

Hybrid Deployable Habitat Structures for Orbital and Lunar/Planetary Applications

Larry Bell

Sasakawa International Center for Space Architecture (SICSA), University of Houston

This is a work of the U.S. Government and is not subject to copyright protection in the United States.

ABSTRACT

Extended-duration space missions entailing expanded crew sizes and activities will produce a need for habitats that combine advantages of conventional hard/fixed and soft/deployable structures. Rigid modules enable pre-integration of utility and equipment systems prior to launch and apply proven technologies. Soft pressure vessels can be compacted to optimize launch payload volume and habitable volume/mass efficiencies, but impose hardware integration challenges, operational readiness requirements, and long-term structural performance uncertainties. This paper discusses concepts and applications that incorporate both approaches. Examples draw upon research and design investigations undertaken by SICSA in support of a NASA-sponsored study conducted by two independent teams, one headed by Boeing, and the other by ILC-Dover. SICSA had key roles in developing overall configuration architectures for both teams.

DEPLOYABLE SPACE STRUCTURES BACKGROUND

The design of habitable space structures must take a broad variety of demanding requirements into account. For example they must typically be stiff enough to accommodate to securely attach external and internal elements throughout rapid launch velocity changes, dampen or isolate vibrations, withstand internal pressures, and avoid thermal stress fatigue. They must shield crews and sensitive equipment from dangerous galactic and solar radiation, orbital debris and/or micrometeoroid damage on lunar/planetary surfaces. They must fit within launch shrouds, and comply with stringent mass budgets and CG placement constraints.

They should be easily and rapidly deployable for operational readiness with least possible human assistance, and provide means for evolutionary changes and growth interfaces with other facilities. And they should provide adequate volume and support systems to serve functional prerequisites throughout protracted design lines.

Conventional "hard" modules apply construction methods that have proven effective throughout the history of human spaceflight. They are simplest to fabricate and deploy, offering dependable structural integrity and reliability that has been demonstrated in harsh space environments. Utility and equipment systems can be installed and checked out prior to launch, and they afford solid attachment points for windows, hatches, berthing ports and other pressure-resistant fixtures. In addition, material failure points and related structural safety factors are well understood. Figure 1 presents a few of many representative examples.



Figure 1. Conventional Structures

Although conventional modules have versatile applications, they also present certain limitations when compared with other potential approaches. Internal capacity expansion can only be accomplished by adding other modules, and the habitable volume in each is constrained to conform within the diameter and length dimensions allowed by the launch vehicle. Accordingly, utilization of these relatively small, fixed modules can require several launches, orbital rendezvous and complex assembly operations to achieve ultimately desired functional capabilities.

Typical modules have “primary structures” that provide structural integrity and attachment features (Figure 2).

- Longerons increase stiffness and load-carrying capacities.
- Ring frames provide attachment points for longerons and panels that resist pressure loads.



Primary Structure of a Typical Module

Figure 2

Telescoping modules such as the SICSA concept illustrated in Figure 3 can potentially offer a means to expand hard shell volume using relatively conventional technology. One hard section would slide into another to shorten the undeployed length during launch/landing for a lunar/planetary application. The inner section would have utility systems and equipment pre-integrated and checked out in advance. Following deployment the vacated outer section can be outfitted for equipment connections using extendable/modular utility lines put in place by crews. However telescoping and pressure seal clearance requirements will restrict viewing and docking ports to endcap locations.



Figure 3. Telescoping Hard Modules

“Inflatable” (or pressurized pliable-walled) structures are less proven than conventional hard modules for space applications but date back more than 40 years when first used as an airlock on the USSR Voskhod-2 spacecraft in March, 1965. Soviet space program founder, Sergei Korolev, commissioned the development to enable cosmonauts to work outside the spacecraft without depressurizing the ship. While the concept worked well, a design miscalculation nearly resulted in tragedy. The airlock’s small hatch was undersized, almost preventing Alexii Leonov’s re-entry due to unexpectedly large pressurized dimensions of his space suit (Figure 4).

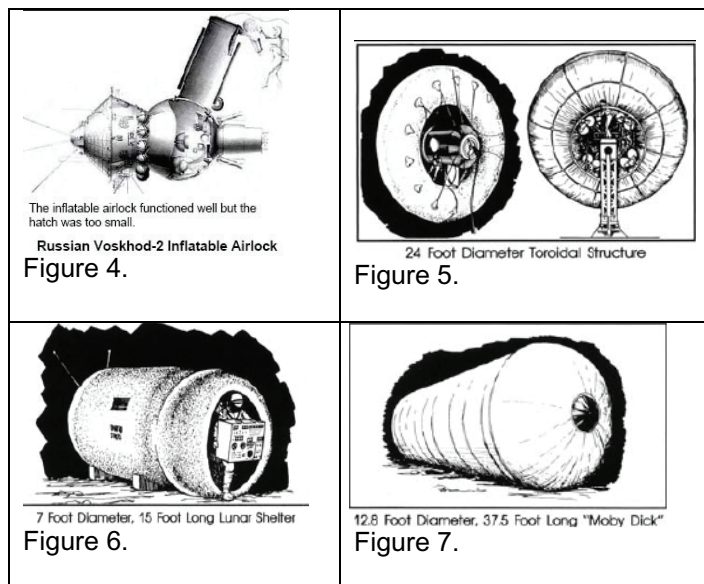
Inflatable space structures continue to gain interest as a strategy for creating spacious habitable environments in orbit and on lunar/planetary surfaces that can be fitted within relatively small-diameter launch and transfer vehicles. NASA recognized potential benefits of this possibility during the 1960s when they first funded the Goodyear Aerospace Corporation to develop and test various inflatable module prototypes. The largest was a 7.3m outside diameter toroidal structure that had a deployed volume of 65m³ and could be packaged into a 2.4m diameter launch vehicle. The module weighed approximately 0.12g/cm² of surface area (Figure 5).

