PRELIMINARY DESIGN STUDY OF LUNAR HOUSING CONFIGURATIONS

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A preliminary design study assesses various configurations for habitation of the lunar surface. The study assumes an initial 4-man habitation module expandable to a 48-man concept. Through the numerous coupling combinations of identical modules, five basic configuration types are identified. A design model presents each configuration in light of certain issues. The issues include circulation, internal and external spatial characteristics, functional organizations, and future growth potential. The study discusses the attributes, potentials, and unique requirements of each configuration.

INTRODUCTION

Numerous studies on lunar bases have concluded with a configuration depicting the necessary scientific parameters for operation and human habitation.

Mathematical laws actually permute an overwhelming number of configuration combinations. The near-infinite choices coupled with human habitation requirements present a dilemma that can best be resolved through architecture.

Architecture enables the selection of potential options that satisfy human needs: a sense of place, a sense of privacy, a fit into the environment, and a sense of well-being.

BACKGROUND

The preliminary design study concentrates on configurations and assumes the scientific parameters developed: module size determined by transport system, materials selections, radiation shielding, temperature control systems, and a closed ecological life-support system. For the purpose of demonstration, the configurations are composed of physically identical and interconnected modules. They establish a complex that can house a population expandable from 4 to 48 people.

The study allows the modules to be configured vertically as well as horizontally. Vertical arrangements present spatial qualities such as privacy. They introduce the potential for connections to experimental below-grade chambers and additional circulation loops.

THE MODULE

Each module shell is identical in composition. The basic shape is cylindrical, with a length twice the width. The interior orientates in any direction. In the horizontal position the plan form is rectilinear, and in the vertical it is circular.

The module is constructed with three openings, one on each end and the third on the side. The side connector demonstrates a greater number of combinations through reflection, translation, and rotation (Fig. 1). Such possibilities become extremely important in determining performance, placement, and siting of a lunar base. The module's sides can be orientated in any direction in the horizontal plane. The introduction of the vertical plane increases the number of possibilities; for example, when eight modules are related horizontally and vertically, the variations in combinations are innumerable. Basic configuration types need to become apparent. Only after identifying the attributes of the basic configuration types can the variations of other techniques be architecturally appreciated (Figs. 2 and 3). A balance between mathematical possibilities, scientific demands, and architectural needs can be attained.

BASIC CONFIGURATIONS

The study's design model categorizes the configurations into five basic groups: linear, courtyard, radial, branching, and cluster. Each configuration responds differently to the circulation and the internal/external spatial characteristics for a lunar base.

A configuration can provide a unique quality of space: open space, inner circulation loops, and privacy. The organization and selection of such qualities is based on the functional and operational procedures of the lunar base. A lunar base may require two or three shifts working and sleeping different hours. A

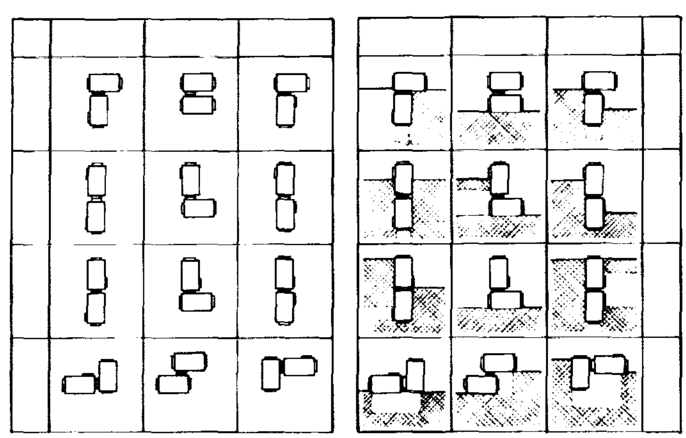

Fig. 1. Some possible combinations of two modules, each with three coupling options. Left is horizontal plane (plan view); right is vertical plane (section view through regolith). Note that varying the relation of configuration to lunar grade increases number of arrangements, especially egress routes.

