COUNTERPOINT : A LUNAR COLONY

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By John R. Dossey and Guillermo L. Trotti

In the September 1974 issue of *Spaceflight* we opened a discussion of the long-term future of the Moon as a source of raw materials and invited contributions from the astronautical community. In an introductory article Dr. R. C. Parkinson dealt with the problem of setting up a minimal lunar base in which pilot experiments could be made into the refining of lunar materials. The March 1975 issue took the arguments further to include Earth-Moon transport facilities and outlined possible operations for an early Lunar Base. A supporting article "Concrete on the Moon" by Dr. D. J. Sheppard considered the possibility of making structures from lunar materials, laying the foundations for an expanding and self-sufficient lunar colony. The present feature takes the theme further, to consider the development of a Lunar Colony, almost entirely independent of Earth, which would begin to take science and technology into an entirely new dimension. In the process the participants would evolve new social structures based on the principles of mutual interdependence and conservation of resources. The study is all the more remarkable when it is appreciated that the authors, John R. Dossey and Guillermo L. Trotti, 27 and 25 respectively, developed their ideas in the form of an undergraduate thesis in architecture at the University of Houston. 'Counterpoint,' as Dossey and Trotti call their design concept, seeks to illustrate how a group of about 15 people could establish a lunar base in George's Crater near the Appennine Mountains in the north east region of the Moon. The site is close to the place where Apollo 15 astronauts David Scott and James Irwin landed in 1971. It is envisaged that the colony would grow over a 10 year period to accommodate a population of some 200.

Kenneth W. Gatland

Introduction

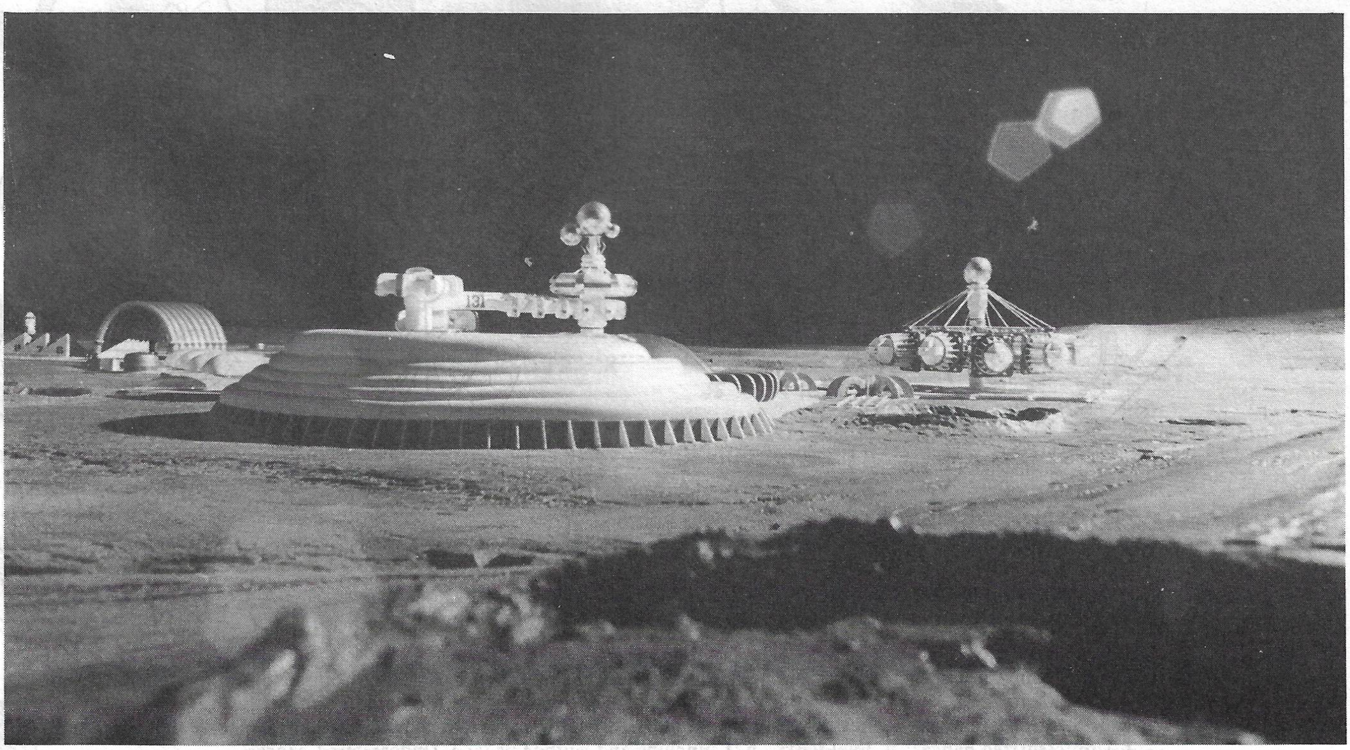
'Counterpoint' is designed to be a fully independent Moon colony for 200 people, sited in the St. George Crater near the landing site for Apollo 15.

Beginning with a skeletal crew of fifteen to twenty, supplied with equipment modules and materials delivered by space shuttle and lunar "tugs," 'Counterpoint' will, over approximately ten years, grow into the self-sufficient lunar base shown. It will have three landing pods for space vehicles; above and below ground hanger and repair areas for space craft; refinery and casting complex; power unit; food production and processing areas including farms for high protein plants and animals; a civic centre for recreational, dining, religious, and administrative activities; living quarters for the permanent population and visitors; and a laboratory-research complex. A 100-in. reflector telescope, one of the primary reasons for constructing the base, will be sited nearby.

The architecture of 'Counterpoint', more than any on Earth, will be a shelter for man, providing protection from an implacable and deadly environment. This architecture must be an expression, first, of the needs of man, and ultimately, of the society which develops there. *'Counterpoint' will not be the "disposable society" of present day Earth. Everything, no matter how small or insignificant, cannot, may not, be discarded.* This heightened concern for the trivial and mundane will carry over into every facet of life on the Moon.

Even while the architecture of the colony is designed to preserve life, it is also undertaken with concern for the natural environment of the Moon. To as great a degree as possible, man's awareness and his technology will be challenged

Ground view of Colony Model.



at 'Counterpoint' to maintain the untouched nature of the lunar surroundings.

Existing in a symbolic relationship with the Earth, initially dependent for supplies, consumables and materials, the colony will provide in return information and perhaps knowledge. *Much research has been directed towards learning about the Moon, but 'Counterpoint' research will be directed, in part, toward learning how to live on the Moon. To this end, research opportunities will not be restricted to the pure sciences, but will include the arts.* While it is conjecture as to what forms drama, music, art and letters may attain, if the arts are expression in sound, words or pictures then "Lunar Art" will be, at the very worst, only different. The possibilities for the emergence of new art forms as a result of the interplay of art and science in this truly remote and isolated locale, are exciting.

