

Chapter XII

THE INDIVIDUAL INTEGRAL SPACE HABITATION ~ PRELIMINARY SKETCH DESIGN OF AN INDIVIDUAL TENSILE SPACE HABITATION, SITUATED WITHIN A LARGE-SCALE CENTRALISED TENSILE LATTICE STRUCTURED PNEUMATIC ENCLOSURE, IN MICROGRAVITATIONAL SPACE

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ABSTRACT

Elsewhere the author presents proposals for very large-scale mega-structures in microgravity, to provide a habitable environment for the future colonisation of Space. A centralised primary tensile lattice of seven miles diameter is tensed by an enveloping pneumatic enclosure, which provides insulation and protection from the vacuum of space, radiation, micrometeorite impact, etc. Thus the necessary habitable atmosphere stresses the entire assemblage. The lattice geometry is that of the centralised zonahedral mandalas discovered by the author. Secondary pneumatic enclosures are developed in zonahedral cells within the primary lattice, and provide large-scale local open spaces, with internal surfaces comprising space habitation neighbourhoods. Secondary tensile assemblages are stressed by means of the primary tensile lattice, and provide local structures as needed. Subordinate tensile assemblages are configured as desired, the entire structural system enabling a "soft" non-rigid tensile architecture to be developed which exploits the microgravitational environment of Space.

This paper presents sketch design proposals for one such subordinate tensile assemblage - an individual tensile space habitation, designed to be located within the context of one such mega-structure. Thus the individual dwelling is surrounded by secondary tensile elements, which provide radial stressing about the entire perimeter as needed. A habitable atmosphere is presumed, as is the provision of services and communications. The individual dwelling is detached from other dwellings.

Modelling of the Space Habitation has been greatly facilitated by the elegant Zometool 31-Zone Structural System graciously made available by Marc Pelletier of BioCrystal Inc.¹ The mock-up uses 60 outer and 21 inner long red pentagonal struts and 32 outer and 6 inner nodes of the Zometool kit.

The author is particularly interested in exploring notions of dwelling in microgravity, and suggesting a tensile architecture that is highly economic, whilst providing for spiritual, psychological and material needs of the dwelling assemblage.

The individual Integral Space Habitation encapsulates these ideas.

IT IS ASSUMED THE INDIVIDUAL TENSILE HABITATION IS situated within a large-scale tensile lattice structured pneumatic enclosure, as described in the author's monograph "The Integral Space Habitation - Towards an Architecture of Space",² and elsewhere.³

This means:

- A SHIRT- SLEEVE ENVIRONMENT

A shirtsleeve environment is assumed within and without the individual space habitation. The atmosphere is breathable, and generally at a comfortable temperature and humidity, although local environmental modifiers such as heaters or coolers, and humidifiers or air driers may be included. Cosmic radiation, solar gain, heat loss, micrometeorite impact and so forth are controlled at the surface of the entire space habitation complex, and need not be considered in the design of the individual space habitation.

- AMPLE SPACE IN SPACE

It is presumed the economics of space habitation have been radically altered, in part through the provision of very large-scale enclosures such as the author is suggesting, and that in consequence, there is ample space within which to structure an individual space habitation. Thus although a very economic use of materials is suggested, through using structural forms of tension, the provision of habitable space is generous and not tightly constrained.

- ACCEPTING MICROGRAVITY

Microgravity is assumed. Although the large-scale space habitation complex is assumed to be slowly rotating, artificial gravity of appreciable extent is not generated. It is rather assumed that technological advances have enabled comfortable adjustment to and dwelling within microgravity for a sustained period.

- POTENTIAL POINTS OF ATTACHMENT ARE PROVIDED BY THE TENSILE ENVELOPMENT

At all points of the large-scale space habitation complex, a general potential for tensile attachment is assumed in all directions, being

provided by the primary tensile lattice that structures the entire space habitation complex, together with subsidiary tensile elements. Thus the individual space habitation is surrounded on all sides by potential points, lines or planes of attachment for providing adequate tensioning to preserve its form.

- **TENSILE STRUCTURE OF THE INDIVIDUAL HABITATION**

The individual space habitation is envisaged and developed as a tensile structure, both for the intrinsic economical use of materials, and for the aesthetic appropriateness of the tensile response to the general microgravitational environment.

- **A POLYAXIAL SPATIO-ARCHITECTURAL FIELD IS USED**

Similarly, minimal effort is made to replicate the psychological environment of the monodirectional gravitational field characteristic of Earth and of Earth-based dwellings. Rather, the spatial potential suggested by dwelling in the polyaxial field of microgravity is exploited.

- **TRADITIONAL SYMBOLIC NOTIONS OF DWELLING ARE INTEGRATED**

At the same time, traditional notions of home and dwelling are integrated in the architecture,⁴ though adapted or transformed in response to the microgravitational context. Thus archetypal symbolic structures of the centre and enclosure are utilised, whilst existential dimensions of up and down, side-by-side, and front/back are translated into inside/out, about the circumference of reference spheres, and towards and away from symbolic foci etc.

