhabitants. Little information about resources and terrain features is available to support planning for a lunar far side facility, and a special communication network would be required.

Survey Missions

The first step in selecting the lunar base site will utilize unmanned polar geomapper satellites to survey candidate locations based upon detectable lunar resources and topological features. This will be followed by one or more manned expeditions to conduct more extensive observations and tests.

The manned surface explorations will be essential for detailed comparative assessments of site alternatives, considering potential material yields and specific facility development implications.



Earth-Moon Cycler Staging

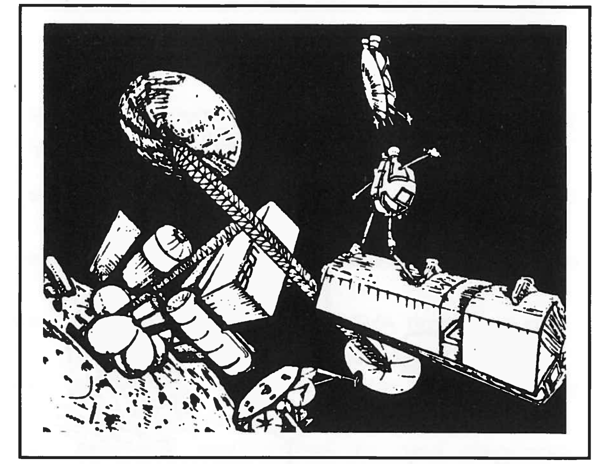
Equipment, supplies and personnel for advanced stages of site development and operations can be transferred between low-Earth orbit and low-lunar orbit by means of an **Earth-Moon Cycler** staging strategy, conceived by the ***Science Applications International Corporation (SAIC).***

In this approach, the spacecraft uses a close flyby at the Moon (Point 1) to alter its line of flight to enable any payloads bound for the Moon to be placed in low-lunar orbit, or any payloads bound for Earth to join the Cycler. By incorporating two or more Cycler vehicles in Earth-Moon space at equal intervals, opportunities to move back and forth occur frequently enough to support a high volume of lunar material and equipment transfer.

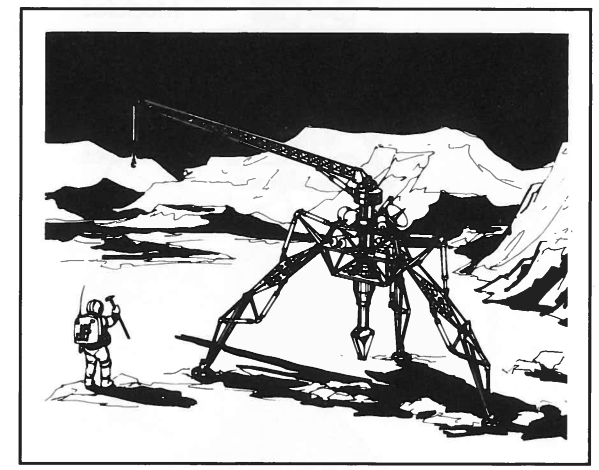
Orbital Transfer Cycler Approach

Continuously cycling orbital transfer vehicles (OTVs) move payloads between low-Earth orbit and low-lunar orbit:

- A small velocity change at Earth flyby places the spacecraft in a phasing orbit (Point 3) until the Moon is positioned for the next flyby.
- A small velocity change at perigee (Point 2) re-targets the spacecraft for the next lunar encounter (Point 4).
- A more significant velocity change at perigee enables Earthbound payloads to be placed in low-Earth orbit for eventual Space Station rendezvous.