Working toward this end and utilizing avenues never before available, the colony will exist at an intense level of awareness; an outgrowth of 'Counterpoint's' separation from Earth, its dependency on Earth, its preciousness as one of a kind, and at least initially, the everpresent possibility of a rapid and irreversible breakdown in life support systems resulting in death. *Man living in 'Counterpoint' must become aware of those technological systems which keep him alive in his totally unique setting, thereby affecting drastically his perceptions of himself as a child of technology, and of his small and remote society.*

Design Constraints

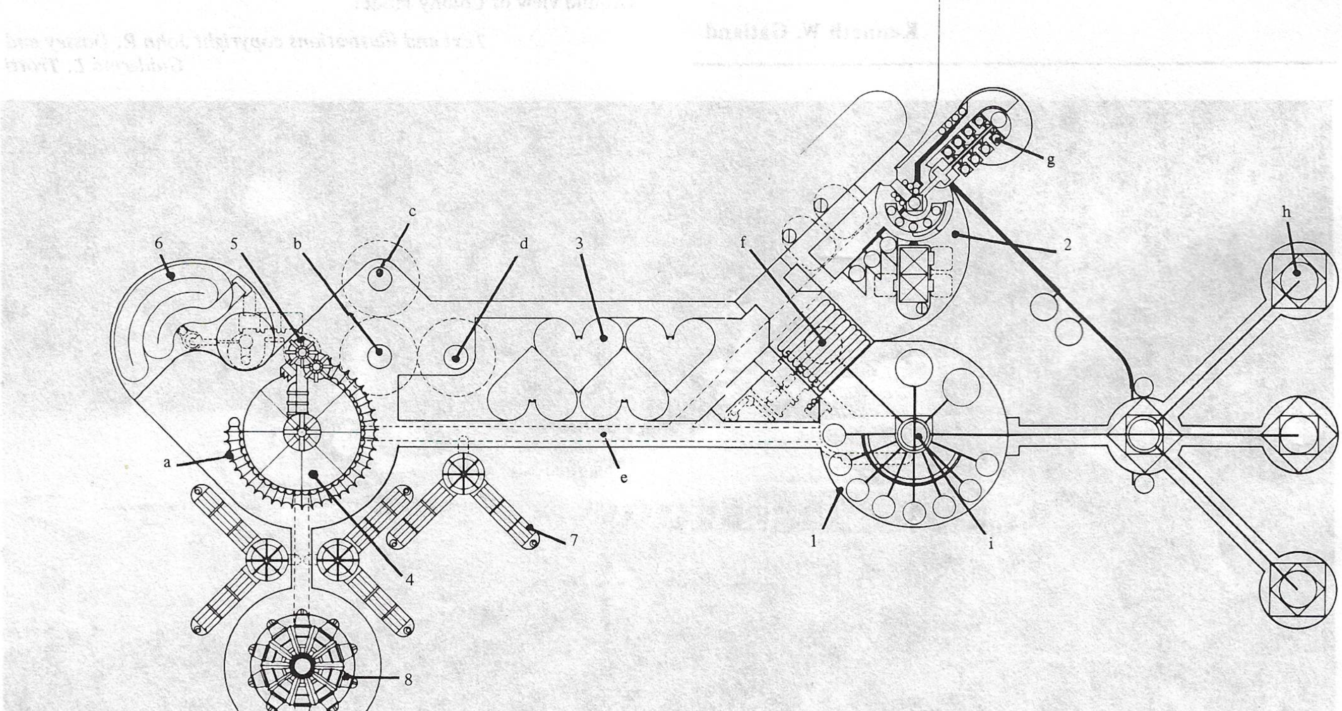
From the beginning of the project it was our intention to make 'Counterpoint' a feasible, and ultimately buildable design. To do so we paid close attention to the stringent requirements of safety and structural integrity indentified for us by NASA and other advisors.

The biggest structural obstacle to be overcome was that of differential atmospheric pressure. An internal atmosphere, as similar to that on Earth as possible, was required to allow for comfortable living conditions. This requires a minimum atmosphere of 3.5 psi of oxygen and 6.5 psi of nitrogen which allows for shirt-sleeve operation. However, because many people do not adjust well to various atmospheric pressures, and because the people who will live at 'Counterpoint' will not be as highly trained and in as exceptional a physical condition as our first astronauts, an atmosphere of 14.7 psi is required in all inhabited areas.

The result of this internal pressure, which amounts to 2000 psf working against the zero atmosphere of the Moon, is to create a tendency for the structures to explode. The problem is not unlike the reverse of deep-sea structures which must resist the tendency to implode, or be crushed under the great water pressure. In both cases, due to their excellent capacity to resist pressure through curvilinear dissipation of internal forces, rounded configurations are made mandatory. Variations of this design criteria came about as a direct result of function.

Three basic structural systems are proposed for different areas of 'Counterpoint'. Generally these systems fall into the following categories:

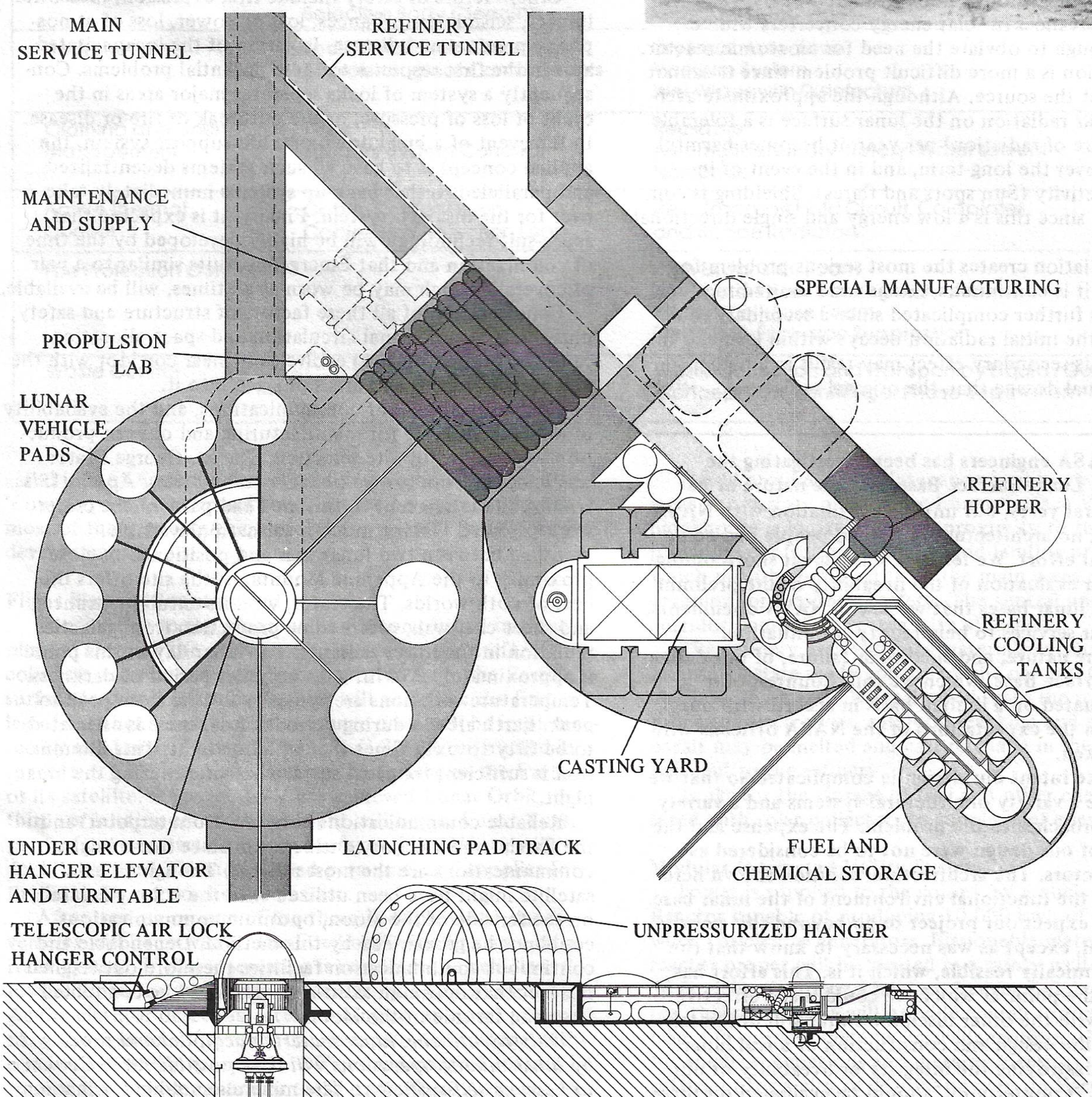
1. The utilization of various cargo envelopes, delivered by spacecraft and capable of withstanding space flight, reused as separate structural entities (laboratory modules);



Counterpoint Master Plan. Key: 1. Maintenance and Hanger Complex; 2. Refinery Complex; 3. Experimental Farm; 4. Civic Centre; 5. Control Tower, Bridge, Library and Chapel Pods; 6. Automated Farm; 7. Living Units; 8. Laboratory and Research Complex; a. Pressurized garage; b. MIUS; c. Nuclear reactor; d. Chemical mixer; e. Main service tunnel; f. Unpressurized hanger; g. Fuel tanks; h. Launching and landing pads; i. Underground hanger.

Lunar Base reconnaissance. Near the point where the authors have set their Counterpoint Moon Colony, the Apollo 15 astronauts look out on the Hadley Delta (right background).

United States Information Service



Maintenance Hanger and Refinery Complex.

2. Sub-surface cast basalt construction as a result of tunelling (living areas);
3. Inflatable surface structures of high, low and zero pressure (civic centre, farm storage).

All the systems are currently technologically feasible, and can be designed to withstand the internal pressures essentially as they are shown in the drawings.

The primary threat to safety at 'Counterpoint' is radiation, which has three components: nuclear (or man-induced), solar, and galactic.

The man-induced nuclear radiation is the easiest to control since we can act at the source by burying or shielding the nuclear reactor that will be an initial part of 'Counterpoint.' It is possible, though not considered likely, that sophisticated advances in solar energy converters will be made soon enough to obviate the need for an atomic reactor.

Solar radiation is a more difficult problem since it cannot be controlled at the source. Although the approximate average dose of solar radiation on the lunar surface is a tolerable 30 rem (measure of radiation) per year, it becomes harmful to human life over the long-term, and in the event of increased solar activity (Sun spots and flares). Shielding is comparatively easy since this is a low energy and single directional radiation.

Galactic radiation creates the most serious problem for shielding since it is continuous, intense and omni-directional. The problem is further complicated since a secondary radiation occurs as the initial radiation decays within a shield. In a thin shield this secondary effect may result in a higher equivalent annual dosage than the original radiation.

A group of NASA engineers has been investigating the feasibility of a Lunar Surface Base, and the nature of its design for several years, but until our affiliation with NASA began in 1973, no architecturally trained people had contributed to that effort. We felt this was a great shortcoming based upon our evaluation of the liveability of the preliminary designs for lunar bases that we saw in NASA documents, and offered our services to help rectify the situation.

However, the nature, and success or failure, of our design for a Lunar Surface Base, which we call 'Counterpoint,' should be evaluated on a limited basis in accord with our intent and with the expectations of the NASA officials with whom we worked.

By deliberate intent our design is complicated so that we might illustrate a variety of structural systems and a variety of stylistic approaches to the problem. The expense and the complication of our design were not to be considered as determining factors. The architectural solution shown here best illustrates the functional environment of the lunar base. NASA did not expect our project to go beyond this point into finer detail, except as was necessary to know that the design was technically feasible, which it is. This effort has brought us to the point at which we could make effective compromises with the other disciplines that will ultimately be involved in the design and construction of a real lunar base, without destroying the integrity or liveability of our overall scheme. 'Counterpoint' should be evaluated on these criteria, and no others.

John Dossey and Guillermo L. Trotti

The easiest shielding material to use on the Moon will be lunar soil. A depth of soil of approximately five metres is required for complete protection from galactic radiation, as opposed to the 0.3 metre depth sufficient for shielding against solar radiation.

The easiest design solution, from a purely functional view, would be to bury the entire base under 16 ft. of soil. We rejected this idea as being "inhuman" psychologically for 'Counterpoint's' residents who will experience an isolation much more severe than any felt by inhabitants of remote outposts such as those in the Arctic or Antarctic. Additionally, we felt it to be important for this first permanent base on the Moon to have a visible "image" of liveability with which people could identify in a positive sense.