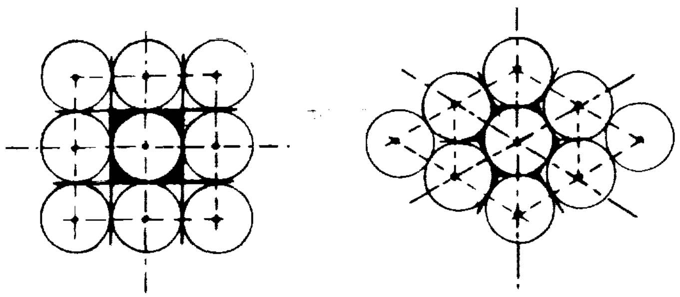

Fig. 2. Two close-packing options for circular modules.

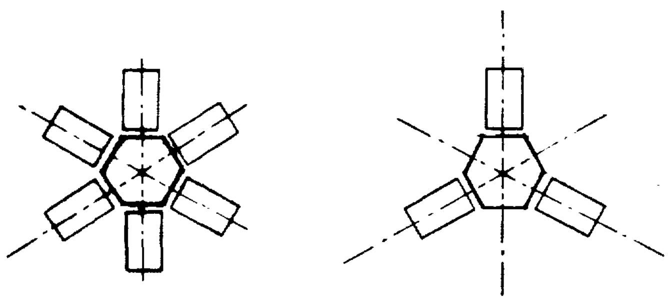

Fig. 3. Plan view of multiple coupling techniques.

configuration that provides three private crew areas, separately located, would permit a congenial working atmosphere, as opposed to the configuration with only one major crew area off a main corridor.

Each configuration provides reliability and safety through redundancy. Dual egress is necessary from any portion of the configuration. Airlocks must be located for easy access by the crew with emergency airlock systems as needed. In some configurations, a secondary safety circulation configuration loop is necessary.

Each of the five configuration types with their distinctive characteristics is presented in Table 1 and discussed in detail below.

Linear

The linear configuration is the simplest of all configurations. It is the repetition of modules with one primary circulation path. It can be stepped, undulating, or spiraling (Fig. 4). The internal distances from one end to the other are maximized. The spatial characteristics are primarily public-type spaces that are noisy and conducive to space-sharing with the circulation path (Fig. 5). Externally the configuration covers minimal area, yet requires maximum enclosure. Expansion possibilities are limitless with the configuration being altered to another form (Fig. 6). One of the main problems with the linear system is safety; a secondary circulation system that requires complicated looping techniques is necessary.

Courtyard

When a linear configuration closes on itself, its basic characteristics change: the area coverage becomes greater and the enclosure minimizes. The courtyard is a unique identifiable space. There still exists one primary circulation path; however, it now forms a closed loop, an internal dual egress system distinguishable from the other basic configurations (Fig. 7). Varying functional organizations are possible including a two-directional corner or nodal point condition (Fig. 8). An additional attribute is the courtyard area itself. It allows complete access to all modules for repair and maintenance and in the future can be altered to usable space (Fig. 9).

Radial

The radial configuration is centralized space with linear extensions in more than two directions (Fig. 3). The central area provides a major functional space with secondary areas radiating. These secondary spaces can be private, quiet areas or main circulation routes to additional functional zones (Fig. 10). The major concern with this configuration is that access to each arm is through a central zone. In terms of safety, this presents a concern with egress technique. A secondary emergency circulation system may be necessary to loop the radiating arms together. One advantage of the radial configuration is the provision of an easily accessible central functional zone. When the radial configuration is combined with another configuration type (i.e., courtyard or branching), it allows for distinct zoning possibilities.

Branching

A linear growth system that expands with secondary circulation paths from a main circulation path characterizes a branching configuration. These branching areas provide transition areas: public from private, noisy from quiet, and primary from secondary (Fig. 11). Functional zoning is diverse, providing multiple options. Also there are numerous expansion options, including in-fill between the secondary systems (Fig. 12).