Lunar Orbiting Space Station Concept



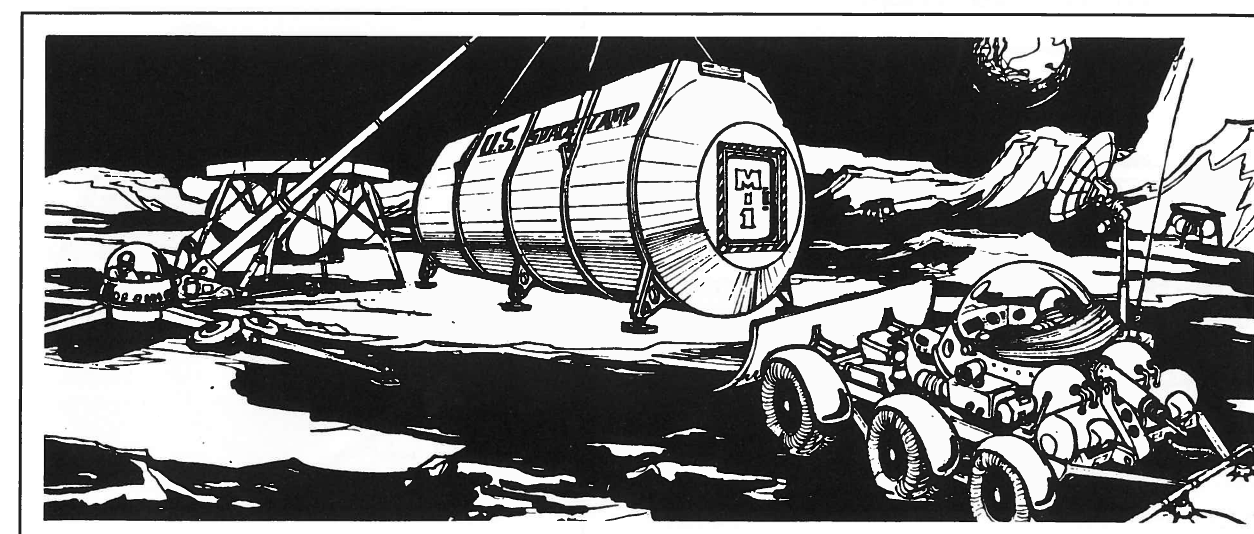
Georgia Tech. *SKITTER* Concept

Construction Camp Development

At the onset of initial construction camp establishment, facilities, personnel, power systems, and surface transportation/preparation equipment are launched to low-Earth orbit, then transferred by OTV to a ***Lunar Orbiting Space Station (LOSS)*** in lunar orbit. Two crew members remain with the LOSS to monitor operations, while the other four are delivered, along with the equipment payload, to the Moon's surface via a reusable landing vehicle. Important payload items include:

- Automated equipment for excavation/grading, soil bagging and placement, surface fusing and module/cargo transfer.
- Pressurized living and work modules.
- Nuclear and solar powered electrical generators.

The crew sets up residence using preexisting exploration base camp facilities and equipment. The power systems are put in place and site preparation begins. The modules are then offloaded from the landing vehicle, positioned in place, leveled, and connected together. After life support and other essential systems are checked out, SoilPAC shielding bags are placed over the modules. A ***Spatial Kinematic Inertial Translatory Tri-ped Extension Robot (SKITTER)*** concept developed by the George W. Woodruff School of Mechanical Engineering at the ***Georgia Institute of Technology*** might be utilized for this.



Construction Camp Concept

Site Preparation Procedures

Site preparation for the main lunar base involves extensive grading and surface treatment operations.

Approximately five hundred square feet of area is excavated to an average depth of about two-thirds of a meter. The surface is then hardened by melting the regolith to a thickness of approximately one decimeter using a microwave sintering process conceived at the ***Los Alamos National Laboratories***. The process fuses silicates in the soil using parabolic reflectors containing magnetron tubes.

After the fused regolith cools, the excavated area is backfilled and leveled. The upper one decimeter is then sintered to provide hard foundations for living and work modules and dust-free roadbeds for equipment.