Other factors of safety include fire, explosion, meteorite impact, seismic disturbances, loss of power, loss of atmospheric pressure and disease. Isolation of the incapacitated area in the first response to these potential problems. Consequently a system of locks separates major areas in the event of loss of pressure, or the outbreak of fire or disease. In the event of a breakdown of a life-support system, the applied concept is to have all such systems decentralized and paralleled so that back-up systems immediately take over for the disabled system. Finally, it is expected that space-suit technology will be highly developed by the time of colonization and that Emergency Suits similar to a pair of coveralls which may be worn at all times, will be available.

Consideration of all these factors of structure and safety, plus those of functional circulation and space allocation, caused 'Counterpoint' to evolve as a linear corridor with the various subsystems and areas plugged into it.

Further problems of communications, and the availability of minerals suitable for manufacturing and oxygen production were solved by site selection. The St. George Crater was selected from twelve possible colony sites. Apollo 15's landing site is adjacent to this area and parts of the crater were explored making much information available.

Lying between two lunar seas and positioned in close proximity to the Appenine Mountains, the site offers the best of both worlds. The crater, with its natural entrance and sheer cliff wall, offers some protection from galactic radiation in the lower radiants. The lunar day at this point is approximately 354 hr. with a similar period of darkness. Temperature variations are typically 270°K from peak to peak. Earth albedo during periods of darkness is estimated to be fifty to sixty times that of Moon light. This illumination is sufficient for most surface activities during the lunar night.

Reliable communications between 'Counterpoint' and the Earth were a major consideration since line-of-sight communications are the most reliable. Though a "halo" satellite might have been utilized with the colony located on the far side of the Moon, optimum communications could not be guaranteed by this method. Dependable and continuous communication facilities therefore outweighed the fact that optimum astro-research could be conducted from the far side of the Moon.

Only by utilizing lunar materials acquired and processed by lunar mining operations will it be possible for the colony to become self-sufficient. The minerals suitable for manufacturing and oxygen production are expected to be found in comparative abundance in the lunar highlands which are in close proximity to the St. George Crater site.

The following chart of systems requirements were investi-

System	Requirement	Solution
Atmosphere Control	Circulation/Ventilation Temperature / Humidity Pressure Control Contamination Control CO_2 Management CO_2 Reduction	Fans / Distribution Ducts Condensing Heat Exchanger Pressure Regulators Catalytic Oxidation / Absorption and Filtration Steam-Desorbed Resin Sabatier-Methane Utilization
Food Management	Provisions Storage Preparation Serving and Cleanup Utensil Washing Waste Management	See discussion "Farms" Turbo Compressor / Air Cycle System Combination Microwave and Resistance Heating Oven Galley / Dining Area Automatic Washer / Dryer see "Waste Control"
Hygiene	Whole Body Cleaning Selective Body Cleaning	Shower Reusable Handwipes
Housekeeping	Tools, Small Parts Cleaning Microbiological Contaminants	Dry Heat, Autoclave Vacuum System Wet Wipes with Disinfectant
Clothing and Linen Management	Type Laundry System Concept	Reusable Automatic Laundry-Rotary-Water solvent Nonionics
Active Thermal Control	Cabin-Coolant Loop Cabin-Heat Rejection Loop	Heat Transport Fluid Circuit, Coldplates and Space Radiators
Fire Protection Control		High Expansion Foam Automated Heat Sensing Actuation Methyl Cellulose Foam Freon 1301-Explosion Suppression
Waste Control		Waste Collection and Transport by Liquid / Gal Flow Concept with Centrifugal Phase Separation / Transfer

gated in NASA studies and considered in the planning of 'Counterpoint'. Optimum solutions are presented although most of the supportive equipment is presently in a state of development.

Flight Plan to 'Counterpoint'

The journey to the Moon will be accomplished in three phases. Through the utilization of space shuttle craft, colonists and material will be transported from the Earth's surface to initial Earth orbit. This will complete the first leg of the flight. Earth orbit to Lunar orbit will be implemented by the Lunar Transport Vehicle (LTV). Constructed in space, the LTV will never land on the surface of the Earth or its satellite. Once the LTV has achieved Lunar Orbit, the third, or landing phase of the flight will begin. Lunar Tugs, permanently on station on the surface of the Moon, will dock with the LTV and off-load personnel and supplies for the final descent to the Lunar Base.

After landing on one of the three Pads provided, space vehicles will be moved to the Fuelling/Defuelling area on a track system. If major servicing is required, the vehicle is lowered into the maintenance facility by a hydrolic elevator. As the elevator descends, a telescoping cover closes pressurizing the area to allow for intricate repairs to be made without need of bulky spacesuits. Offices and control centres ringing the complex monitor these operations. Adjacent to the maintenance facility is an engine testing area and various supply and storage services. A zero pressure inflatable structure may be utilized for surface repairs during periods of daylight.

Placed around the maintenance facility are maintenance areas and surface parking for Lunar Surface Vehicles. A blockhouse is located in close proximity to the landing areas, providing control of launching and landing procedures, which must be removed from the main areas of the lunar complex for reasons of safety. The central underground corridor connects this area with all others.

The refinery area provides materials extracted from lunar mines in a state ready for use by the colony. Oxygen, water and building materials are derived from the refinery by processes electrolysis, catalytic cracking and smelting. Lunar basalt may be melted and cast to shape in the casting area adjacent to the refinery.

Tanks for the storage of fuel and other chemicals are faced with solar collectors to supplement energy production.

Modular Integrated Utility System

Power is supplied to the colony by a nuclear Thermionic Reactor capable of producing 10,000 kwh of electricity when coupled to generators. Fissionable material of the reactor proper will be located in a safety well approximately 50 ft. deep. Utilizing a heat exchanger coupled with a generator, this power unit will provide energy for oxygen production, life support systems, miscellaneous machinery necessary for ancillary functions and metals processing. This power is sufficient for a city of 75,000 persons on Earth.

Adjacent to the power unit on the surface is the Chemical Mixer. This system will produce water and other necessary compounds and will act as a supplementary chemical supply facility for the Modular Integrated Utility System.

Utility systems for the colony will be controlled and maintained by the MIUS similar to those now under development for manned space stations. This fully automated system will manage the dispensation of power, atmosphere, water and waste for the entire colony.

Farms

A farming system was designed to implement food production that will be an integral part of successful colonization. Soybeans were the obvious choice for the main crop due to their high protein yield, excellent growth rate, and ability to renitrogenate the soil. Human body requirements of 50 grams of protein per day per person dictated the size of the farm.

Initially lunar soil will require leeching by nitrogen and biological fixation, metal extraction and possibly earthworms. After this preparation period of approximately one year, the farm will be planted, tended and harvested by an automated system and harvesting device operated by one man. Production is expected to reach 2,400 lb. of soybeans per year. Light for growth will be provided by high intensity grow lux fixtures providing 10,000 ft. candles of illumination per square foot.