Cluster

Cluster configurations have no dominant circulation patterns. They have the most open sense of circulation allowing for flexible, close proximity of functions and close packing of modules (Fig. 13). Generally a large central area is created, and a closed circulation loop is obtained. Private and/or quiet areas can be separated from public and/or noisy activity areas. With modules abutting one another, any necessary repairs or maintenance can cause a potential problem.

CONFIGURATIONS IN THE VERTICAL PLANE

So far the configurations discussed are with the circulation movement in the horizontal plane. With the introduction of a module in the vertical plane, different criteria are established: the relation of the configuration to grade and to itself. The circulation movement may be one configuration in the horizontal and another in the vertical. For example, a branching configuration may branch horizontally, yet with the introduction of vertical modules and a second plane of horizontal modules, a courtyard configuration could also appear.

TABLE 1. Characteristics of five basic configurations.

	Linear	Courtyard	Branching	Radial	Cluster
Basic Characteristics					
Length/width ratio	maximum	maximum	average	average	minimum
Area coverage	minimum	maximum	maximum	minimum	average
Enclosure	maximum	minimum	maximum	maximum	minimum
Circulation					
Type of circulation route	primary	primary	prim.+second.	multi	multi
Circulation intersections	none	none	multi	one primary	multi
Travel distances	maximum	maximum	average	minimum	minimum
Closed vs. open loop	open	closed	open	open	open
Dual egress	no	yes	no	no	no
Safety egress possible?	complex	exists	possible	possible	possible
Spatial Characteristics					
Primary space	yes	yes	yes	yes	yes
Secondary spaces	no	no	yes	yes	yes
Quality of space	noisy	noisy	noisy/quiet	noisy/quiet	noisy/quiet
Public vs. private	public	public	public/private	public/private	public/private
Space shared with circulation	yes	yes	not necessary	not necessary	not necessary
Type of space (interior)					
open or enclosed	enclosed	mainly enclosed	open/enclosed	open/enclosed	open/enclosed
vary size/shapes/locations	minimal	minimal	max. at nodes	central max.	maximum
vary circulation path type	minimal	minimal	maximum	average	maximum
Functional Organization					
By definition of configuration	decentral	decentral	central	multicentral	central
Adjacency or interconnect	yes	yes	yes	yes	yes
One-sided organization	yes	yes	yes	yes	yes
Multisided organization	no	yes	yes	yes	yes
Nodal organization	no	minimal	yes	yes	yes
External Characteristics					
Maintenance/repair	accessible	accessible	difficulty	difficult at central node	inaccessible
Emergency egress safety	complex	dual egress	secondary system necessary	secondary system necessary	dual egress
Single module disfunction	inoperable	operable	part operable	part operable	operable
Direct exposure sol-radiation	maximum	minimum	maximum	maximum	minimum
Shade formed by configuration	maximum	maximum	maximum	maximum	minimum
Sol-radiation/shade ratio	average	minimum	average	average	maximum
Regolith coverage required	maximum	minimum	average	average	minimum
Expansion/Future Growth					
Limitless growth horizontal	unidirectional	no	multidirectional	unidirectional	no
Future in-fill	no	yes	partial	partial	partial
Vertical expansion	yes	yes	yes	yes	yes

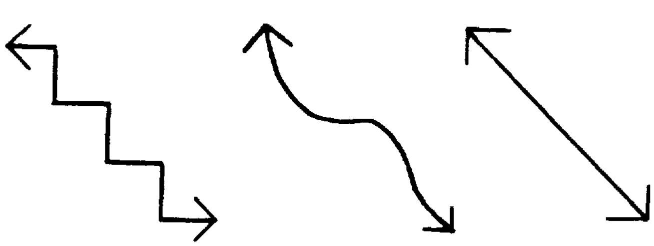

Fig. 4. Linear circulation paths.

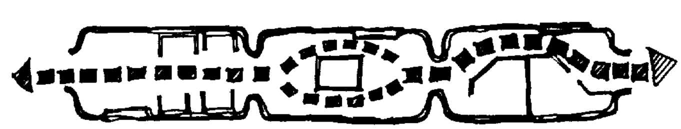

Fig. 5. Schematic plan of linear configuration's spatial characteristics.