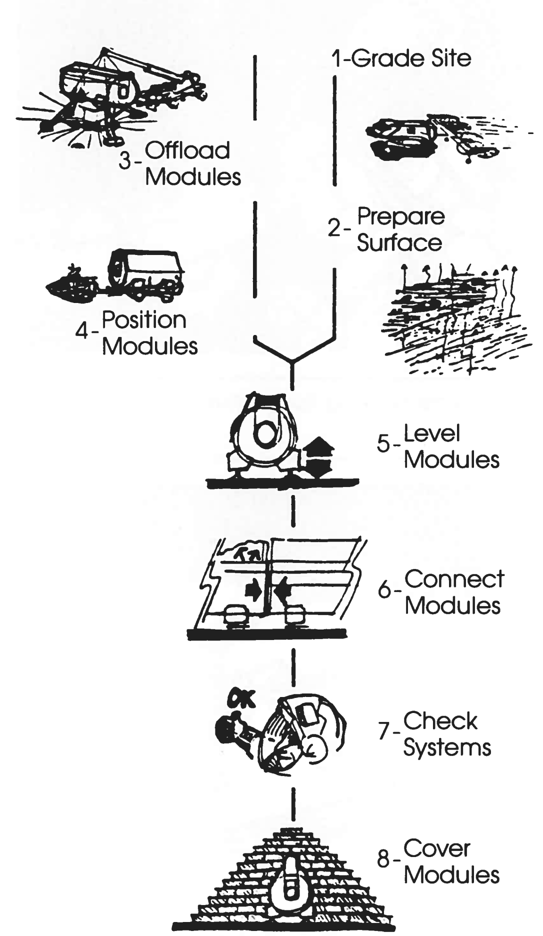
Surface Preparation Steps

Lunar base modules are then offloaded from the landing vehicle and placed in position for leveling, interconnection, and power hookups.

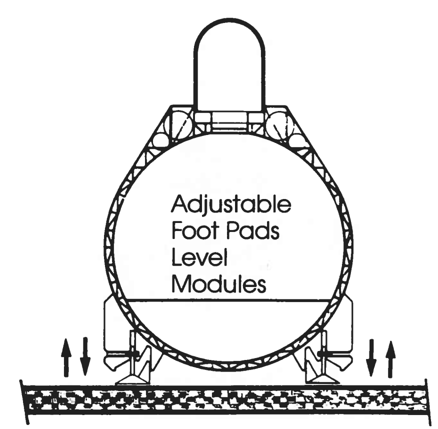
Facility Installation

The modules are leveled using adjustable legs anchored to the sintered foundation with foot pads. After completion of structural and utility connections, primary systems are turned on and monitored for proper operation. Following any necessary adjustments, repairs and final checkouts, the modules are covered with SoilPAC bags to a minimum depth of three meters. These bags can later be removed to enable module reconfiguration with minimal risk of damage to adjacent modules or creation of loose dust. The bags can be sintered by the microwaving process to increase particle density as an additional dust control precaution.

Base Establishment Steps



Module Leveling



Environmental Influences

Reduced gravity and other conditions on the Moon influence lunar base design:

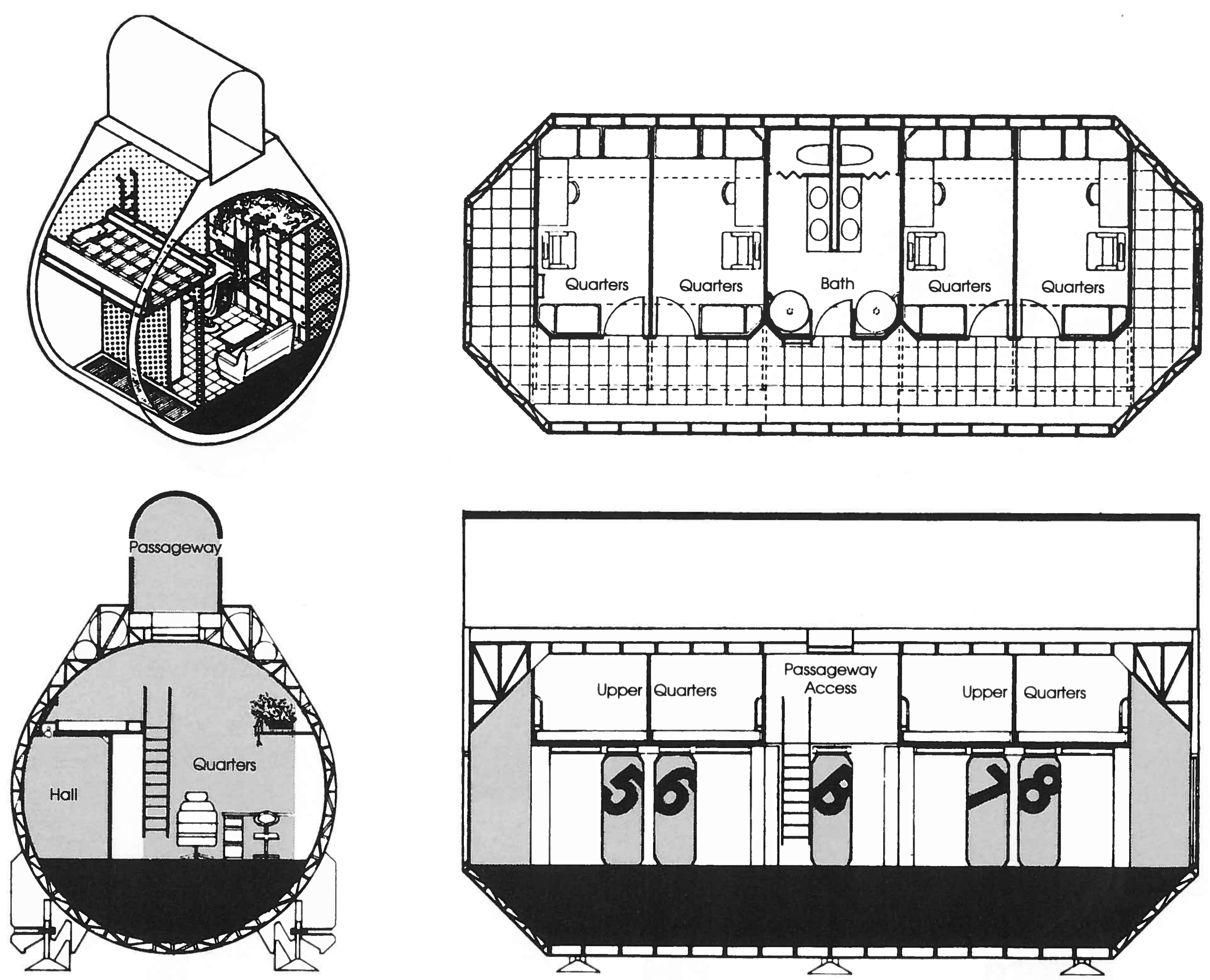
- Gravity-induced structural loads are dramatically reduced.
- People and equipment can easily move items of large mass.
- Radiation hazards limit EVA time and pressure suits reduce physical dexterity.
- Radiation, micrometeorites, and thermal extremes deteriorate exposed materials.
- Abrasive dust clings to and degrades moving mechanical connections.

Modular and Inflatable Elements

Pressurized living and work facilities are conceived to include a combination of aluminum modules and inflatable membrane structures.

The four basic module types are: 50 ft. long, 20 ft. diameter ***Habitat Modules*** and ***Laboratory Modules***; 25 ft. long, 20 ft. diameter ***Airlock Modules***; and 16 ft. wide, 20 ft. high ***Interconnect Nodes***. Pressurized overhead passageways provide secondary circulation and utility spaces.

Inflatable membrane structures offer generous interior volumes to accommodate large scale operations at advanced stages of lunar development. Their size may be as large as 120 ft. in diameter and 60 ft. high.