The farm complex is divided into three separate production areas all housed under the helmet-shaped inflatable dome. The largest area is for the primary soybean system, with smaller areas for animal production and food preparation. *The bean crop is grown in soil trays equipped with special plumbing which allows for the recycling of water and precious nutrents. In order for the farm system to be automated, the soil trays take on a brain-like configuration surrounded by tracks which allow the farming vehicle to travel in a continuous loop around the perimeter of the trays.*

To produce the necessary soybean crop, two acres of concentrated farm area are required. The soil trays are stacked in two levels, one above the other to acquire the requisite ground space without enclosing excessive surface areas. A low pressure dome maintaining a carbon dioxide-nitrogen atmosphere of 3 psi covers the complex.

Since the soybean farm operates as a low pressure system, the farming vehicle is equipped with a pressurized cabin, allowing the farmer to work in a shirt-sleeve environment as he tends and harvests the crop. The vehicle spans 30 ft. between tracks and all necessary farm implements to procure a healthy crop can be attached to it.

The animal production area is housed under a dome which maintains an Earth atmosphere of 14 psi. This area is the large round shape adjacent to the soil trays, and is also covered by the pneumatic skin of the soybean farm. Although a luxury at 'Counterpoint,' the most likely fresh meats would be chicken and fish. Optimum animal production would

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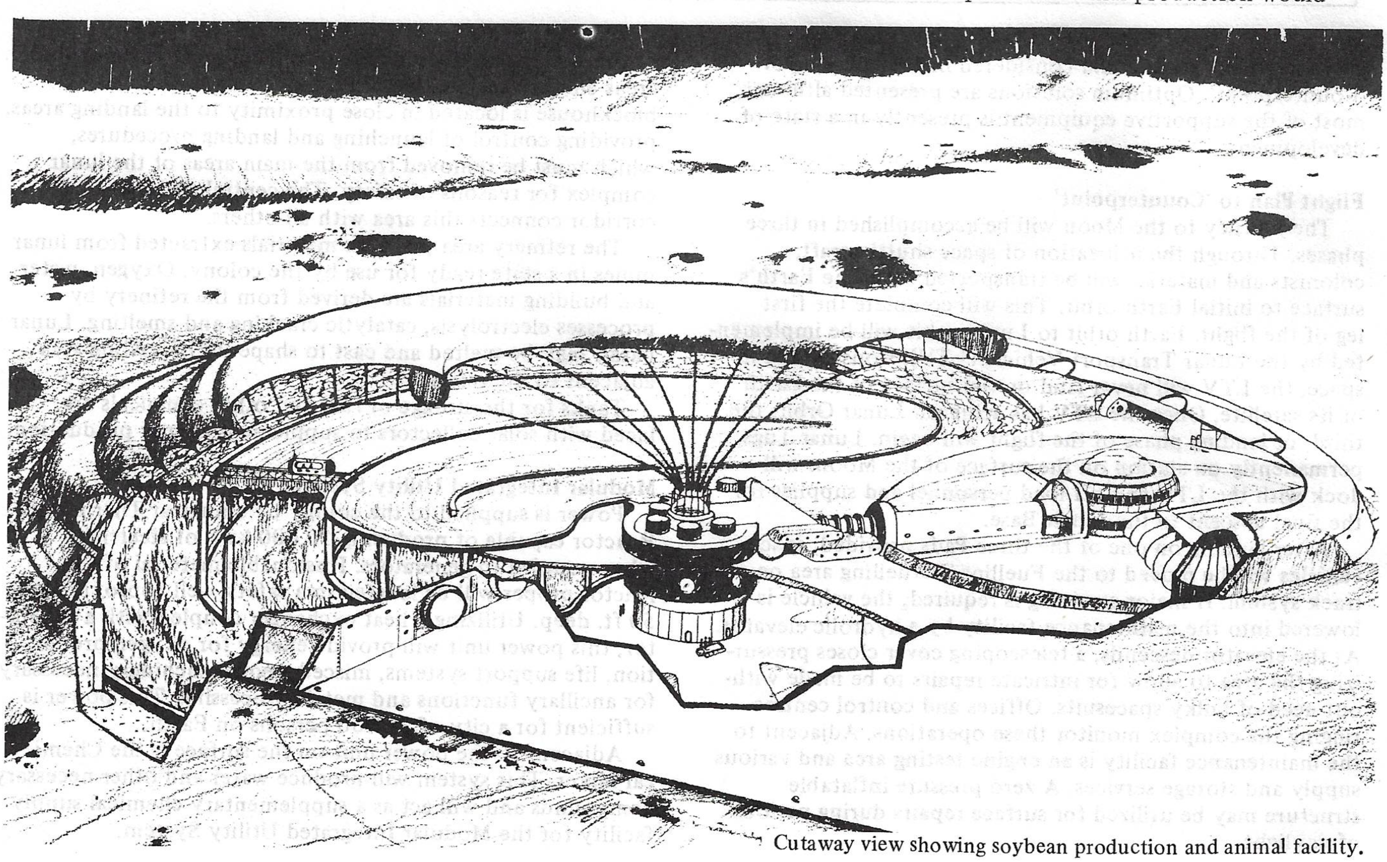
You are thinking and formulating in ways I discipline myself to pursue. Don't loath to discard your "beautifully complex" solutions and substitute your undramatically simplest solutions and do that again and again until it all looks so obviously simple that everyone will say "anybody could design that." And they will never know what you went through, how much God went through before evolving his hydrogen atoms and blades of grass and eggs—

Buckminster Fuller, April 18, 1974



Cutaway view showing soybean production and animal facility.