- **POLYAXIAL SYMMETRIES OF THE POLYHEDRA ARE UTILISED**

The polyaxial spatial field of microgravity is conveniently structured in accord with the central symmetries of the regular and semi-regular polyhedra,⁵ this providing a natural spatial structuring and suggesting appropriate existential dimensions and orientations. (In this design however, true polyaxiality is compromised to a degree by the quasi-crystalline subdivision of space used).

- **ADEQUATE SERVICING IS PROVIDED**

The provision of essential and preferable services is assumed, such as potable water, electricity, communications, waste disposal, sewerage reticulation or processing, etc.

The existential structures considered important in the design include:

- Dwelling as a psychological centre for the inhabitant.
- Clear demarcation of inside and outside.
- Concentric zones of inwardness / privacy.
- Circumferential differentiation in accord with polyhedral symmetries.

- Centre has symbolic potential for transcendence - analogizing vertical transcendence axis at centre of Earthbound traditional sacred architecture.
- Polyaxial microgravitational analogue of traditional courtyard housing - "rooms" look into central void, which has openness to infinity within (rather than above/beyond).
- Minimal concern with communal relating, which is envisaged as taking place elsewhere, in public and communal spaces. The individual space habitation is regarded more as a sanctuary for the individual, though provision for meeting callers and entertaining guests is included.

A key determinant of the design is the envisaging of the individual space habitation as being itself a centralised tensile lattice. For this to be achieved in a regular, rather than haphazard fashion, the geometry of the centralised zonahedral mandalas the author has elsewhere described is appropriate.⁶ This limits the available configurations, and ensures the symmetries of the tensile lattice are those of the regular and semi-regular polyhedra. However, this true polyaxiality is compromised by the non-periodic quasi-crystalline subdivision of space, though local centres do exhibit subsets of polyhedral symmetry, and are oriented to one another. And although quasi-crystalline subdivision in principle transforms the centralised form considered important for the tensile lattice into a more diffuse order (irregularly but harmonically decentralised?), a measure of centralised structural integrity is here maintained - i.e. the tensile lattice works.

At the symbolic level, the geometric grid of the zonahedral explosion may also be considered as a form of *linee occulte*, and significance granted to the primary polyaxial dimensions. One envisages an exploratory and symbolic "taking possession" - an active cognitive structuring of habitable microgravitational space, which is also a recognition, a discovery and fleshing-out of latent ambient potential...

It is as if a natural harmony of space awaits our realisation, which is at the same time a symbolising activity. On Earth, Man has made the brick and the cubic form his own over thousands of years of architectural development. In Space it may be that men and women make the pneumatically stressed tensile lattice their own, and its constituent zonahedral cells, particularly the basic acute and oblique Ø parallelepipeds.

These abstract formal notions are conditioned somewhat in the process of giving tangible expression. Firstly the geometry the author has elected to use is that of the six-zone star of the vertices of the regular icosahedron. The overall bounding polyhedron is a regular rhombic triacontahedron. This is then subdivided in a quasi-crystalline manner into a short 5-zone rhombic triacontahedron on axis, five acute Ø parallelepipeds, which cluster about the main axis, and five oblique Ø parallelepipeds. The effect of this subdivision is to transform the icosahedral-dodecahedral polyaxial

symmetry of the whole complex into monoaxial fivefold symmetry. In developing monoaxial differentiation, the clustering establishes one male axis of the six male, ten female and fifteen neutral axes of the enveloping rhombic triacontahedron as being primary to the spatial and existential articulation of the dwelling.

The mathematics of the elements of this clustering are presented in the author's *Integral Space Habitation - Towards an Architecture of Space*.⁷

Relevant data is here given for surface diamonds of edge length $\sqrt{(\emptyset + 2)}$, with diagonal lengths of $2\emptyset$ and 2 .

Thus the tensile ties which structure the space habitation are in the proportion $\sqrt{(\emptyset + 2)}$, which is conveniently taken to correspond with an actual length of 9 ft. 4", that is phi times the height of a 5 ft. 9" man, and giving diagonals of the surface diamonds of 15 ft. 10 1/2" and 9 ft. 9 3/4":

Conversion factors:

length: "1" = 4.906824 ft.

area: "1" = 24.076918 sq. ft.

volume: "1" = 118.141195 cu. ft.