Habitat Module

Evolutionary Support Capabilities

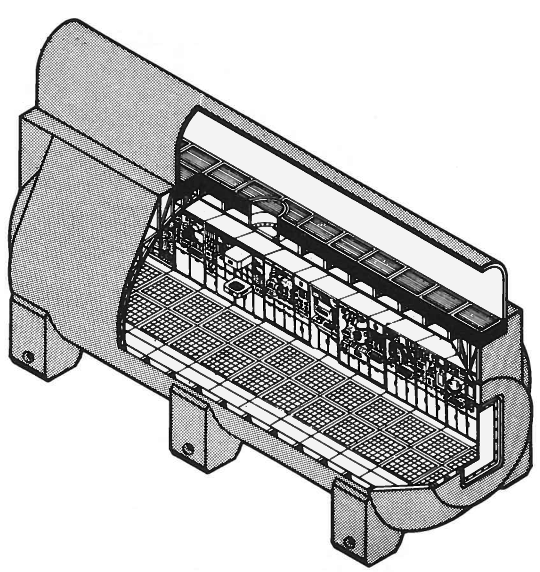
Lunar base growth staging is planned to accommodate increasing evolutionary levels of activity, productivity and operational complexity.

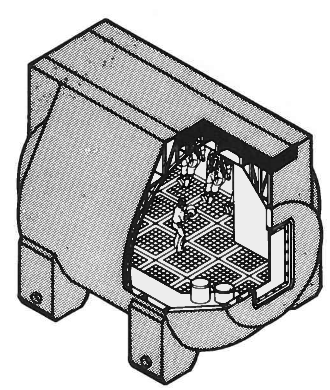
Early development stages are premised on small, launch-efficient modules and very limited crew sizes and specialties. More advanced stages introduce construction and production processes that involve extensive use of lunar materials and automation technology. The large inflatable structure proposed in Stage Six, for example, is envisioned to be a composite membrane produced in the lunar ceramics and glasses production plant.

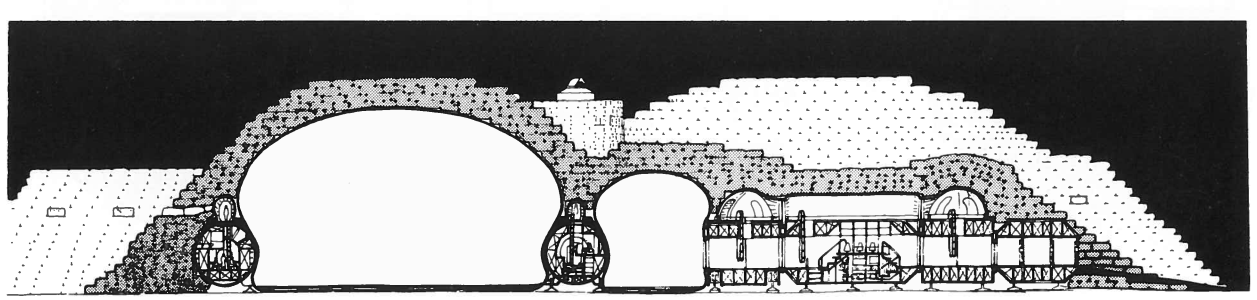
Evolutionary Buildup

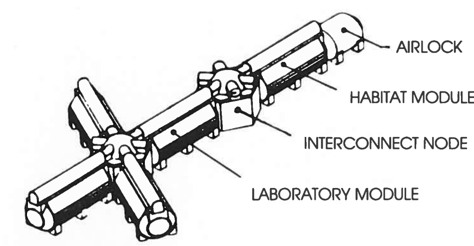
The six growth stages envisioned are :

- ***Stage One*** - initial construction and checkout (6 people).
- ***Stage Two*** - initial extensive research operations (10 people).
- ***Stage Three*** - initial mining and lunar oxygen processing (14 people).
- ***Stage Four*** - ceramics/glasses/metals pilot plant (22 people).
- ***Stage Five*** - ceramics/glasses/metals production plant (26 people).
- ***Stage Six*** - full scale oxygen production operations (30 people).