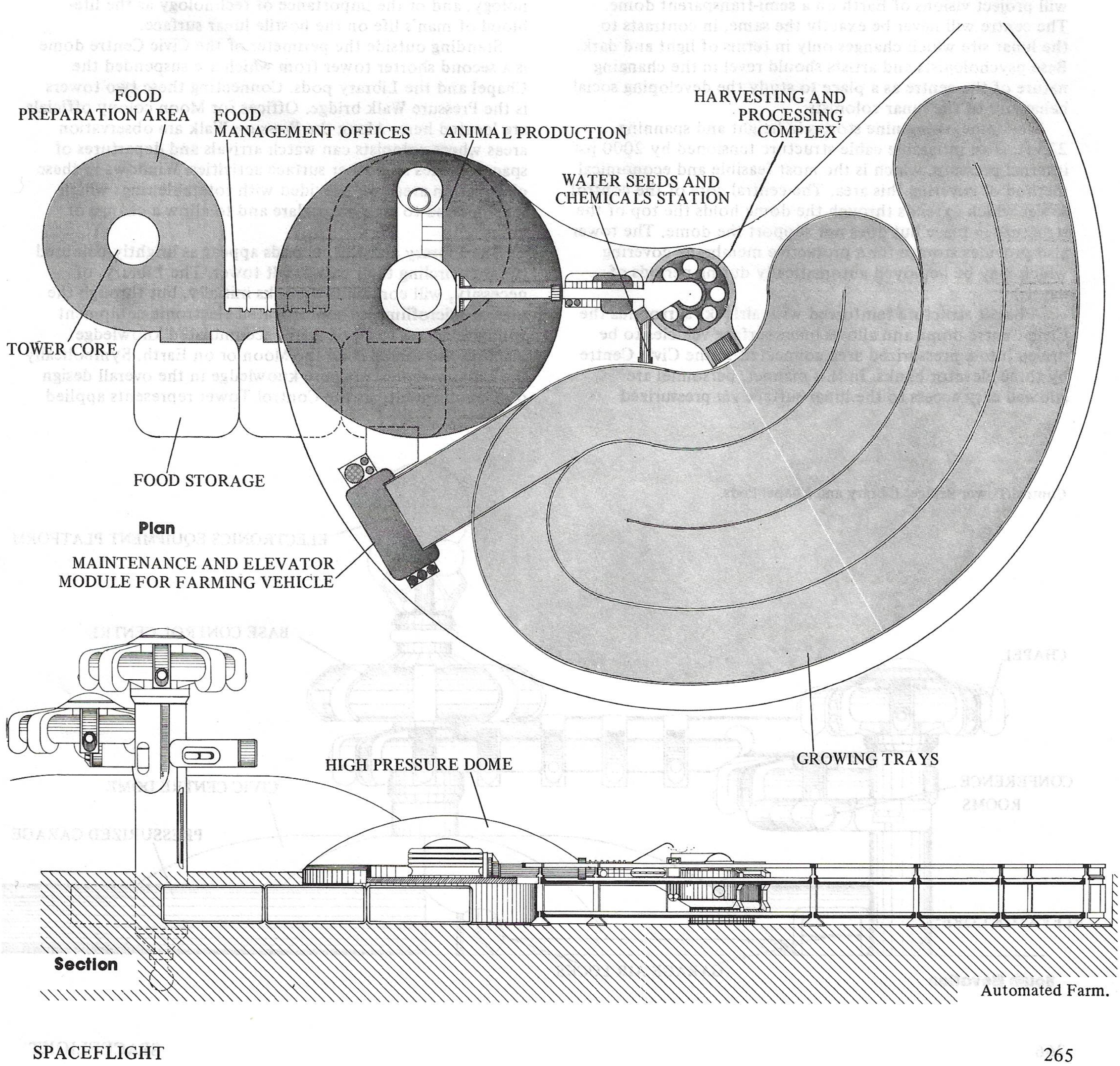
include: 200 chickens, allowing one square foot of growing area per chicken; thousands of catfish and trout, requiring one gallon of water per fish; and 50 miniature goats as a cost of 10 square feet per animal. By providing for animal companionship, the farm also adds to the psychological comfort at 'Counterpoint.'

The food processing and preparation areas are a continuous system that begins at the vertex of the soybean farm, travels through the animal production area to the storage and kitchen spaces, and terminates at the doors of the cafeteria. By the turn of the century soybean technology is expected to be sufficiently advanced so that the food stuff can be disguised into appetizing, but artificial, foods such as steak, pork chops, bacon, and some vegetable substitutes. These foods, combined with the other available plant production of the experimental farm, will allow a wide range of foods to be served to the colonists. Drinks such as wine, coffee, tea, and beer may be possible once the farming process reaches full production.

The experimental farm, where plants will be hand-tended by the colonists, is covered by a series of heart-shaped pneumatic domes maintaining a 14 psi shirt-sleeve environment. As in the soybean farm, the plants will grow in soil trays equipped with recycling apparatus. From this, farm agricultural technology will be expanded as many varieties of fruits and vegetables undergo successful experimentation.

Civic Centre

Because of the psychological problem associated with isolation and colonization, 'Counterpoint' will contain a Civic Centre for use by the colonists during leisure periods.



Automated Farm.

This area is the most innovative of the entire complex, and exemplifies the "otherworld" quality of the base. The centre is designed as a multi-level structure containing features to stimulate the senses, to influence minds through fantasy and to stimulate new sensitivities toward the environment. In this whimsical and active space, the colonist will be encouraged to escape his routine.

The Civic Centre will contain swimming pools, the base dining facilities, theatre, fountains and places for lunar sporting events which will take on unique characteristics in an environment in which a man can lift 600 lb., or jump vertically 30 ft. Environmental features will be programmed into the life support centre and will change. There will be periods of light and darkness, times of cool and warmth with humidity variations. It may even rain. A hologram sky will project visions of Earth on a semi-transparent dome. The centre will never be exactly the same, in contrasts to the lunar site which changes only in terms of light and dark. Base psychologists and artists should revel in the changing nature of the centre as a place to study the developing social behaviour of the lunar colonists.

The dome, rising nine stories in height and spanning 225 ft. is an inflatable cable structure tensioned by 2000 psf internal pressure, which is the most feasible and economical method of covering this area. The central core of the control tower which extends through the dome holds the top of the structure in place but does not support the dome. The tower also provides storage for a protective membrane covering which may be deployed automatically during periods of daylight.

A basalt structure reinforced with airlocks surrounds the Civic Centre dome and allows lunar surface vehicles to be driven into a pressurized area connected to the Civic Centre by three elevator banks. In this manner, personnel are allowed easy access to the lunar surface *via* pressurized vehicle. The ring also provides a buffer area around the dome for safety purposes.

