TRIGON Modular Robotic Construction System

A self-assembling construction system for surface habitats and vehicles

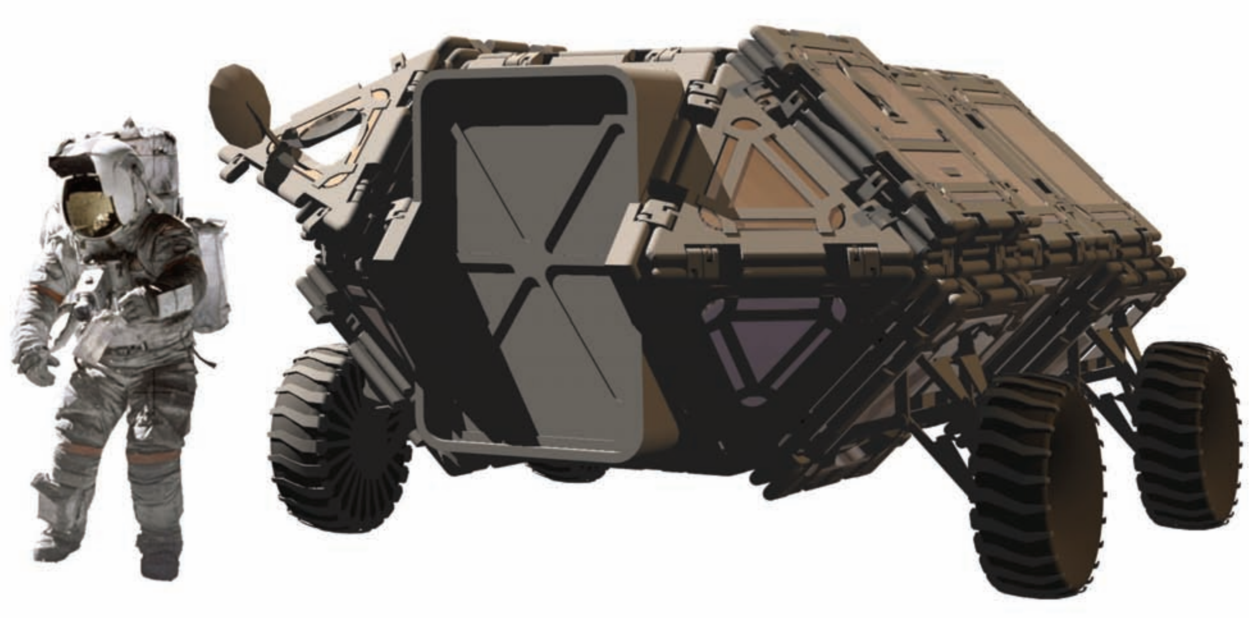


Figure 1: Small pressurized rover constructed of Trigon units

Summary Data (estimates for small pressurized rover Figure 1):
Mass = 2,700kg folded
Power Requirements = 1kW max for assembly process, ~15kWh for mobility
Volume: 4.5m^3 folded, 9.5m^3 in operation mode

Concept Overview

The Transformable Robotic Infrastructure-generating Object Network (TRIGON) system has been conceived for use on the surface of the Moon, Mars, and other planetary bodies. The self-constructing / self-reconfiguring intelligent modular robotic construction system can be used to assemble a variety of planetary surface structure configurations, for both habitats and vehicles, and integrates mobility systems. The panels in the system can “tumble” across existing structure in order to relocate themselves at different locations in the structure. Trigon units can piggyback and carry away other units, allowing for self-repair and disposal of obsolete units. The system can be stored in a compact form for shipping, and deployed into self-leveling rigid structures.