$\emptyset = (\sqrt{5} + 1) / 2 = 1.618...$

Zonahedron edge length $\sqrt{(\emptyset + 2)}$	Axial Diameter Vertices	Transverse Diameter (Vertices)	Dihedral Angle(s) ($2\pi = 1$)	Solid Angle(s) ($4\pi = 1$)	Sum Solid Angles	Sum Surface Area	Volume
Regular 6-zone Phi Rhombic Triacontahedron	$2\emptyset\sqrt{(\emptyset + 2)}$ = 30.16 ft.	$2\sqrt{3}\emptyset$ = 27.46 ft.	$8/20$	$5/20$ $7/20$	10	$60\emptyset$ = 2,320 sq. ft.	$20\emptyset^3$ = 10,009 cu. ft.
Short 5-zone Phi Rhombic Triacontahedron	$\sqrt{5}\sqrt{(\emptyset + 2)}$ = 20.84 ft.	$\emptyset\sqrt{(3\emptyset + 7)}$ = 27.3 ft.	$8/20$ $6/20$	$5/20$ $4/20, 7/20$	6	$40\emptyset$ = 1553 sq. ft.	$10\emptyset^3$ = 5,004.5 cu. ft.
Acute Phi Parallelepiped	$\sqrt{3}\emptyset^2$ = 22.22 ft.	$\sqrt{(\emptyset + 6)}$ = 13.52 ft.	$4/20$ $6/20$	$1/20$ $3/20$	1	$12\emptyset$ = 466 sq. ft.	$2\emptyset^2$ = 618.6 cu. ft.
Oblique Phi Parallelepiped	$\sqrt{3}/\emptyset$ = 5.25 ft.	$\sqrt{(5\emptyset + 6)}$ = 18.4 ft.	$8/20$ $2/20$	$7/20$ $1/20$	1	$12\emptyset$ = 466 sq. ft.	$2\emptyset$ = 382.3 cu. ft.

One envisages this primary axis as being imbued with cosmic significance; ideally parallel to the primary axis of rotation of the entire space habitation complex, itself perhaps aligned with the Sun, or parallel to the axis of rotation of the Solar System, or of the Galaxy, or of the local cluster of galaxies etc.

This subdivision of the whole provides one large space, five equivalent medium spaces, and five equivalent small spaces. These are in the volumetric ratio:

6-zone Regular Rhombic Triacontahedron	:	5-zone Short Rhombic Triacontahedron	:	Acute Phi Parallelepiped	:	Oblique Phi Parallelepiped
$20\emptyset^3$:	$10\emptyset^3$:	$2\emptyset^2$:	$2\emptyset$
$10\emptyset^2$:	$5\emptyset^2$:	\emptyset	:	1
26.18	:	13.09	:	1.618	:	1

The large space (which is thus precisely half the volume of the entire space habitation) constitutes the living room/lounge, and is for general relaxation and entertaining guests. The space also acts as a courtyard onto which the five medium spaces open, and as a means of connection to pass from one of these to another. One of the medium spaces (the acute \emptyset parallelepipeds) comprises an entry vestibule, with portal to the outside, through connection to the lounge, and side access to two adjoining acute \emptyset parallelepipeds. One of these adjoining acute parallelepipeds is the kitchen, and the further acute \emptyset parallelepiped adjoining it is the dining alcove which opens off the kitchen, and also off the main lounge.

The second adjoining acute \emptyset parallelepiped to the vestibule acute \emptyset parallelepiped is the bathroom/laundry; again one passes through that to reach the further adjoining acute \emptyset parallelepiped, which is the master bedroom, which is also accessible directly from the lounge.

Thus vestibule, dining alcove and master bedroom each open onto the lounge, whilst kitchen and bathroom are connecting spaces between the vestibule and the dining alcove and master bedroom respectively.

The five oblique \emptyset parallelepipeds, the small spaces, are service spaces used for storage and service requirements, opening off the other spaces. Although large enough to enable the occupant to pass through, they would

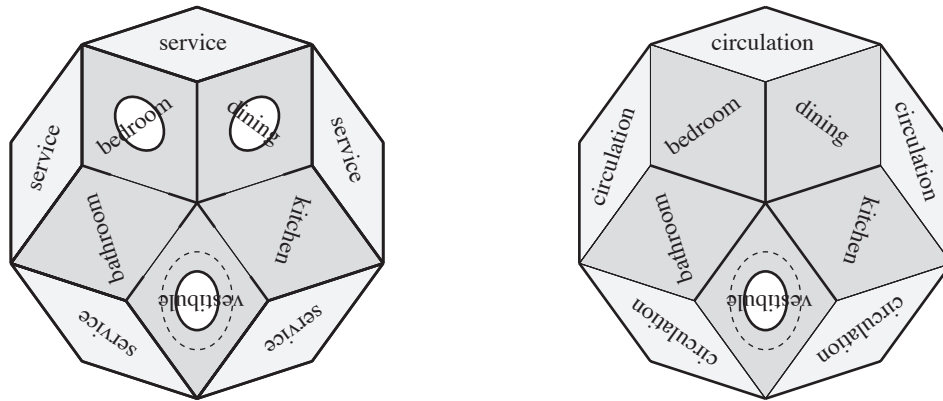


Figure 1: Axial Section of medium acute \emptyset and small oblique \emptyset parallelepipeds - Alternatives 1 and 2