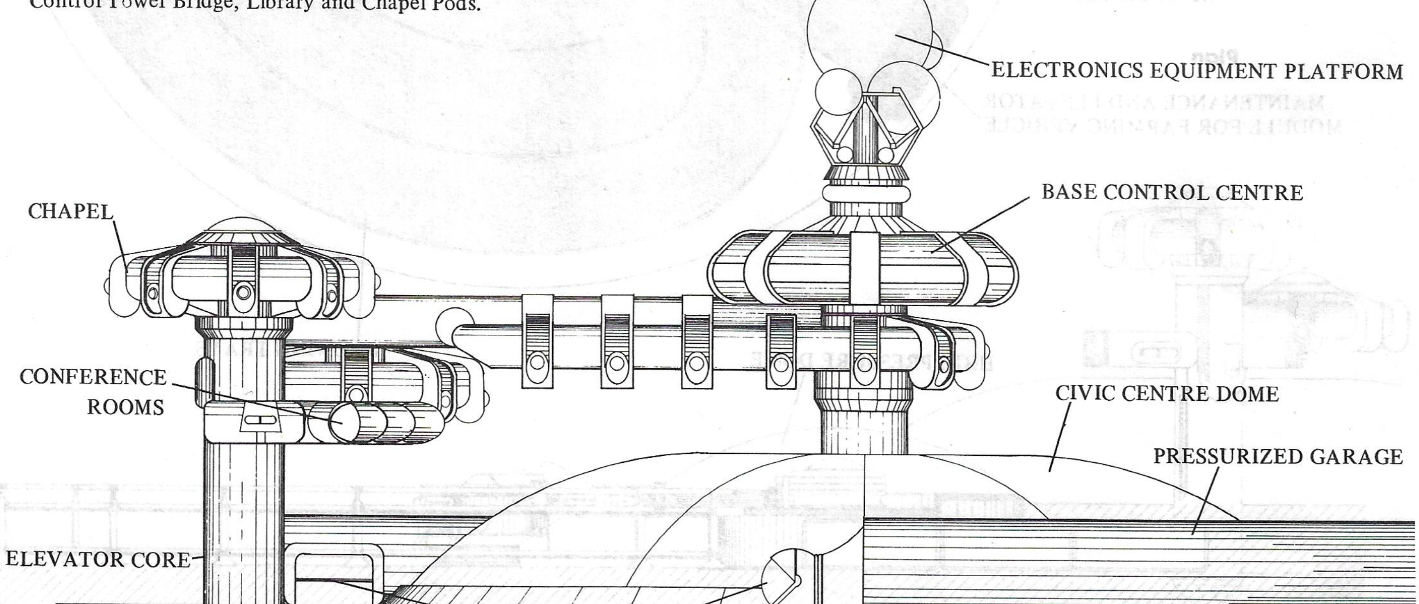
Control Tower Bridge, Library, and Chapel

Thrusting up through the dome of the Civic Centre is the central control tower with its bridge and communications platforms elevated above the dome. The bridge of the tower is a polished hollow metal belted tube which hangs delicately in tension just below the flight observation and electronics equipment platforms. It is easily the most important area of the entire 'Counterpoint' base complex, both literally and symbolically. It is the operational and administrative area, housing the computers that control all life support functions of 'Counterpoint.' As a symbol it represents the highest degree of sophistication achievable by man through technology, and of the importance of technology as the life-blood of man's life on the hostile lunar surface.

Standing outside the perimeter of the Civic Centre dome is a second shorter tower from which are suspended the Chapel and the Library pods. Connecting these two towers is the Pressure Walk bridge. Offices for Moon colony officials are located here. Along the Pressure Walk are observation areas where colonists can watch arrivals and departures of space vehicles and other surface activities. Windows in these observation areas are provided with rotatable rings which may be used to alter solar glare and to allow a change of vistas.

The Library and Chapel pods appear as brightly coloured tubes encircling their cast basalt tower. The Library, of necessity, will contain few books initially, but through the uses of microfilm and sophisticated electronic equipment will have access to all of man's accumulated knowledge whether the source is on the Moon or on Earth. Symbolically the Library represents pure knowledge in the overall design of 'Counterpoint,' as the Control Tower represents applied

Control Tower Bridge, Library and Chapel Pods.



South Elevation

knowledge.

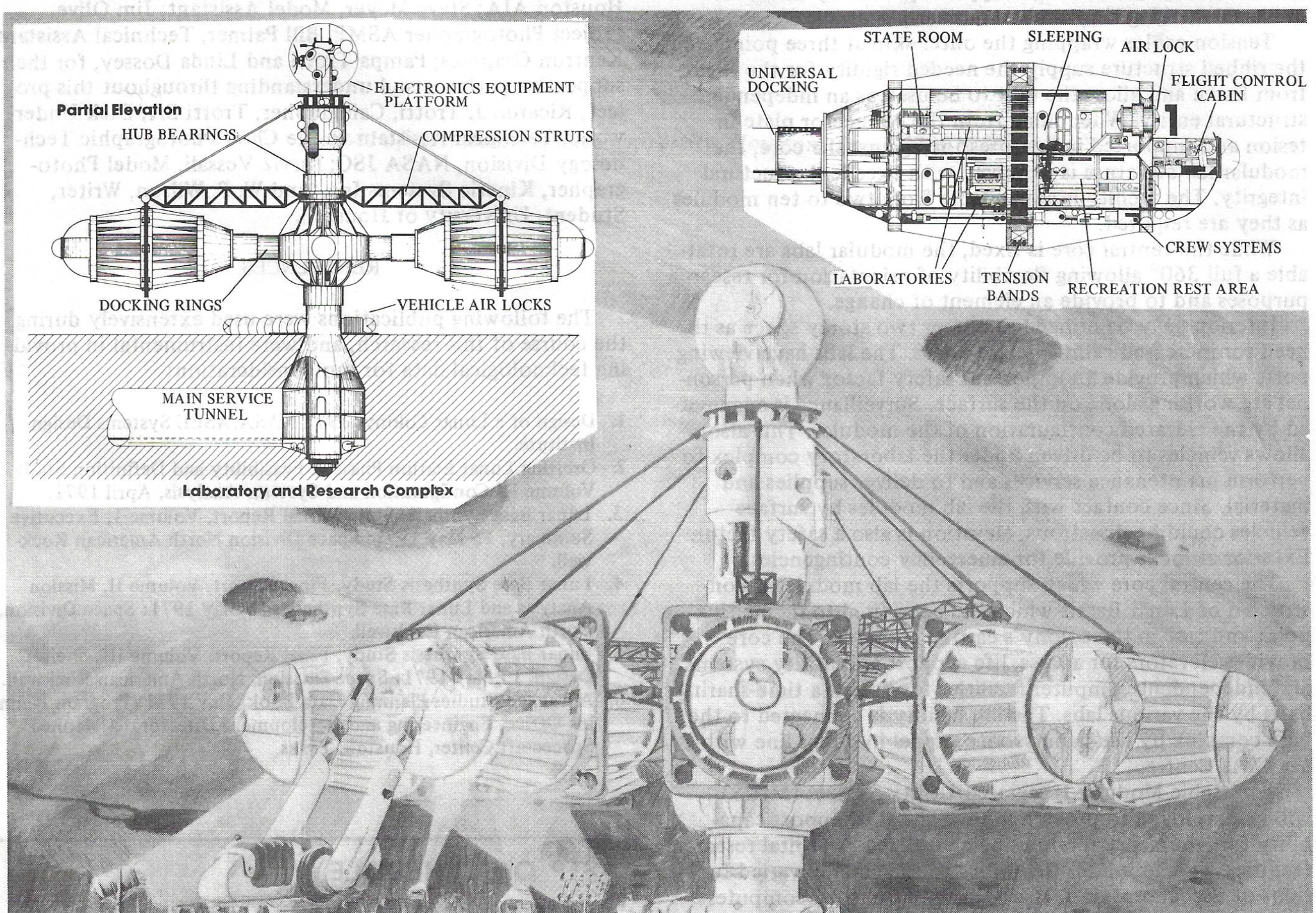
Seats within the Chapel, located at the end of the Pressure Walk, are canted toward a transparent dome. The focal point is upward, with ministerial functions centred immediately below the centre of the dome. Looking upward through the dome in this non-denominational space, may be looking homeward, toward Earth, or it may be looking beyond the space of 'Counterpoint.' Moon and Earth, into the extra-ordinary depths of space and by transposition, into the extra-ordinary depths of human existence. Symbolically, the Chapel represents the mystical and irrational nature of man in his unexplicable desire to go beyond, toward the unknown in imagination and in knowledge. Together the three areas – Chapel, Library and Control Tower – are literally and symbolically the three sides of man in the Universe.