In 1965 GAC developed an inflatable lunar shelter concept which was proposed to support two-person crews for periods of 8-30 days. Given the fact that the Moon has no atmosphere to reduce micrometeoroid hazards, the structure incorporated outer and inner layers of a polyamide nylon fabric (similar to bullet-proof vest material) for ballistic shielding. The intermediate structure between these layers was comprised of closed-cell vinyl foam for radiation and thermal protection. The total module and airlock volume was 14.6m³ (Figure 6).

GAC also developed a larger 11.4m long lunar module design in 1968. The structure was constructed of a

4.3mm pressure bladder covered by 44.4mm thick, flexible, polyurethane foam and an outer nylon fabric laminate layer. The structure weighed 735.7kg, and was designed for 5psi pressure (Figure 7).

Goodyear developed and fabricated two expandable/pliable crew transfer tunnels for space during the 1960s-1970s. The first was a 3.65m long element in 1966 to connect a Gemini capsule to the Skylab space station's Manned Orbital Laboratory (MOL) crew quarters under contract with the US Air Force Propulsion Laboratory.



The second was a 4.3m long flexible section to connect the Space Shuttle Orbiter's crew cabin and Spacelab module. It was developed under contract with McDonnell Douglas for the NASA Marshall Space Flight Center in 1979 (Figure 8).

In 1967 GAC developed a 1.89m long inflatable airlock that was designed to be mounted on a Skylab-type spacecraft. The structural pressure layer used a 3.6 mil filament-wound wire for tensile strength. Flexible polyurethane foam provided a micrometeoroid barrier, and a fabric-film laminate offered thermal control. (Figure 9)

Goodyear's experimental tests demonstrated that the early designs afforded many advantages, including compact packaging, easy deployment, low leak rates and good structural integrity, but did not meet upgraded NASA fire safety requirements. This problem was later overcome in the 1970s when the company successfully tested a nonflammable wall using a 50.8mm thick "XTC-4" combination of laminated materials that incorporated an "XPB-14A" flame/gas barrier (Figure 10).

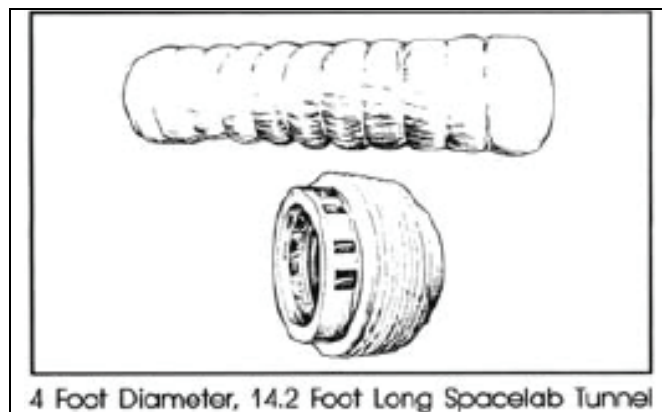


Figure 8.

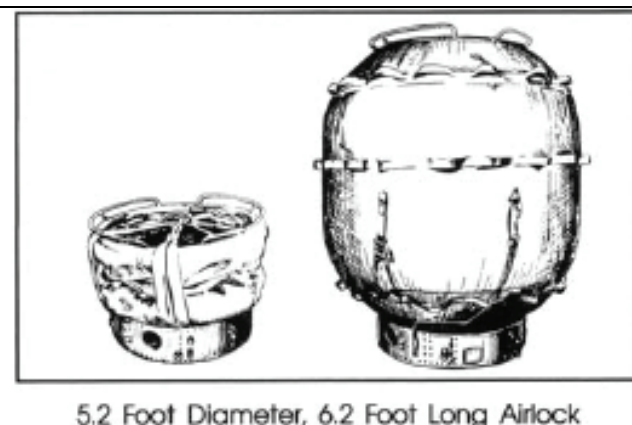


Figure 9.

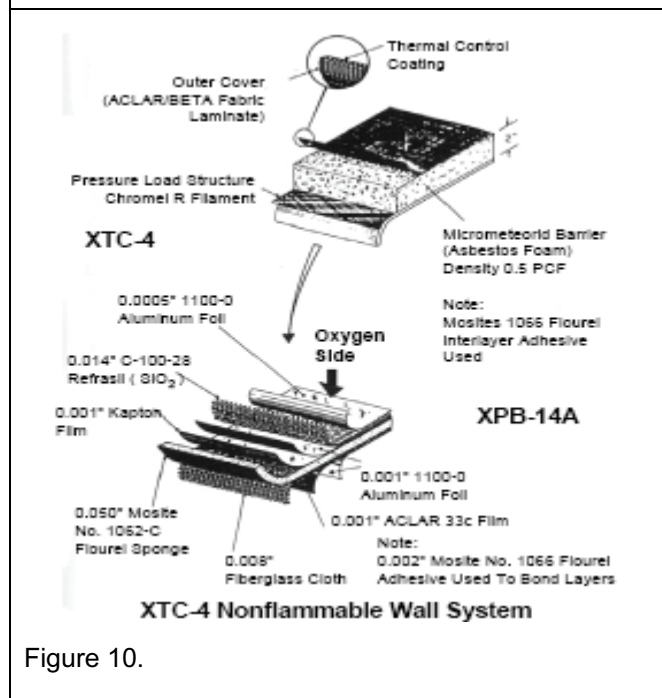


Figure 10.