Excerpt For Public Release:

# Technical Proposal: Self-Assembling Space Structures



## Part 1: Table of Contents



## Part 2: Significance of Self-Assembling Space Structures

For the exploration and settlement of space there is a need for large structures for many purposes: large radio antennas, solar energy collection, spheres for the containment of asteroids and asteroid rubble for mining, spheres for the containment of atmosphere and exclusion of radiation for human habitation, and cylinders to slowly rotate to create artificial gravity for human, plant and animal life. For planetary surfaces there is the need for large enclosures such as domes, discs to cover lava tubes, or other shapes to contain air, let in light, and keep out radiation.

See Figure 1 and Figure 2 for an example:

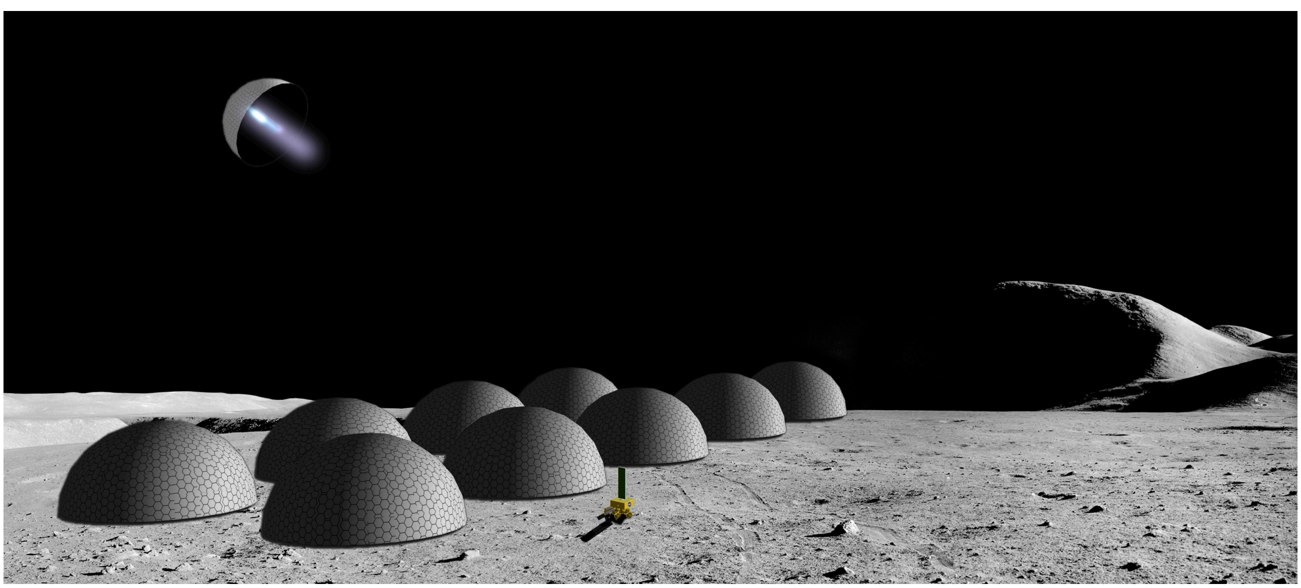

*Figure 1 Moon Base with Domes Assembled in Orbit and Landed Intact*

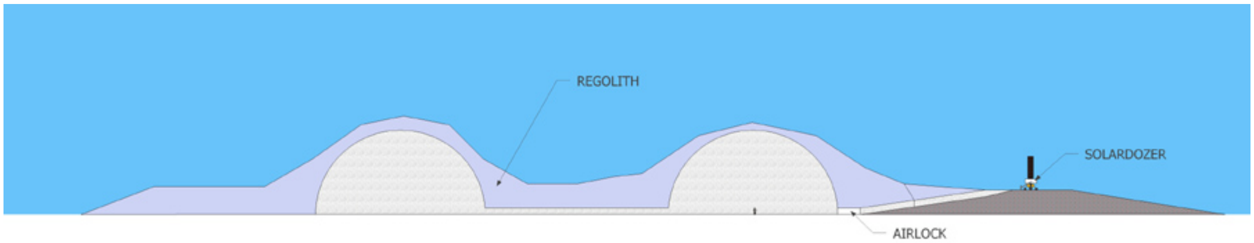


*Figure 2 Cross Section of Domes After Regolith Applied by Solar-Powered Bulldozer*

Theoretically, very large yet thin structures of carbon fiber composite combined with native materials, like water ice or regolith, would fulfill this need, however the problem exists with assembling the carbon fiber panels after launch. Humans work slowly in spacesuits and their labor is costly and dangerous. The assembly can be done robotically, however fully autonomous robots capable of finding, grasping, and moving large objects and joining them together have not been demonstrated. Assembly in a gravity field requires a large crane, further adding to the complexity. Ideally, then, the structures should autonomously assemble themselves in zero gravity. They should also be able to repair themselves in zero gravity without human assistance.