Residential Apartments

Residential warrens will provide necessary privacy during lunar tenure which is expected to be approximately one year. The luxury of "my home....my place" will doubtless prove a necessity. Gregarious or not, colonists must have a place of solitude, a place to reflect, to contemplate, to be alone. The apartment-like configurations of the warrens were designed with this in mind.

The warrens are designed as three pairs of tunnels 150 ft. long in a two-storey configuration, 40 ft. in diameter with 10 ft. head clearance. They will provide accommodations for 240 persons, the resident population and visitors in single, double and quad units. Construction will be accomplished by utilization of a hydrogen thermal drill, now undergoing prototype testing. Basalt casting in conjunction with the drill will allow the tunnels to be literally melted from the surrounding rock. Sixteen feet of soil and rocks separate the warrens from the lunar surface to preclude the possibility of over exposure to solar and galactic radiation during periods of rest. Solar panels designate the position of the warrens on the surface, and supplement power production of the colony.

Warren tunnels are entered through buffer areas. These compression structures are of cast basalt from inverted domes and serve to separate the units from the main base complex. Personal spaces are comprised of one and two bedroom units with private baths. These areas will be finished in natural rock, sprayed acoustic ceilings and textured floor coverings. Of necessity furniture must be lightweight, probably inflatable or light plastic. Bath units will be fabri-



Moon Mobile "Spider' positioning Lab Module into core or Laboratory and Research Complex. *Inset, top right,* Laboratory Module. For description, see page 268.

cated on Earth, reassembled and plugged in at 'Counterpoint.'

Access tunnels are provided with an independent pressure system and are separated from living units by a fire wall. Should structural integrity of the living units be violated, this tube-with-a-tube configuration will be invaluable. All utility functions are located on the side opposite the access for safety purposes. An aid station, emergency airlock and space suit storage are located at the outer extremity of each tunnel. Laundry facilities for personal use are provided adjacent to the hub of each tunnel pair.

Laboratory

The laboratory and research modules are manufactured on Earth. Utilized as transport vessels, they are placed in Earth orbit by space shuttle craft now being built. Connected in multiple unit caravans, they are flown into lunar orbit and are then delivered to the lunar surface by space "tugs." The cargo is removed and the modules are picked up by the "Spider" crane, which is equipped with a servo-hydraulic manipulator capable of micro-fine adjustments enabling the crane to position and install all lab units. Although the modules can be used independently at sites remote from the base, normally they are plugged into the central core which contains all utilities and life support systems by means of universal docking rings and connector plates.

Tension cables wrapping the outer skin at three points and the ribbed structure supply the needed rigidity for the flight from Earth and allow the unit to be used as an independent structural entity. When hung from the connector plate in tesion and supported in compression against the core, the modular lab structure is endowed with excellent structural integrity. The facility is expandable from two to ten modules as they are required.

While the central core is fixed, the modular labs are rotatable a full 360° allowing flexibility of orientation for research purposes and to provide an element of change.

Interiors may be utilized as one or two storey space as the need for increased ceiling height arises. The labs have viewing ports which provide an important safety factor when personnel are working alone on the surface. Surveillance is augmented by the elevated configuration of the modules. This also allows vehicles to be driven under the laboratory complex to perform maintenance services and to deliver supplies and material. Since contact with the lab modules by surface vehicles could be disastrous, elevation is also a safety factor. Exterior airlocks provide for emergency contingencies.

The central core which supports the lab modules is constructed of Lunar Basalt which has been fired to its melting point and cast in the colony's casting complex. The core provides elevators for access, life support and utility systems and independent computer facilities for use on a time-sharing basis by the various labs. The lab facility is connected to the base complex by the main service tunnel in direct line with the Civic Centre.

A portable Modular Integrated Utility System (MIUS) will be employed to provide motive and life-support capability for laboratory modules being utilized as orbital research facilities. This unit adds flexibility to the already varied functions of the laboratories. In addition to onboard computers for research purposes, the portable MIUS will contain those systems necessary for long periods of isolation from the lunar colony.

Conclusion

This project is dedicated to Howard Barnstone, F.A.I.A., Professor of Architecture at the University of Houston, whose initial efforts on our behalf made the entire project possible. It was his imagination and genuine enthusiasm that fostered such an elaborate undertaking. His interest and guidance throughout the course of the project have been of immeasurable benefit.

We would also like to acknowledge special recognition to the Houston Endowment for the funding of the project, and to the people at the Johnson Space Center for their continuous technical support and inspiration throughout the course of this project.

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4. Lunar Base Synthesis Study, Final Report, Volume II, Mission Analysis and Lunar Base Synthesis, 15 May 1971: Space Division, North American Rockwell.
5. Lunar Base Synthesis Study, Final Report, Volume III, Shelter Design, 15 May 1971: Space Division, North American Rockwell.
6. Advanced Studies Planning Data Book, May 1971: Program Planning Office, Engineering and Development Directorate, Manned Spacecraft Center, Houston, Texas.

ASTP ON SCHEDULE

After spending 28 April inspecting Soyuz spacecraft and launch pads at the Tyuratam cosmodrome in central Asia, two Soviet and two American crews training for the ASTP docking experiment in July held their last joint Press conference. Next time the prime crews meet will be in orbit.