Close-Pack Modules for Manned Space Structures

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Introduction

CURRENT space station planning focuses on the cylindrical pressure vessel module, a natural carryover from Earth-based technology. However, for this application, there are many drawbacks to the cylinder as the basic building block. Access to the various regions of a multimodule system is cumbersome. The volume of any one module is limited by the booster capacity. There is much redundant mass in a multimodule grouping, i.e., clustering cylinders so that their parallel sides touch to form, in effect, a large, one-cylinder-length-thick disk indicates that the walls on the outermost aspects (forming the faces and edge of the disk) are the only necessary walls, assuming, of course, adequate sealing. There is no option to spin the most publicized of the current designs for artificial gravity since, for example, the induced loads pass through the seal regions. Adding open framework is cumbersome.

To bypass these restrictions while retaining the modular concept, close-packable (all-space) polyhedra will considered here as the basic building blocks. Examples of polyhedra that can be stacked face to face so that there is no space between them in three dimensions are the cube, certain irregular tetrahedra, and a combination of octahedra and regular tetrahedra (regular tetrahedra without octahedra interspersed are not all-space filling) as well as other possibilities.[1] Because of reasons that will become apparent, we will concentrate on the irregular tetrahedra, specifically the isosceles tetrahedron. (See Fig. 1.)

Since all-space polyhedra form a continuum infinitely extensible in three dimensions, a multi-module grouping can be thought of as a solid block of material that may be sculpted into virtually any shape. Thus, cylinders, disks, spheres, and spoked wheels are examples of common spinable shapes of virtually any size that can be developed with only the isosceles tetrahedron module of a given size. A three-dimensional triangle-based network is formed with the option to remove internal modules or parts thereof for unobstructed volume and reuse of material to continue building outward with a minimum of mass. In groupings of a few modules, possible shapes include closed tubes of any length of triangular, square, and hexagonal cross sections.

Construction Features

The basic module consists of a separate frame on which removable panels are mounted. (See Fig. 2.) The seals make the intermodule boundaries as well as the module itself airtight so that cabin pressure is maintained on removal of redundant components as the structure grows. (See Fig. 3b) Loading is through columnar compression and tension of the frames; there is no appreciable loading through seals and panels. The intermodule portion of the seal would account for possible misalignment of module faces, simplifying intermodule connections and eliminating shearing of seals. Since modules are interconnected through receptacles at the corners of the frame faces with locking pins (Fig. 4), there are no bending/twisting loads through the frames, seals, or panels that might tend to degrade the seals or bind the removable panels. The locking pins are retractable so that a new module may be snapped to an existing complex grouping without binding.

The frames themselves are composed of extrusions of angle stock joined at the corners so that partial or total disassembly is possible in order to remove redundant members as the structure grows. Such take-apart frames also permit efficient transport by booster, reuse for new orbital constructions, and panel removal.

The panels are of stamped sheet stock with radially directed stiffeners in back of the seal region (Fig. 5). All panels are identical. This is a principal reason for choosing the isosceles tetrahedron over two other all-space filling tetrahedra—the duplication of only one panel and two frame members (identical but for length).

The seals must hold integrity for at most a few cycles of panel removal, unlike the small round reusable hatches of cylindrical modules. (Of course some such reusable hatches will be required.) This permits the option of supplementary sealing compounds. With take-apart frames it is also necessary to seal frame joints. This is done by a one-piece frame seal that is the shape of the inside of the assembled frame, covering the entire inside and a portion of the outside

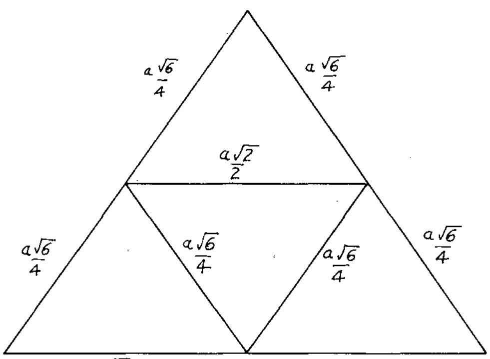

Fig. 1 Pattern for isosceles tetrahedron as defined.[1]

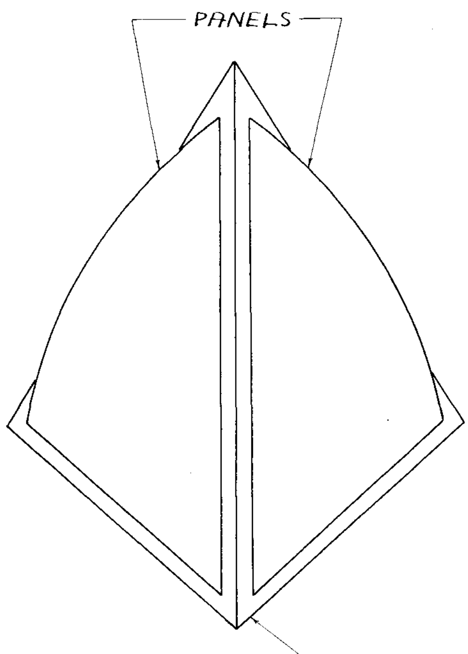

Fig. 2 Isolated module with frame in the form of an isosceles tetrahedron and an outwardly bulging removable panel on each of the four faces.