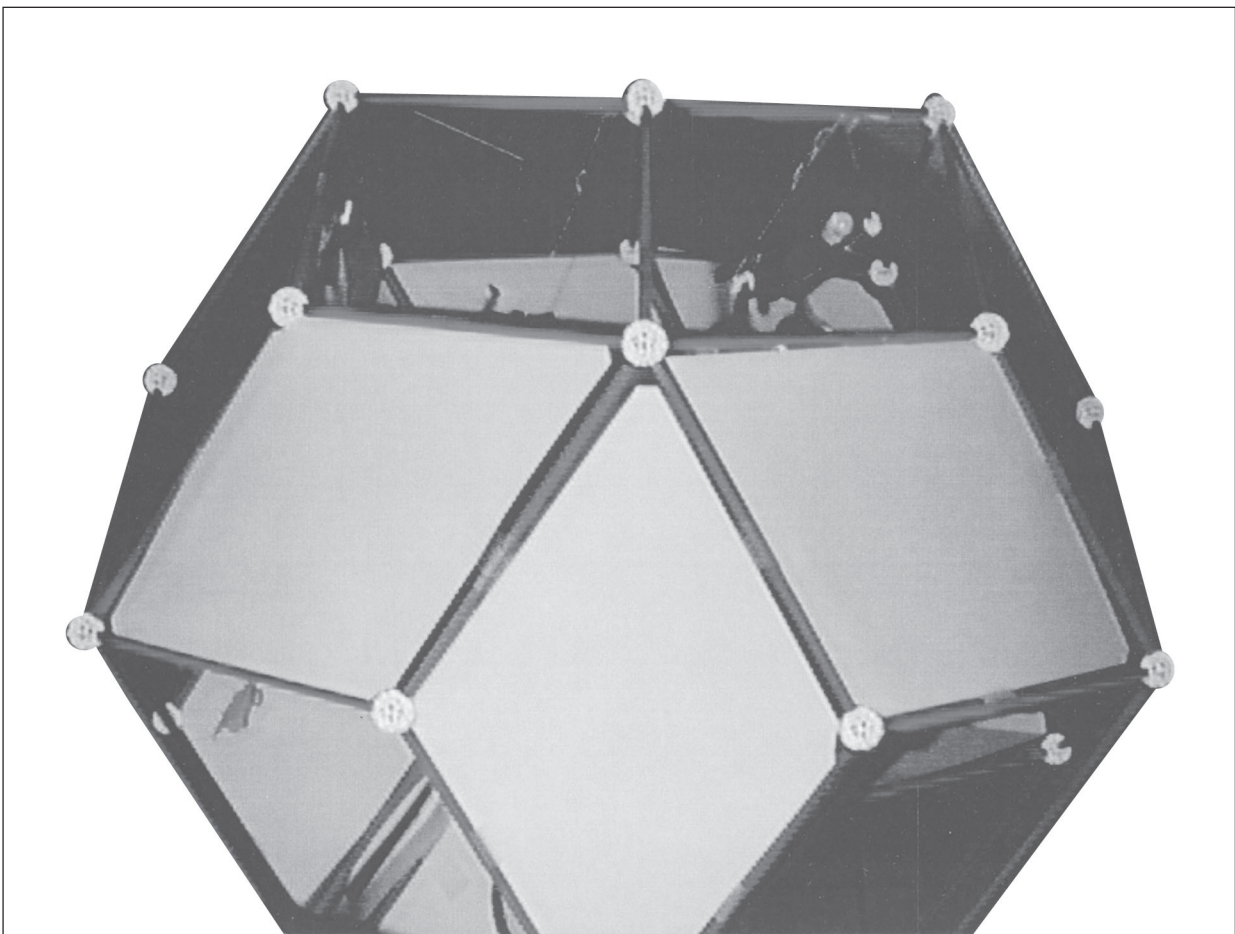


Figure 2 : View of the Individual Integral Space Habitation

normally be subdivided (conveniently into thirds and sixths) to provide adjunct sub-spaces.

Thus the main lounge consists as it were of two flattened hemispheres; with ten diamond faces of one hemisphere to the outside of the space habitation, and ten diamonds of the other hemisphere to the inside, of which three contain portals to the vestibule, dining room, and master bedroom respectively.

It will be appreciated that this is the preliminary sketch design of a conceptually new architectural schema in microgravity. The spaces and their arrangement are open

to criticism from a sophisticated architectural perspective; for example the modularity of the medium sized spaces does not accommodate the diverse functions for which they are utilised without considerable compromises. Nevertheless, the spatial schema does serve to clearly illustrate the type of space habitation that is envisaged. Later schemes will provide ample room for refinement.

The structure consists of equal length tensile ties in parallel bundles, and its size is determined by the thickness between opposing faces of the acute \emptyset parallelepipeds, relative to the human body. That is, the separation of these