What we propose is to create self-assembling structures. They would be launched packed closely together as stacks of panels, assemble themselves like crystals in a solution while in orbit, and then be landed intact onto the surface of a planet or the Moon, or be used in orbit or moved into deep space. See Figure 3 for an example of in-space assembly:

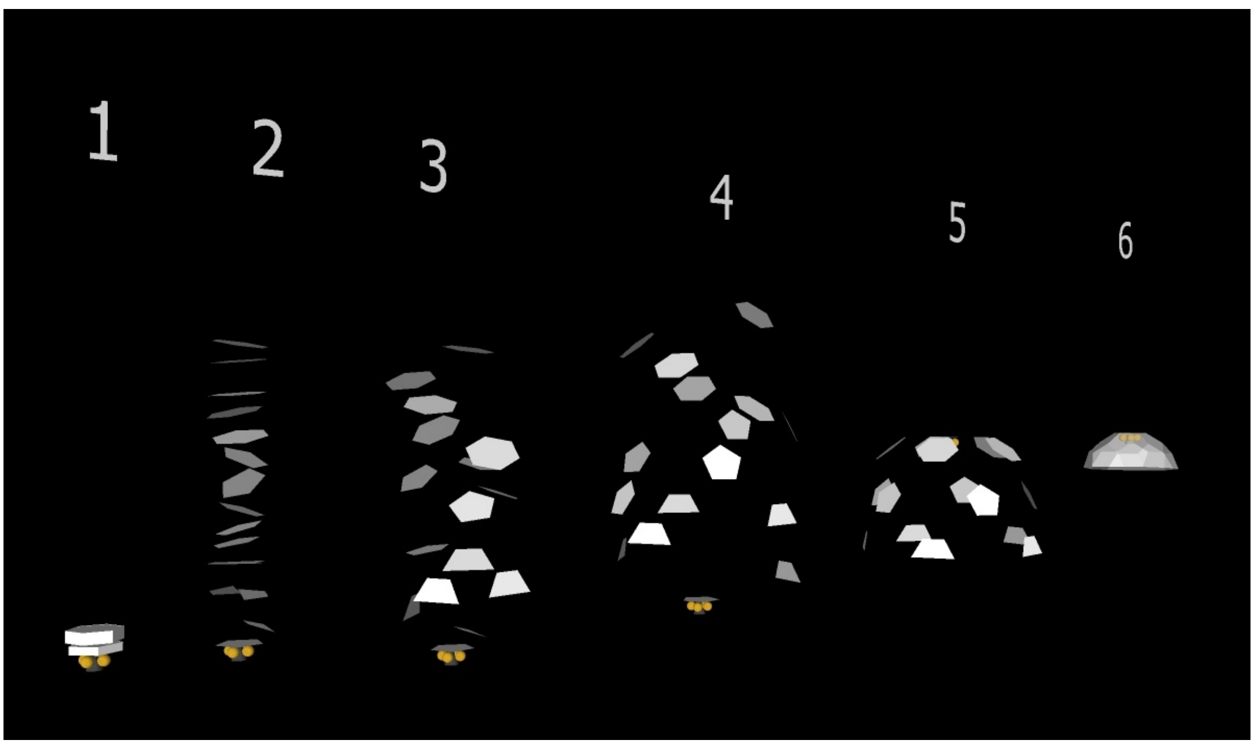


*Figure 3 In-Space Self Assembly of Geodesic Dome with Upper Stage Attached*

In place of random natural forces controlling the assembly of the structural elements, the assembly would be controlled by computer software running autonomously in each structural element, with minimum or no real-time supervision. The panels would move very slowly in zero gravity using gas thrusters, avoiding collisions, and connect to each other by using magnets and locking pins. Also, for lowest cost the structures would be robotically manufactured using 3D printing and standard commercial components. The goal is 100 dollars per square meter ($2000 for one 20 $m^2$ panel). Yet the goal is also to make the structure extremely fault-tolerant using redundant panels and majority-vote control systems. Panels would have internal redundancy to detect failures in themselves or detect failures in other panels, and together with the swarm, vote out the failed panels.