Concept of Operations

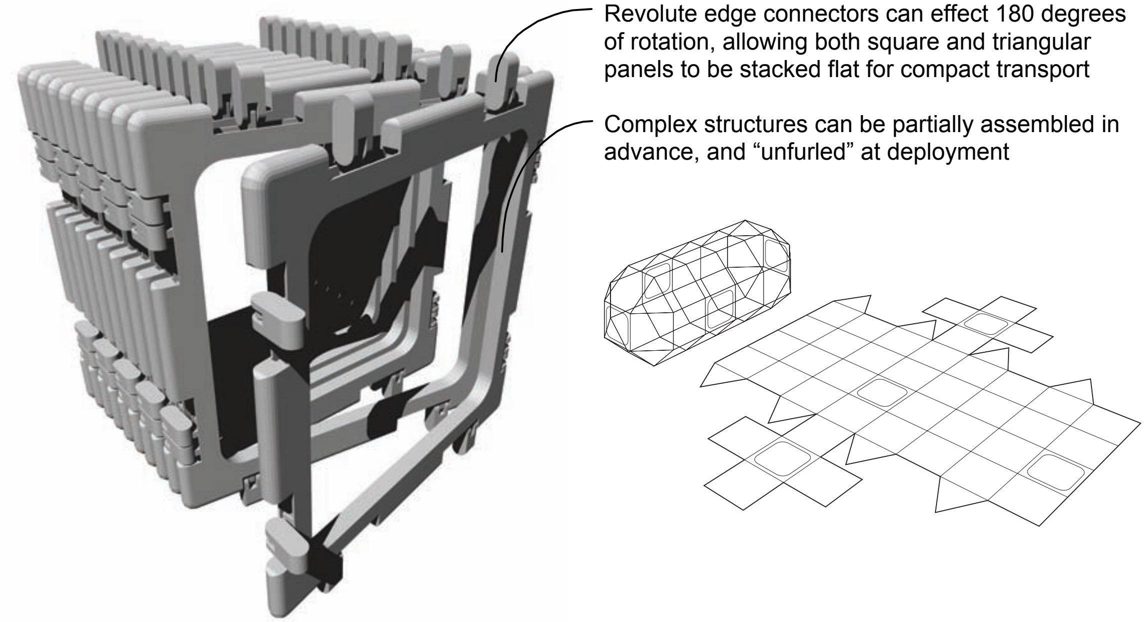
A compact stack of panels with core payloads can be delivered to the Moon’s surface in a tight package with low mass penalty. Upon landing, the integrated mobility systems can relocate the package to a target site, and the self-assembling Trigon panels can configure themselves into a variety of structures, such as habitat, rover, or other infrastructure element. In-situ materials can be added for radiation shielding, and the resulting structure would be of a much greater volume than the original package as delivered. An inflatable lining can be deployed as a pressure vessel.

The modular grid structure of the system represents a known environment within which panels can autonomously traverse to relocate themselves. Therefore any self-assembly or reconfiguration that occurs within the system has the options of being completely autonomous, teleoperated from earth, or directed locally by astronaut crews. Package delivery, surface mobility, and other activities that require interaction of the system with the surrounding environment would be facilitated by plug-in sensors and vision systems and could also be autonomous, teleoperated from earth, or directed locally.

Upon completion of the mission, a structure would be able to disassemble itself and relocate to a new location autonomously (or via remote teleoperation) after the crew departs. Alternatively, the panels could reconfigure themselves into a new configuration, habitat, or vehicle.

Concept Details

The Trigon panels have edge actuators that clasp and lock neighboring panels. An offset axis of rotation at each edge allows the panels to orient themselves 180 degrees from each other to facilitate stacking (Figure 2). Trigon panels can be configured to form a particular geometry, and selectively detach to unfold or stack in a compact form. On deployment, the stack would then “unfurl”, reattach the loose edges, and recreate the target geometry.



Revolute edge connectors can effect 180 degrees of rotation, allowing both square and triangular panels to be stacked flat for compact transport

Complex structures can be partially assembled in advance, and “unfurled” at deployment

Figure 2: Trigon panels can stack into a compact package

Each panel is an independent autonomous agent that can use the underlying previously assembled structure for mobility. The panels can temporarily attach themselves to the structure, “tumble” end over end attaching and releasing its hold on the underlying structure until it finds its target location. The computing resources within the panels are linked into a network after assembly, and can be reprogrammed for new tasks such as GNC, IVHM, communications, life support, science, etc., saving on the weight of add-on computers and the complexity of getting them integrated after assembly.

Since the inboard computer, electronics, and all the mechanisms needed for panel connection and self-assembly are located in the edges of the Trigon unit, the center hole can be fitted with a “payload” panel, consisting of a variety of secondary elements including instrument packages, mobility systems, robotic arms, etc., drawing power and communcations from the Trigon unit.