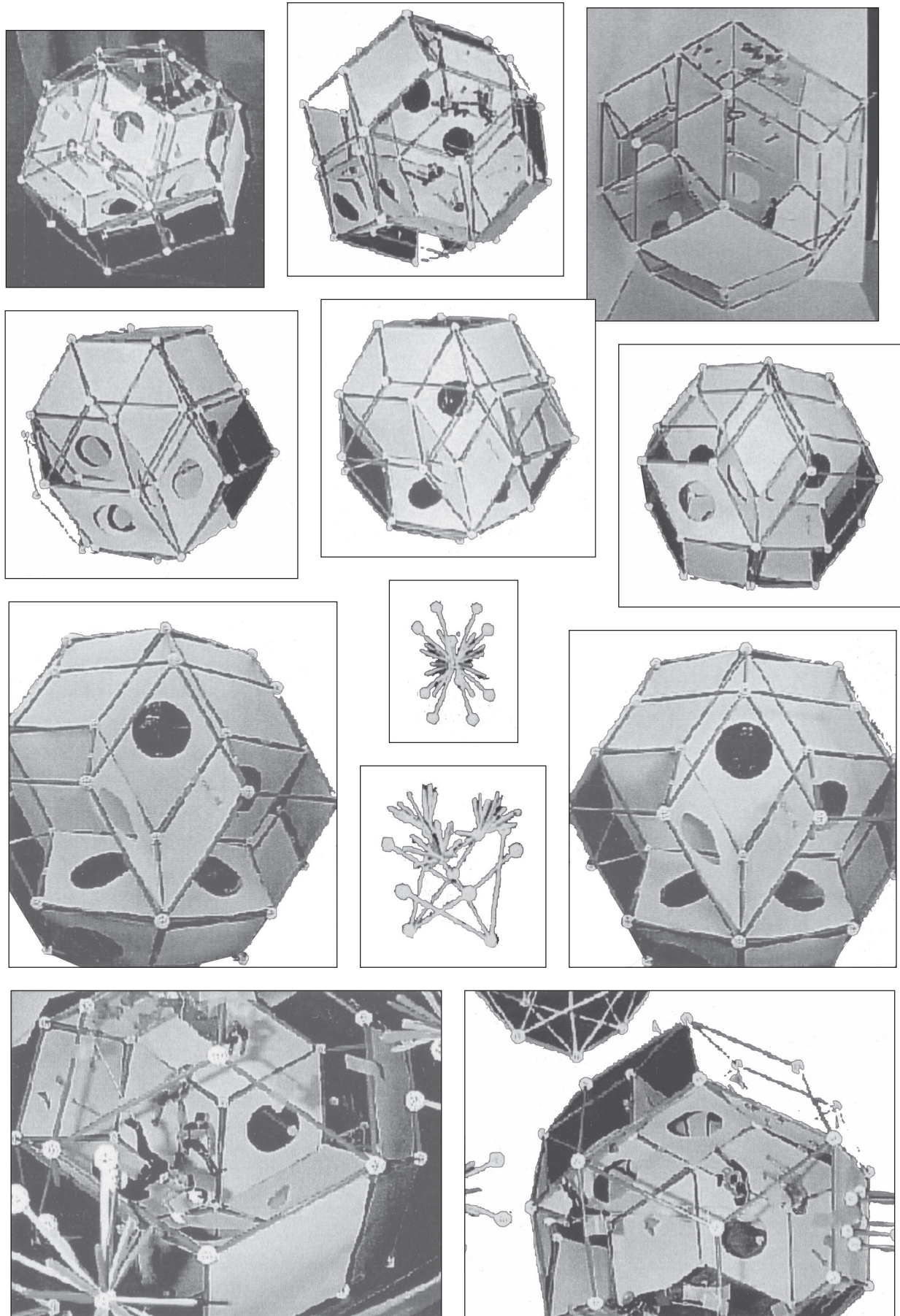


Figure 3 : Views of the Individual