## Theory of Operation

Consider a large, flat, carbon composite panel floating in space. See Figure 4.

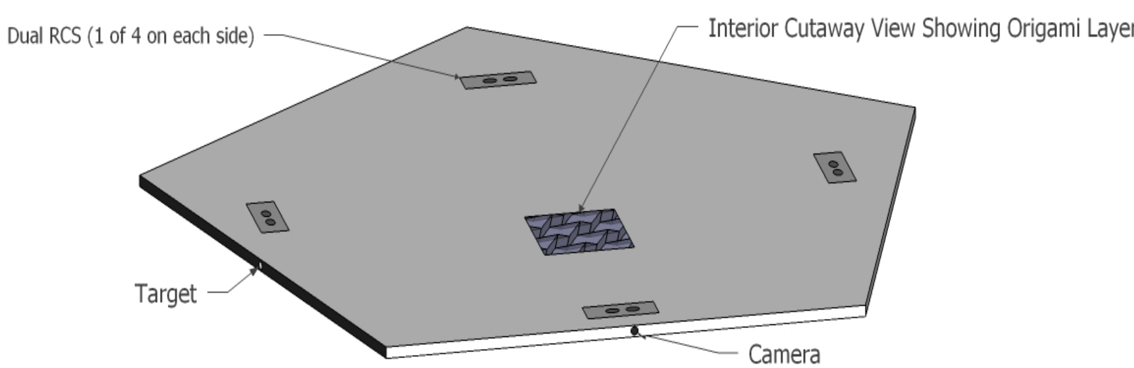


*Figure 4 Carbon Composite Smart Panel*

The panel is hexagonal or pentagonal in shape and 100's of them can fit within a 5m payload shroud. An interior origami-like structure provides stiffness and strength but minimal added weight.


*Figure 5*

This subscale panel was made by the author from 3 sheets of ordinary typing paper. The center sheet is an origami accordion fold and is glued between the other two sheets. The panel is supported at three points underneath. It can support more than 45 times its own weight in the center. (Panel weight is 15g, full coffee cup weight is 675 g).

Also inside the panel, created with 3D printing, are cavities for housing wax motors, reaction control jets, solar cells, miniature cameras, radio transceivers, and other devices.

Recessed in 4 places on the panel, on both sides, are cold-gas RCS pods, and in the center a triple redundant microcomputer with navigation and position processing, as well as image processing and two-way digital radio communication. Some of the subsystems are off-the-shelf: for example the NanoTron device (see below in Figure 6):


*Figure 6 Nanotron Radio Position Sensor*

This is a tiny, single-chip radio positioning device for factory floors that can automatically sense its distance (with 1km range and 10cm accuracy) to other sensors in the network. It can also pass data from one unit to another. This time-of-flight method of range finding will be the primary navigation system instead of GPS or INS so the system can work in deep space or on other planets, and will have very low cost. Since there will be at least three widely-spaced sensors in each panel, the system will determine both position and orientation from triangulation with other sensors in the network. For orbital applications the upper stage or payload adapter will be attached to one of the panels and serve as the point of origin.

This method will obviate the need for more expensive methods such as inertial navigation, star field tracking, radar tracking or radio tracking.

As depicted in Figure 3 the panels float in space and seek out their designated connection point to a growing geodesic dome in space. Guided by the digital radio sensors, gas thrusters bring the node to within 50cm of its ideal position on the structure. It moves very slowly ( <1cm/sec) to conserve thruster gas. Tiny valves inside the RCS pods require very little current (100mA) to open (see Figure 7 below).

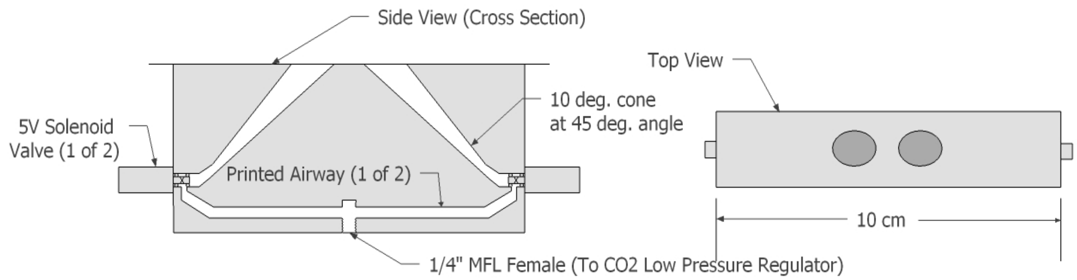


*Figure 7: Low-Cost, Cold-Gas, Dual RCS with Integrated Valves*

Once the panel is close to its final position, video cameras are used to navigate the final zero to 100cm, and permanent magnets pull the joints together (see Figure 8).

