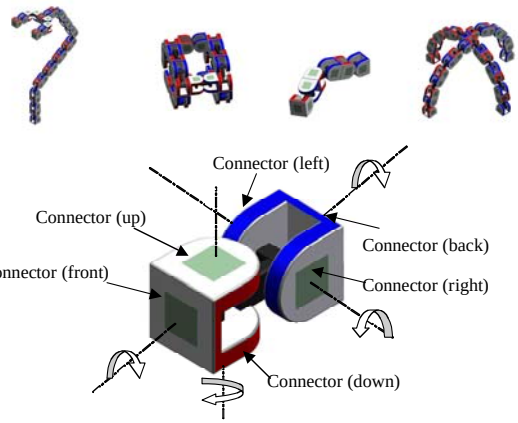
SUPERBOTS: MODULAR, MULTIFUNCTIONAL, RECONFIGURABLE ROBOTIC SYSTEM FOR SPACE EXPLORATION. W.-M. Shen[1] J. Bogdanowicz[2], W. Chun[3], M. Yim[4], P.M. Will[1], M. Sims[5], S. Colombano[5], D. Kortenkamp[6], S. Vanderzyl[7], E. Baumgartner[8], J. Taylor[9]. [1]USC/ISI (4676 Admiralty Way, MDR, CA, 90292, shen@isi.edu), [2]Raytheon, [3]Lockheed Martin, [4]UPenn, [5]NASA ARC, [6]Metrica, [7]ASI, [8]JPL, [9]U.Hawaii.

Introduction: Robotic systems are essential for space and lunar exploration. They perform tasks that range from inspection, maintenance, and assembly in space, to scientific exploration, transportation, habitat construction, resource utilization, and astronaut assistant on planetary surface. However, the traditional approach of building special robots for each of a large variety of tasks is not practical as it requires many specialized robots that are expensive and difficult to deploy from earth. This paper proposes a new *Superbot* robotic system that uses modularity and self-reconfiguration as an effective means to achieve low cost, multifunction, and adaptive capabilities. This approach has been partially realized under the support of NASA's H&RT program. This paper describes the unique features and experimental results of the Superbot modules and systems, and highlights a set of space applications using Superbots. The details of applications are described in the companion abstracts.

Superbot System Features: The Superbot system consists of a set of Lego-like but autonomous robotic modules that can *self*-reconfigure into different systems for different tasks. Examples of configurable systems include rolling tracks or wheels (for efficient travel), spiders or centipedes (for climbing), snakes (for burrowing in ground), long arms (for inspection and repair in space), and devices that can fly in micro-gravity environment.



Each Superbot module is a complete robotic system and has a power supply, micro-controllers, sensors, communication, three degrees of freedom, and six connecting faces (front, back, left, right, up and down) to dynamically connect to other modules. This design combines the advantages of many existing reconfigurable robots such as CONRO, PolyBot, MTRAN, and ATRON, and allows flexible bending, docking, and continuous rotation. With these features, any single Superbot module is a complete robot itself and can move forward, back, left, right, flip-over, and rotate as a wheel. Modules can communication with each other for totally distributed control and can support arbitrary module reshuffling during their operation. They have both internal and external sensors for monitoring selfstatus and environmental parameters. They can form arbitrary configurations (graphs) and can control these configurations for different functionality such as locomotion, manipulation, and self-repair. With a standard interface for docking, Superbot modules can connect to any specialized instrument, tool, or device and use them as an integrated part of the system.

Experimental Results: Under the NASA's H&RT program, the team has built prototypes of Superbot modules, tested behaviors of a single module, collaborations of modules, and simulated many challenging system behaviors. A single Superbot module has been demonstrated to move forward, backward, turn left and right, and flip-over from upside-down, and can run 250 meters with 33% of battery capacity and an average speed of 6.9cm/s. A two-module Superbot robot has been shown to move like a caterpillar, a sidewinding snake, and can stand up on various faces. A four module Superbot has been shown to roll like a track. In simulation, Superbot robots with multiple modules can form configurations such as chains, trees, legged walkers, rolling tracks, snakes, centipedes, balls, and long-arms. A 6-module rolling track can move 100cm/s on flat terrain and another configuration can climb slopes up to 50 degree. All control algorithms are distributed and support arbitrary dynamic reconfiguration. Our next step is to demonstrate the reconfiguration of the system.

Applications for Space Exploration: Various application scenarios have been developed to utilize Superbot's novel capability, including [1] Multi-Use Lunar Explorer (MULE), [2] a Habitat Maintenance and Operations System (HOMS), [3] a cost-effective robotic method to detect H2O or seismic features, and [4] a set of flying maneuvers and mini-RMS for inspection and maintenance on and near CEV or Space Station.

References: [1] Lentz et al., this volume, [2] Taylor et al, this volume, [3] Lawrence et al, this volume, and [4] Kortenkamp et al, this volume.