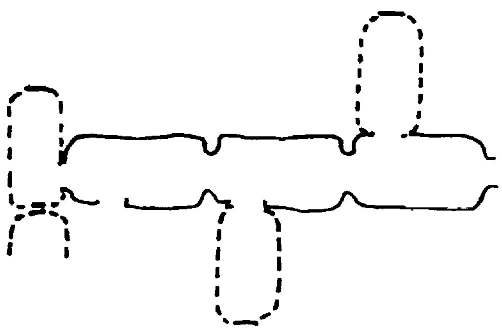

Fig. 6. Schematic plan of expansion potential of linear configuration.

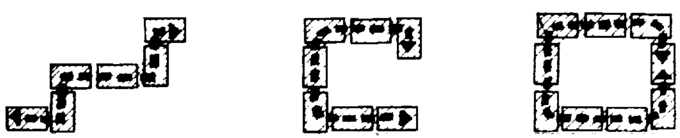

Fig. 7. Courtyard configuration is formed when linear path closes on itself.

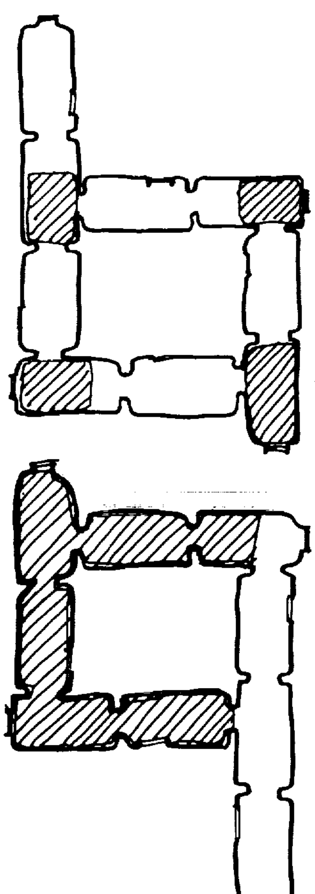

Fig. 8. Plan of courtyard functional organization options.

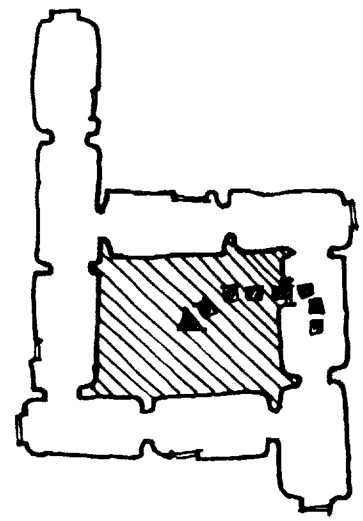

Fig. 9. Schematic plan of courtyard in-fill zone.

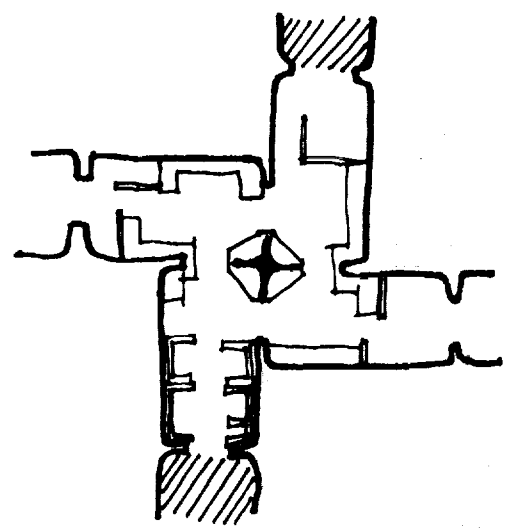

Fig. 10. Schematic plan of radial configuration.

