The Space Place – The Place For Space

Space is the Place

Thomas Lee Elifritz
The Archimedes Group, Marshall Space Flight Center, Marshall, Wisconsin USA

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The cryogenic fuel tanks of large upper stages are the ideal places to develop the colonization of space. In this paper I will discuss my early work on the design and construction of hydroponic grow rooms in regard to modern closed ecological life support systems in small inflatable spheres and airlock systems.

In the mid 70s, shortly after initial work on lunar mass drivers and space colonies by Gerard K. O'Neill, a flourishing underground industry developed involving artificial lighting and indoor hydroponic plant growth in sophisticated grow rooms. These quickly grew into large and technologically advanced plant production facilities, rivaling anything ever anticipated or produced by NASA for human space flight. Early results were self published in a manuscript entitled '*The Hydroponic Nutrient Solution*', shipping out with every automated robotic gravity driven hydroponic plant growing system leaving my factory. Nutrient solutions were presented in terms of the Steiner universal anion and cation triads with nutrient solution uptakes in minimally buffered, continuously variable reservoirs verified by flame photometry. The initial technological breakthrough enabling lighting for such operations was the tubular fluorescent light bulb followed by high intensity discharge metal halide arc lamps developed for industrial lighting.

Modern space habitats will consist of inflatable sphere pressure vessels, capped by reinforced hatches, in a tire hub arrangement inflating directly into upper stage fuel tanks of large reusable launch vehicles. Hub berthing rings and airlock hatch plates may be connected together by multiple cables, in order to further stabilize the vessel, particularly in the anticipated low gravity environments such as the moon, or on large slowly rotating space habitats. Inflation of habitation spheres directly into the internal space of lightly pressurized metallic and insulated upper stage fuel tanks will greatly simplify their design, allowing them to stow flat inside the tops of fuel tank domes, and deploy directly into the empty tanks.

The geometry of internal inflatable habitation spheres resemble modern illuminated Chinese lanterns. Rigid hardware is incorporated into two opposable flat pressure hatch plates and rings, which are very nearly identical. Flanges and grooved rings serve as pressure seals and rims for the inflatable spherical habitat tubes on the internal sides, and as docking node seals and clamps on the outer sides. The hatch plates are pressure sealed and open hinged internally into the inflatable habitat. Hatch plate structural rings are secured together with a lightweight cable lattice or array, to inhibit torquing and swaying of the inflated spherical structure and to guard against gravity stresses if they exist. The geometry of the load bearing fiber layer and gas bladder are greatly simplified, and may be stowed flat into the closed cavity formed by the two hatches in the retracted position, and integrated into the top of the upper stage fuel tank dome. Alternatively the structure may be folded and pressed flat against the upper surface of the fuel tank dome and protected by a membrane for the brief time it is in contact with cryogenic fuels during the loading and launching of the vehicle. Topological considerations favor the latter approach.

Modern lighting systems consist of arrays of broad spectrum LEDs powered by solar electric energy. Entropy considerations demand passive techniques for delivering raw light into closed and pressurized space habitats and dissipating that heat, increasing the efficiency of delivery of natural light for plant growth, and reducing the cost, weight and complexity of the lighting system. The central portion of each hatch plate contains a transparent window to allow outside light to be piped in and then reflected in stages, outwards onto surfaces of the inflated tori, as it cascades down through the habitats. Darkness may then be easily created by deploying an temporary expandable reflective cylinder down the light pipe or tube channel, without disrupting the light flow though multiple windows, hatches and habitats.

No thermal, impact or radiation protection will be included in the inflatable segment, greatly decreasing its packed size, weight and overall complexity. Minimal components necessary in this environment will be the pressure containment netting or cordage, and the flexible polymer pressure containment vessel. With the vastly reduced material loads, the pressure vessel can be collapsed and either twisted or folded into a flat thin space located between the opposing metal pressure plates and positioned at the top of the fuel tank - completely protected and never fully immersed or in direct contact with the cryogenic fluids. An alternative pressure sphere collapsing strategy involves the external stowage of the flexible pressure vessel and load bearing cordage outside of the hatch plates, and up against the upper fuel tank dome, as one would flatten a Chinese lantern. This technique eliminates any oblique pressure stresses along the attachment ring, as the membrane and cordage no longer needs to be folded back across the raised rim that is necessary to create the stowage space. This requires a separate cryogenic fluid protection barrier, and necessitates an alternative fuel tank filling port and mechanism farther down through the tank wall.

An innovative new concept immediately presents itself for sphere folding and deployment – 'wringing', which is particularly suitable for low gravity environments. A pair of separated flat circular pressure plates with a rigid pressure locked seal to the tubular membrane and netting, can literally be twisted closed with the fabric forming a topological loop which naturally forms a coil storable in a flat position. Retraction and deployment of the habitat, particularly in a low gravity environment, consists of simply dropping it down into the vertical tank and allowing it to 'spin out'. This novel and new idea can be easily modeled on a sub scale basis in ambient atmosphere and small vacuum chambers. In ambient atmosphere the inflatable spheres and cryogenic oxygen and fuel tanks can be over pressurized to 1.5 and 2-3 atmospheres. Various pressure differentials from zero to several atmospheres can be tested, as well as a wide variety of air pressure leaking and pressure vessel rupture scenarios, with little danger.

Regardless of the folding strategies for thin walled membrane style spherical pressure vessels, it is clear that a wide variety of material, design and operational strategies can better be tested at the small scale. Properly designed hatch plates could support sequences of spheres within pressurized cylindrical upper stage fuel tanks greatly increasing the value of such a system for space based refugia and cargo storage. In addition to producing the scalable components for space development and colonization architectures, inflating pressurized habitation spheres with external and internal hatches into prepressurized cylinders allows the internal empty and unused fuel tank space to be used as storage space for cargo, supplies and waste, i.e. - radiation shielding, impact protection and thermal buffering mass and fluids for the habitat, with redundancy of the pressure sleeve as a guard against leaks or rupture and to facilitate maintenance.

After fuel depletion and orbital attainment, the upper stage fuel tank must be retroactively pressurized, and any remaining residual fuel must either be evaporated away, converted using a hydrogen fuel cell into water, or otherwise stored into smaller tanks. The fuel tank must then be repressurized using gases from the oxygen tank, to an ambient pressure of roughly 5 pounds per square inch of pure oxygen gas. Further inflation of a 10 psi spherical habitat into a pressurized upper or core stage fuel tank allows for recirculation of the gases and internal and external maintenance of the pressure containment vessel net and membrane. Universal docking port nodes, berthing rings and airlock hatches can be supported by capsule based passenger delivery, command, control and life support, for the duration of their stay in space. Linear sequences of connected cubic nodes form a hub of individual spheres or rooms in secure pressurized space, easily accessible by short term space flight tourists equipped with pressurized suits.