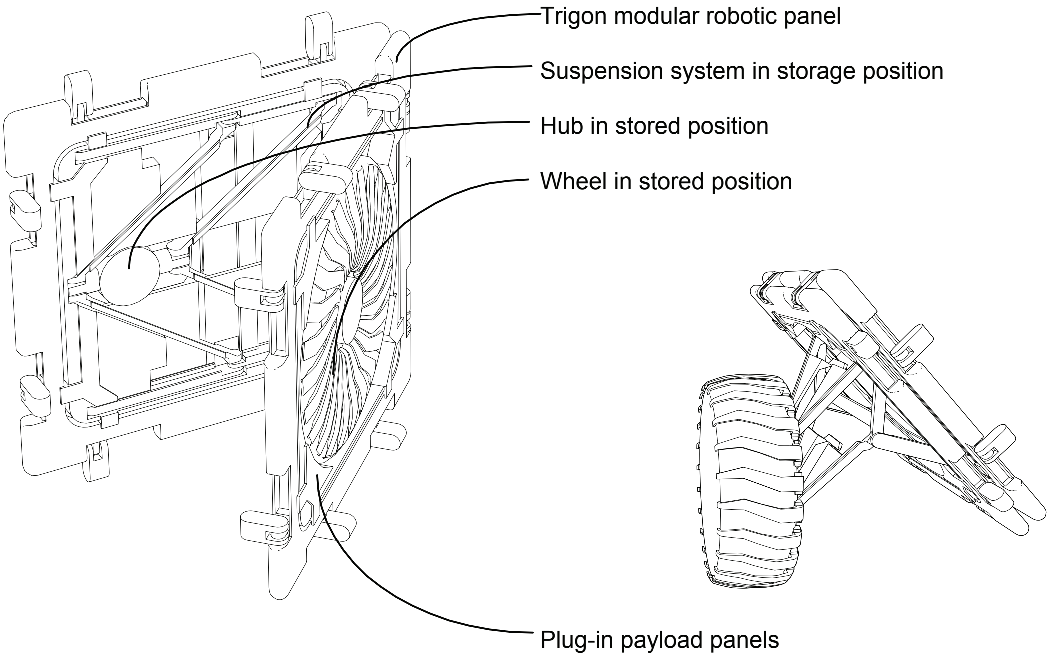


Figure 3: Foldable mobility system compact within "payload" panel

One useful system that can be carried on the “payload” panel is an integrated wheeled mobility system that folds out to become wheels for rovers and other vehicles (Figure 3).

Concept Maturity

HERITAGE: Modular robotic systems are designed to reconfigure themselves into a variety of useful functions, including mobility. The Trigon concept was inspired by two types of modular robotic system: lattice-type and chain-type.

Lattice systems are cubical in nature, where each cube is a self-mobile unit that can move orthogonally to a vacant position by sliding along existing portions of structure, such as the Telecube developed at PARC (TRL 5).

A second type of modular robotic system is a chain-type system where modules link together linearly in multiple chains, such as the Polybot developed at PARC, and CONRO / Superbot developed at USC (all TRL 5). Chain-type systems can reconfigure into snakes, walking robots, and a variety of other configurations by connecting and detaching any of its joints.

The Trigon system adds a new type: a panel-based system, where panel edges are linked together to form shell structures.

TECHNOLOGY READINESS:

The Trigon systems are currently at TRL 4 readiness level. The system has been modeled computationally and performance measured via computer analysis, and tested with working breadboard mechanism prototypes. Also, a variety of structural target geometries have been conceived and computationally tested with the system. However, the analysis has been limited to the functionality of individual components in respect to the overall geometry, and limited coordination between groups of components. System-wide performance via object-oriented performance and programming has not been evaluated.

Concept Sizing Model Description

The optimum sizing of the panels depends on the intended use. The possible panel sizes may vary from 10cm to an edge, to 2 meters edge dimension. The example pressurized rover shown in this summary (Figure 1) is assuming a 1m panel edge for ergonomic reasons, for fitting hatches etc.

References

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