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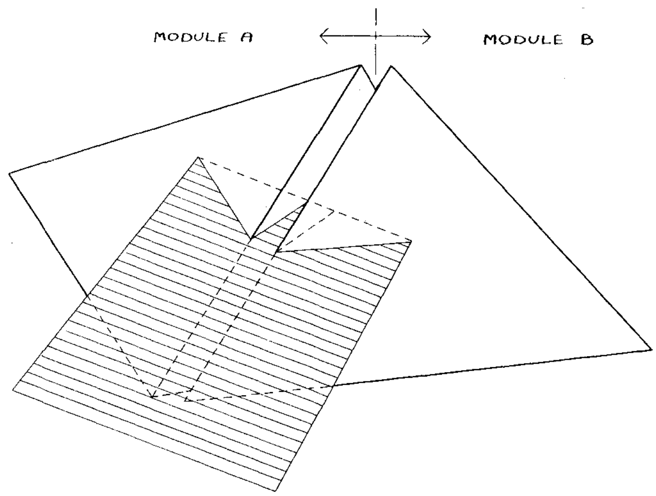

Fig. 3a Two modules face to face, indicating the cutting plane for the section view of Fig. 3b.

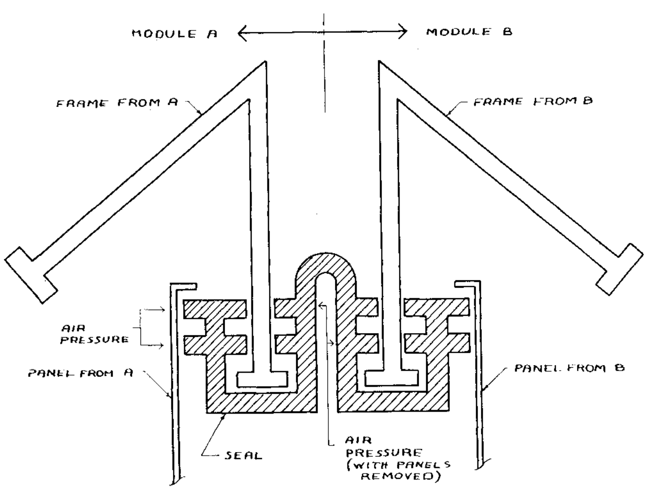

Fig. 3b Cross-sectional schematic view of the seal region between two different modules, indicating the relationship of principal components. When two modules are placed face to face as shown, both of the panels illustrated would normally be removed to provide a large unobstructed volume; at least one of the panels must be removed due to the outwardly bulging panel forms. "T" sections on frames balance corner "V" sections, providing necessary rigidity in the seal regions for potentially high columnar loading, and also hold seals in place before air pressure is applied.

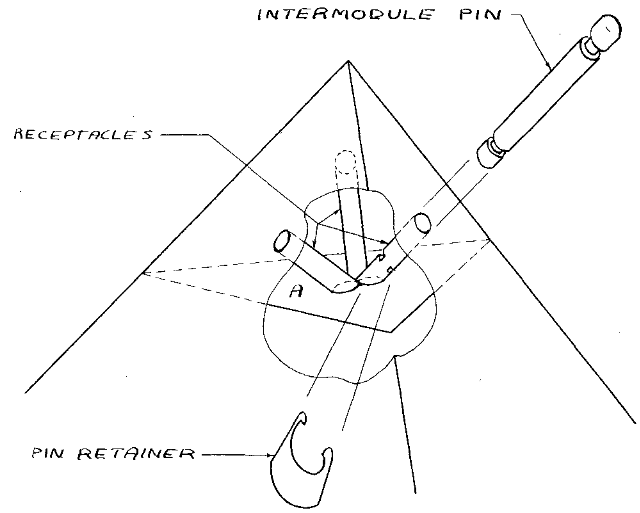

Fig. 4 Schematic of any corner region of any module indicating intermodule connecting pins, receptacles, and pin retainers. Access to the retainers is from inside the module through plate A, so that pins may be fastened and released when the corner is completely surrounded by other modules.

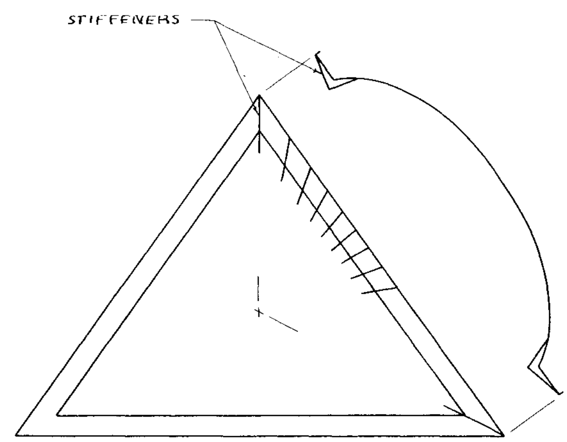

Fig. 5 Back of panel indicating radial stiffeners at the seal region. The outwardly bulging forms obviate the need to extend stiffeners, minimize weight, and provide more usable volume, especially in small complexes.

frame surface. The panel seals are positioned over this mounted frame seal, one for each of the four faces. Each panel seal is common to an adjacent module face, sealing both modules (with one or more common panels removed). In other words, the panel seals serve two functions: maintaining the integrity of each separate module, and the integrity of a large unobstructed volume composed of parts of many modules. As shown in Fig. 3b, the panel seal and intermodule seal are two aspects of the same component.

Concluding Remark

It is hoped that the design flexibility permitted by the adaptation of close-pack polyhedra will resolve some of the conflicting requirements for permanent manned space facilities.

Reference

[1]Fuller, R. B., Applewhite, E. J., and Loeb, A. L., *Synergetics,* Macmillan, New York, 1975, pp. 531-554, 836-855.