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Designs for Space-Based Construction Using Force Fields

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This paper presents advances towards developing optimized designs to construct large-scale, radiation-sheltered human habitats in Space using extraterrestrial materials. The Tailored Force Field (TFF) concept uses the radiation pressure and gradient forces in potential fields to organize random collections of objects into desired shapes such as walls. In a series of papers over the past seven years, we have presented the theory and development of the concept for moving objects using first acoustic and then electromagnetic fields into discrete shapes. Solar power requirements for a sample test case of a 50m diameter, 50m high cylinder with 2m thick walls were shown to be within reach. A preliminary mission concept considered the issues of separating the frequencies required to position, form and sinter construction material. Midway through a Phase 2 project from the NASA Institute of Advanced Concepts (NIAC), we now describe subsystems, optimization of the system designs, and an evolutionary path to such a large-scale endeavor.

Full-Scale System

A mission to build a complete 5-module 1-G radiation-shielded permanent station would involve 10 to 16 Delta IV heavy-lift class launches, with a total mass comparable to the International Space Station delivered to Low Earth Orbit. The station would be built at a mission continuous-thrust delta-v of roughly 11km/s using primary solar propulsion, comparable to the requirements to reach Earth-Sun L-4 or one of several candidate Near-Earth Objects (NEOs). Clouds of construction blocks would be formed into desired shapes using a standing radio-wave cavity similar to a Fabry-Perot resonator, comprised of four or five 100mx100m antenna/transmitter reflector craft, each powered by its solar sail / collector and high-intensity solar conversion array. Rendezvous and quarrying of the NEO would be performed using a robotic spiral excavator craft using Nd-fiber Laser and plasmajet cutters. The excavator would run on beamed microwave power from the TFF craft. The initial design for the solar collectors is driven by the propulsion requirement, leaving a large surfeit of power for excavation and construction - adequate to perform such construction as far away as the orbit of Mars as well.

Subsystems adapted to the excavator craft include an integrated pulsed plasma thruster / impact torque driver to enable maneuvering, rendezvous, attachment and release of the craft at the NEO. A truncated “Aerospike” modular nozzle integrates each laser cutter tool with a protective low-spreading plasma jet sheath, intended to lift blocks of material as they are cut out and float them slowly towards the shape-forming resonator cavity. As each cylindrical wall is formed, it is sintered into place using microwave/ infrared beams depending on material properties. During final assembly inflatable interior structures would be deployed, and interior systems installed by robots.

Design Point 1: Full-scale

Two design points for the system are considered. The first is the full-scale station, whose parameters are optimized based on anticipated developments in cutter technology, radio resonators, high-lift vehicles, solar propulsion, power beaming and inflatable structures.

Design Point 2: Evolutionary Path subscale system

A second design approach is to launch a much smaller system that can be used to robotically build the habitat module from much smaller pieces, and only form those pieces.

Design Point 3: Ground Test / space experiment system

New facilities for parabolic "drop test" experiments enable development of a system to validate the TFF concept in Earth-based facilities, and design of space experiments.

Technical issues

As permitted by the length constraints of the paper, we will also discuss the various validation points and other technical issues.

Conclusions to-date

1. A first-iteration design has shown closure on a system design to build a large-scale (50m dia, 50m tall, 2m thick) cylindrical module, using solar power and primary solar propulsion to a construction site equivalent to Earth-Sun L-4.
2. Sufficient excess power is available to consider construction near Mars.
3. A development path appears to be viable, using Earth-based facilities and a small-scale demonstration, based on validation using microwave resonators.
4. A facility suitable for building smaller sub-assembly parts of the larger habitat also appears to be feasible to develop, on an evolutionary path towards the full-scale system.

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