Integral Space Habitation

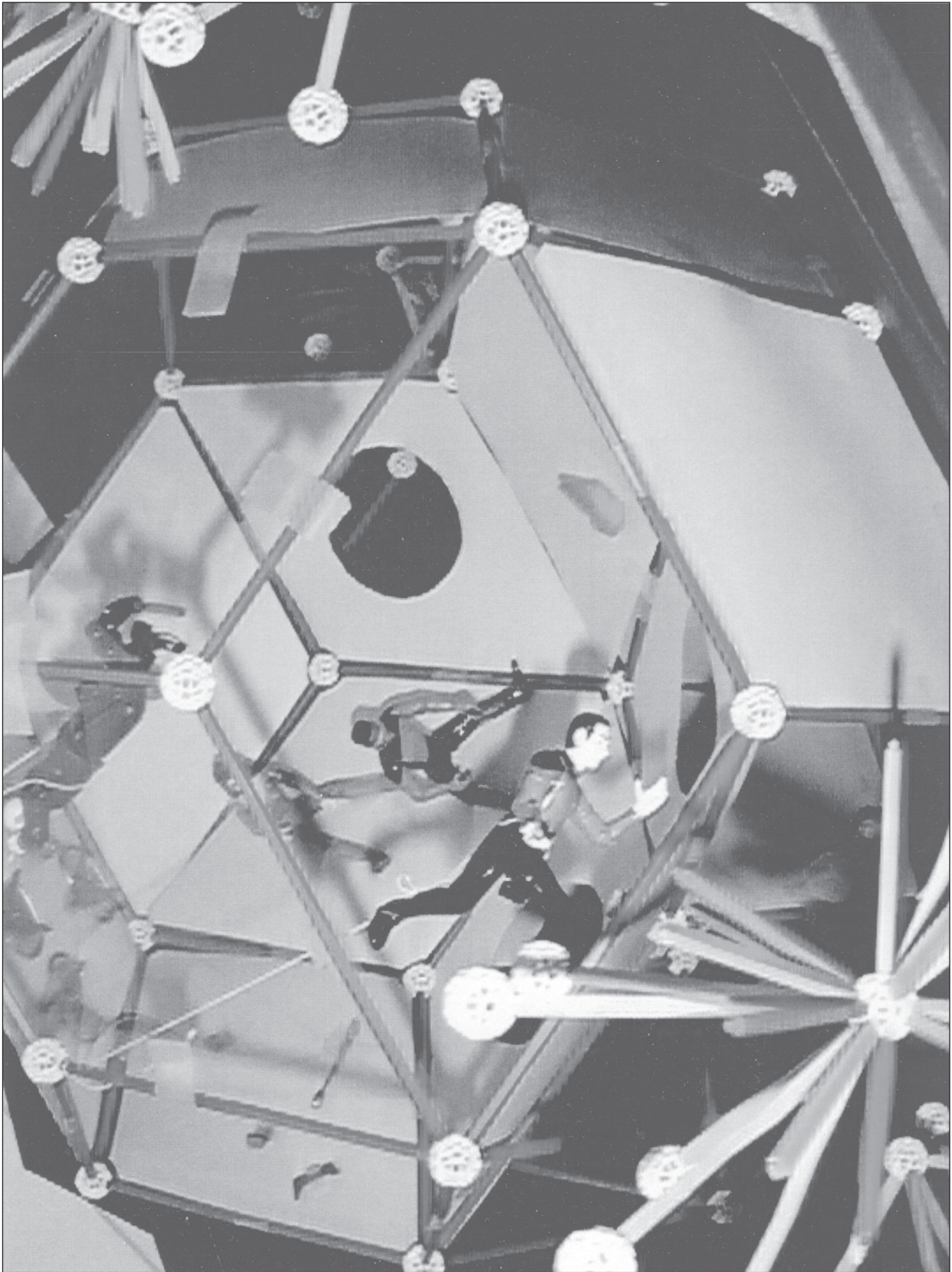