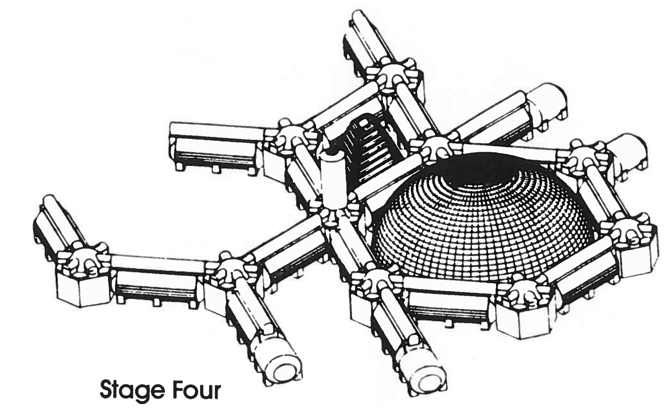

Laboratory Module

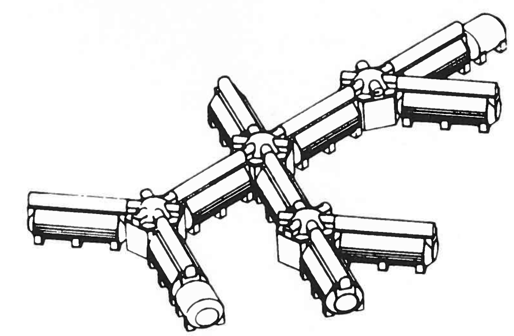

Airlock Module

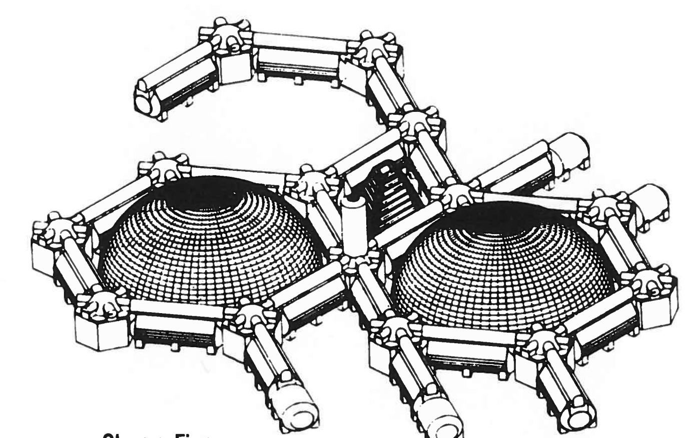

Section Through Site

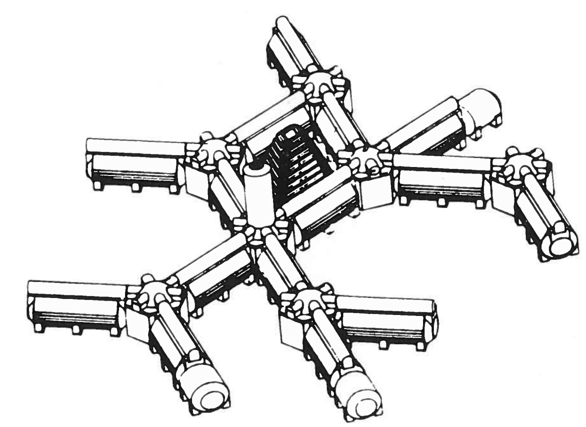


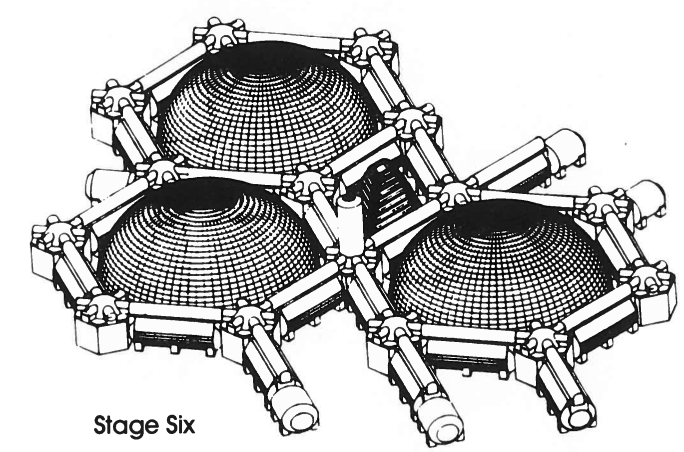
Stage One


Stage Four


Stage Two

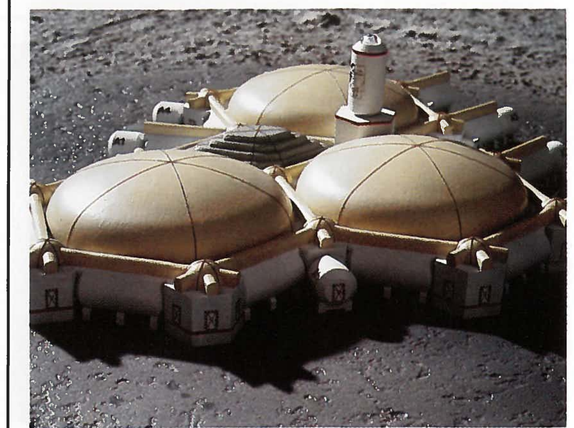

Stage Five


Stage Three

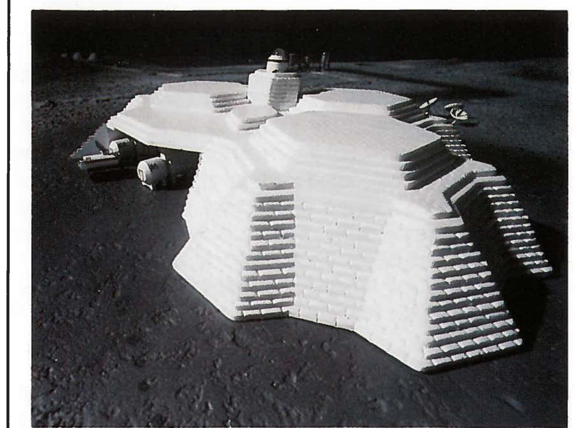

Stage Six

Growth Stages

Lunar Base Site Development - Photo by Jim Olive

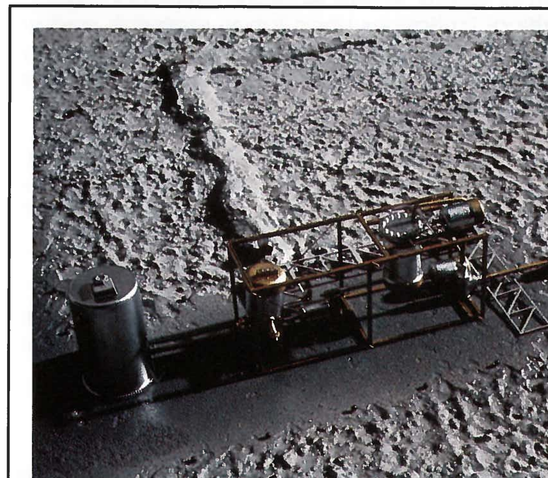


Structures Without Shielding

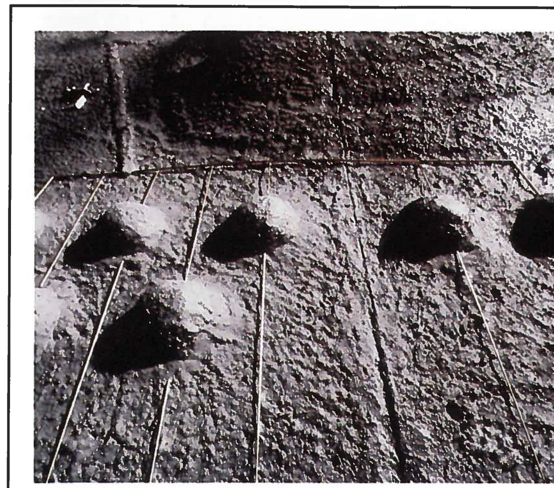


Structures With SoilPAC Shielding

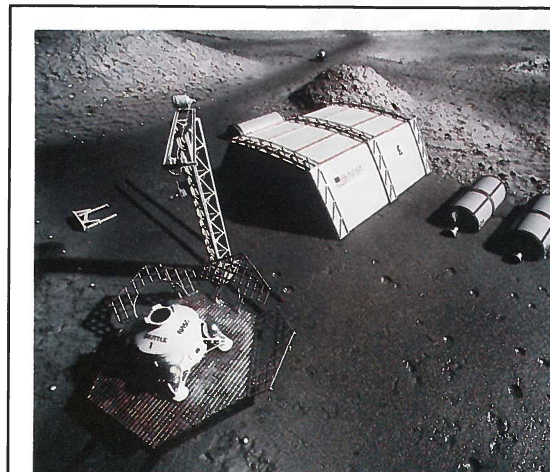
Lunar Surface Mining



Liquid Oxygen Processing Facility



Liquid Oxygen Propellant Storage



Launch and Landing Service Facility

Photos by Jim Olive

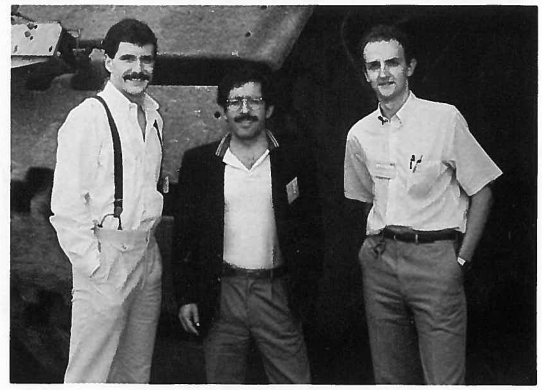
SICSA Background