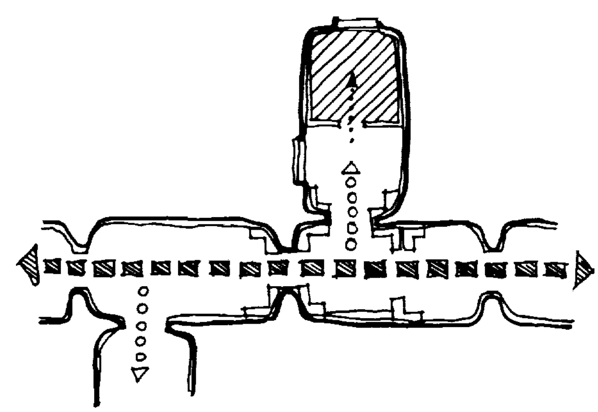

Fig. 11. Schematic plan depicting portion of a branching configuration.

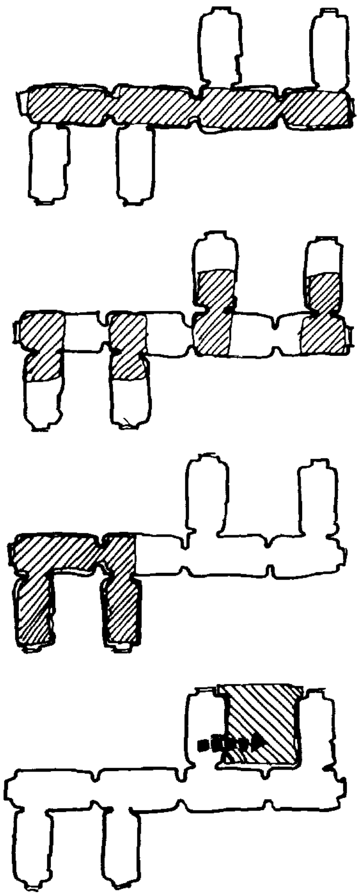

Fig. 12. Schematic plan of functional options for branching.

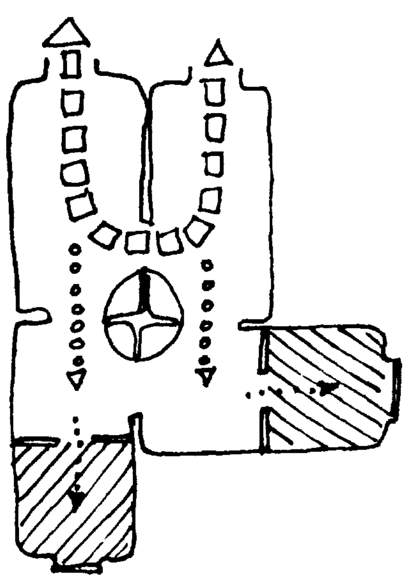

Fig. 13. Schematic plan of a cluster configuration.

Once a vertical module is introduced, it allows the configuration to expand in a different dimension. The expansion may be to connect the horizontal portion with a below-grade chamber, extend the base into a hill to a similar shelter deep in the regolith, or it may step the horizontal configuration to adjust to the lunar site.

EXPANSION OF THE BASE

In time it may be necessary to expand the initial configuration. The expansion can follow its natural progression of growth, or it may deviate. The deviation is dependent on the purpose of expansion, the construction materials, and the site conditions.

The expansion can take the form of an addition to the existing module, in-fill or underground expansion, or a separate facility. An addition to the existing module can be the coupling of new modules or an experimental space to the facility. Expansion by in-fill requires minimal additional material (Figs. 9 and 12). The adjacent modules become the exterior walls of the new area. Underground expansion, after initial testing, requires less additional material, only a circulation connection and interior finish. A separate facility connected through a circulation corridor to the existing requires a separate life-support system.

Each of these expansion types can be composed of similar modules or by an experimentally accepted construction method. Examples are actual on-site construction, transported fabric systems, and lightweight composites.

CONCLUSION

Independent of the lunar base's construction technique is the configuration's composition. Five basic configurations have been identified. From these basics innumerable arrangements can be derived. Each has advanatages and disadvantages. The optimum habitation will be a combination of the five basics, and its functional and operational requirements will be dependent on population sizes and activities.

Scientific parameters, typology, and combinatorics all play a key role in the selection of one design over another, but there still exists a human need that must be satisfied. This can only be accomplished by an architecture that combines science and art.