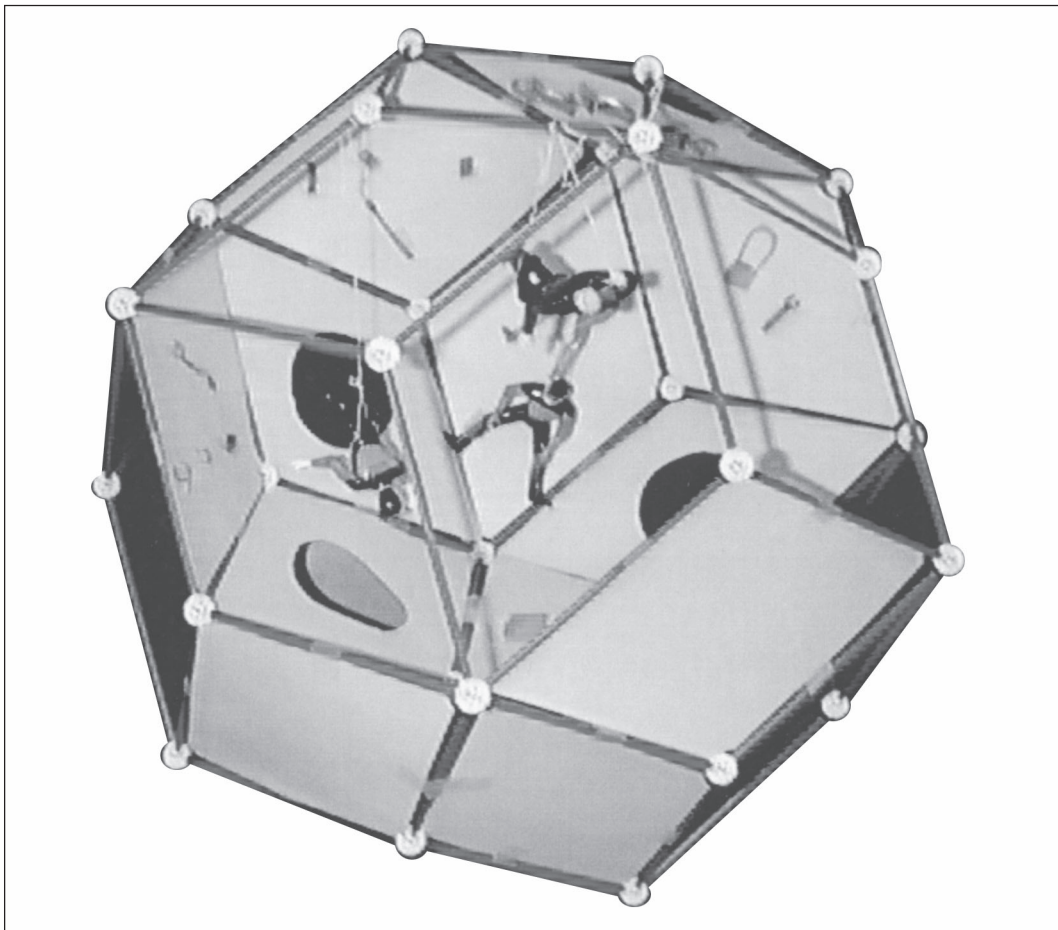
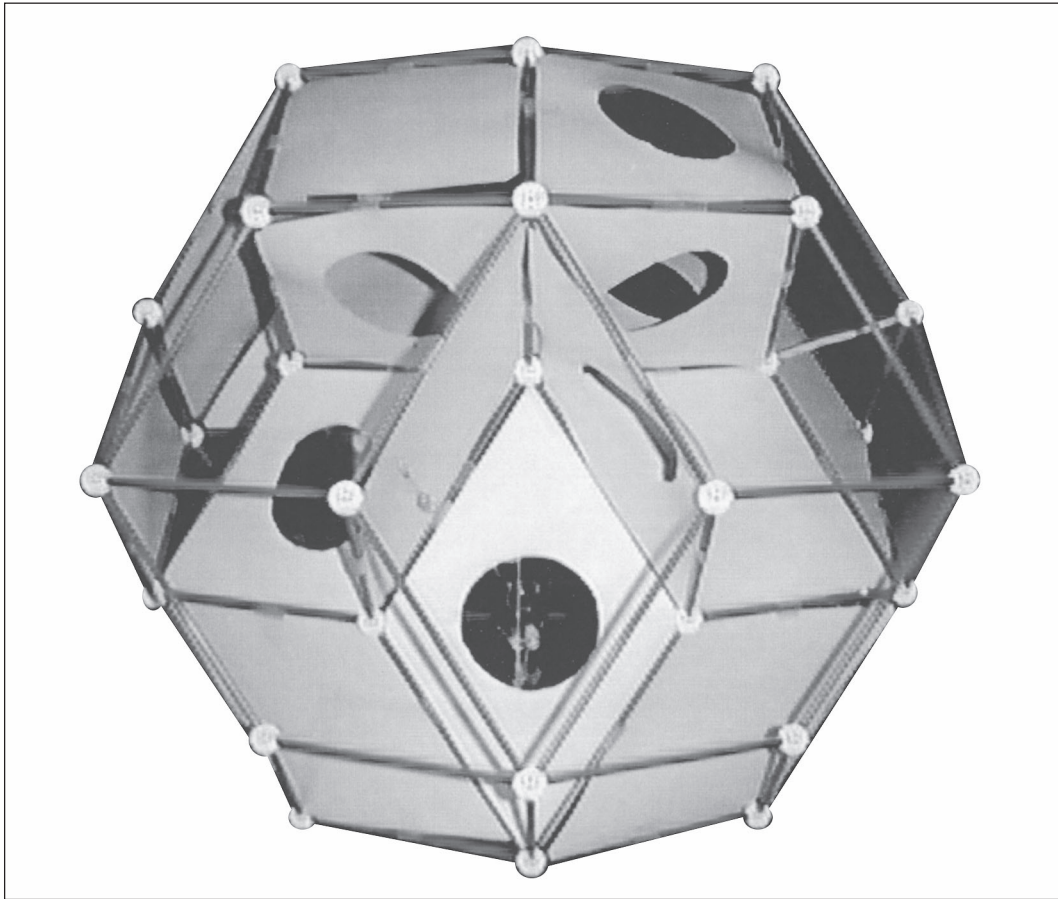