SICSA is a nonprofit research, design and education entity of the University of Houston College of Architecture. The organization's purpose is to undertake programs which promote international responses to space exploration and development opportunities and needs. Important goals are to advance peaceful and beneficial uses of space and space technology, and to prepare professional designers for challenges posed by these developments. SICSA also explores ways to transfer space technology for Earth applications.

SICSA provides teaching, technical and financial support to the ***Experimental Architecture*** graduate program within the College of Architecture. The program emphasizes research and design studies directed to habitats where severe environmental conditions and/or critical limitations upon labor, materials and capital resources pose special problems. Graduate students pursue studies which lead to a Master of Architecture degree.

SICSA Outreach highlights key space developments and programs involving our organization, our nation, our planet, and our solar system. The publication is provided free of charge as a public service to readers throughout the world.

Inquires about SICSA and Experimental Architecture programs, or articles in this publication, should be sent to Professor Larry Bell, Director.



Project Team:

Jeff Brown, Sam Ximenes, and Francis Winisdoerffer

Project LEAP was undertaken as a graduate research and design study within the UH Experimental Architecture program. The project has been presented at the ***Third annual Conference: Universities Advanced Engineering Program*** cosponsored by NASA/USRA in Washington, D.C., July 16-19, 1987 and will appear at the ***38th Congress of the International Astronautical Federation*** sponsored by the British Interplanetary Society in Brighton, England, October 10-17, 1987.

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