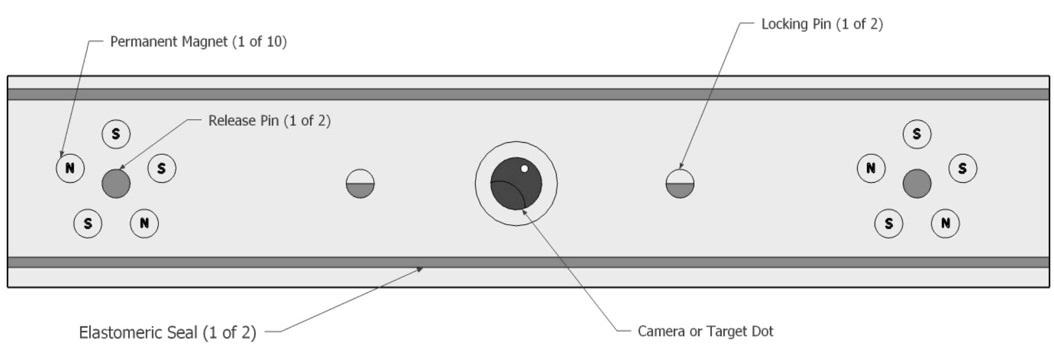


*Figure 8 Docking Panel*

Finally, locking pins driven by wax motors insert into the adjoining panel. For each pin there is a 2nd pin (not shown) that dovetails with it and locks it into place. The return force of the pin is very high and can easily compress an elastomeric seal on both top and bottom. The typical face of one panel is shown above, but not to scale. The actual panel surface would be approximately 5 cm high and 2 m long with the docking features spread out over the full length of the panel.

The panel can also unlock itself by reversing the action of the locking pins and then using the release pins in each circle of magnets to push away from the adjoining panel.

Once the structure is completed, it is taken to its final destination by an upper stage engine and landed (if the destination is a planetary surface or the Moon) using the same engine.

*(Proposal Details Removed for Public Release)*

## Example Usage in Deep Space Exploration:

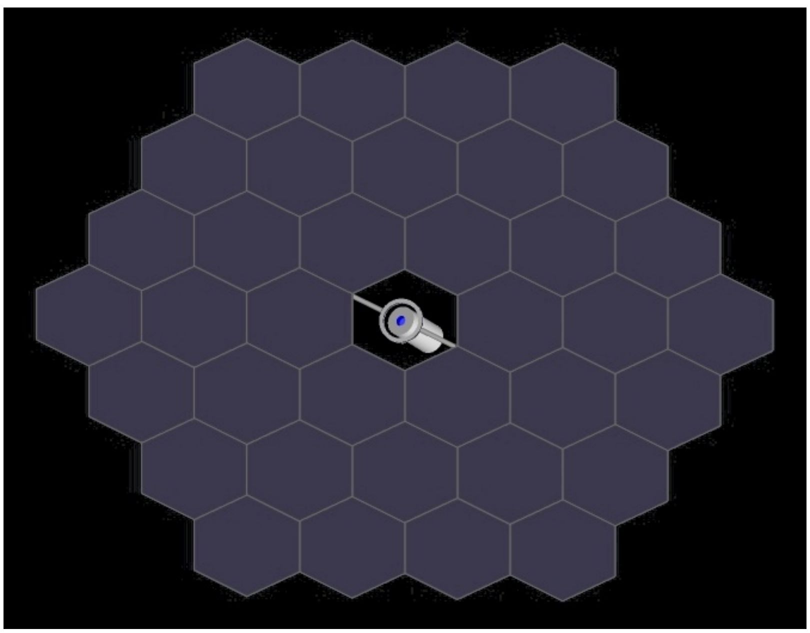

*Figure 9: Solar Tug*

30-m wide Solar Electric Propulsion (SEP) module with solar array self-constructed from 36 5-m panels, scalable to 100 m wide by adding 6 times more panels. The only size limit is the current-carrying capacity of the panel contacts near the center. The thruster, fuel tank and cargo are on a gimbaled mount so it can thrust at any angle relative to the Sun.