Figure 4 : View of the Individual Integral Space Habitation

Figure 5 (opposite) : Views of the Individual Integral Space Habitation



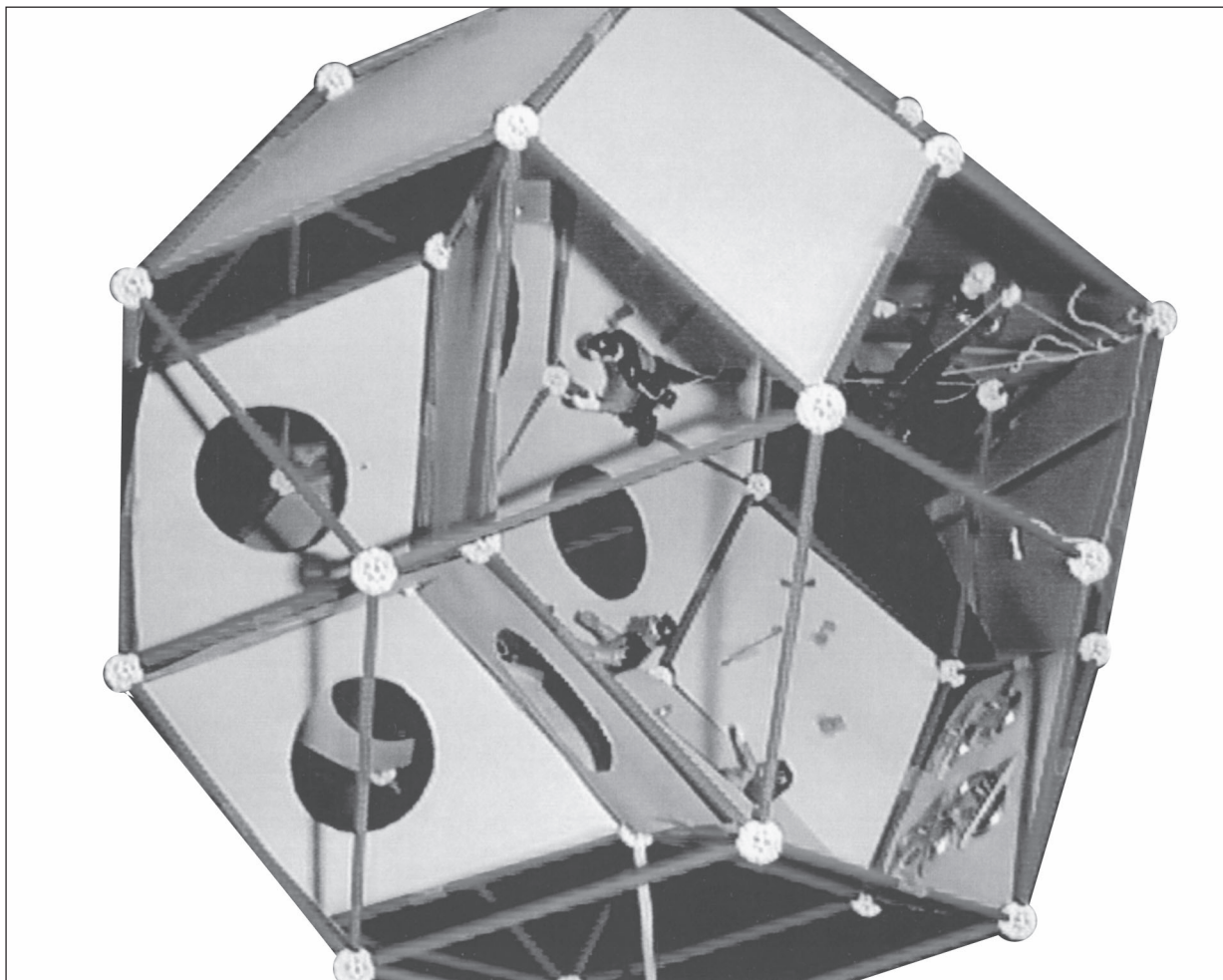


Figure 6 : View of the Individual Integral Space Habitation

walls is presumed to be that convenient to spinning about in microgravity - with arms and legs extended, contact is made with these opposing walls to provide a bearing surface to reorient one; by contracting the extremities into the body, clear separation is provided to enable turning. The volumes of these acute \emptyset parallelepipeds are large enough to facilitate the purposes for which they are intended; these spaces would in normal use only house one or two people in fairly intimate proximity. Nevertheless at this scale, the main lounge is generous and permits relatively vigorous movement if desired, and the entertainment of several people.

In relaxation within the main lounge, one of the hemispheres would be primarily a resting surface against which one cushioned oneself, and was restrained, by

velcro; whilst the other hemisphere functions more as a visual relief and communications surface, with lighting, views, projections, television screens, etc.

One envisages the occupant (and his guests) in continuous gentle movement, gently bouncing off surfaces and being wafted through the habitation in the course of the diverse existential components of his dwelling, as he proceeds on his daily round. And the entire assemblage moves gently with the internal resonances and equilibrating of internally generated stresses, and the imported stresses from the secondary tensile lattice of the entire space habitation lattice as it in turn responds to the dynamic stress patterns of the primary tensile lattice. One envisages the gentle movement of the space habitation as being akin to the gentle wafting of a jellyfish in the ocean...

- 1 Further information is available from Marc Pelletier, BioCrystal Inc., P.O. Box 7053, Boulder CO 80306, USA, ph. (303) 786 9888, fax (303) 786 7312, web page <<http://www.zometool.com>>.
- 2 Meurant, Robert C., *The Integral Space Habitation ~ Towards an Architecture of Space*. The Opoutere Press, 1989.
- 3 Meurant, Robert C., *Structure, Form and Meaning in Microgravity - the Integral Space Habitation*. International Journal of Space Structures, Multi-Science Publishing Co. Ltd., Brentwood, Vol. 5 No. 2, 1990.
- 4 See the author's *Radical Tradition*, The Opoutere Press, Auckland, 1989.
- 5 See the author's *A New Order in Space - Platonic and Archimedean Polyhedra and Tilings*. International Journal of Space Structures, Multi-Science Publishing Co. Ltd., Brentwood, Vol. 6 No. 1, 1991.
- 6 In addition to the author's *Integral Space Habitation* (1989) and *Structure, Form and Meaning...* (1990), see his *The Aesthetics of the Sacred*, The Opoutere Press, Auckland, 1989.
- 7 Op. cit., pp. 30-1.