Extreme Mobility: Next Generation TET Rovers for the Lunar Surface. P.E. Clark[1], S.A. Curtis[2], M.L. Rilee[1]. 1Catholic University of America (Physics Department)@NASA/GSFC, 2NASA/GSFC, Greenbelt, MD 20771, Pamela.E.Clark@NASA.gov.

Addressing the Need for Autonomically Smart 'Target of Opportunity' Rovers: Tetrahedral Explorer Technology is addressable reconfigurable robotic architecture with bilevel intelligence applied to rovers to achieve a high mobility and truly autonomous operation [1,2]. TETs are shape shifting mobile platforms based on the tetrahedron as 'building block' with reversibly deployable struts forming edges and connecting via nodes at apices. Conformable tetrahedra are the simplest space-filling forms the way triangles are simplest plane-filling facets. The 12Tet consists of 26 struts and 9 nodes forming 12 interlinked tetrahedra. These undifferentiated (with no permanent appendages such as wheels) interlinked forms have the degrees of freedom necessary to develop a variety of gaits from simple rolling to crawling or reaching, and, at their most efficient, resembling amoeboid movement. As a result, tetrahedral rovers are optimally reconfigurable to allow operation on rugged, unprepared surfaces in natural terrains.

Control is a key challenge in realizing a rover with a highly addressable structure that can operate in highly irregular terrain such as a highly bombard or volcanic landscape filled with rocks or sheer cliffs, where locomotion requires an intimate blending of dynamics and statics, i.e. pushing, bracing, and balancing to make progress. Most means of locomotion "finesse" the situation by minimizing the complexity of the terrain: typically, rovers have featured wheels or legs that are larger than the terrain scale sizes, or locomotion that is slow to allow expert computer systems time to figure out where to go next. The 12 TET rover is designed to become a moving part of the terrain, its vision system providing volumetric information about its surroundings. Gaits suitable to rugged terrains and metrics to measure performance are being developed and tested. With information about the geometry of its environment as well as information about its own geometry, the 12 TET places itself within and moves through its environment.

This capability is accomplished with the use of a neural basis function with bilevel intelligence. Genetic algorthims dynamically generate gaits (a series of actuator deployments) in response to sensory input in a simulated environment appropriate for a given landscape (such as the Moon). This autonomically smart system, which allows the rover to travel from target to target with out external direction, is linked to higher level heuristic (decision making for target selection) intelligence system through an evolvable interface. Target selection could also occur via human interface.

Progress in Meeting Tetrahedral Mechanical/Mobility Challenges: To date, we have built and tested three operational prototypes. Prototype 3 is a 12Tetrahedral Walker with 5:1 extension ratio double sided struts expandable. It has extrudable plastic, strong but lightweight struts and nodes, with keyed shape to prevent slipping, a ruggedized (screw drive) deployment mechanism, patented string pots to allow accurate determination of strut length, 3-axis accelerometer chip to measure strut inclination, and lightweight piezoelectric gauges to assess strain on deployment mechanisms.

We have initiated the development of TET operational scenarios by considering mobility requirements as a function of terrain and by developing test gaits, such as the 'amoeboid gait' inspired by the most efficient naturally-occurring 3D locomotion mechanism. The present prototypes are teleoperated, which has required the design of macros for coordinated movements, definition of actuator commands and incorporation of sensor telemetry parameters as feedback for the actuation process via a wireless communication scheme through a user interface. The next step will be to develop autonomic intelligence to modify the basic gaits as the terrain requires. The behavior of the rover will be dynamically controlled by SANE (Stability Algorithm for Neural Entities) to maintain the system within operational limits. ST8 Autonomous Rendezvous and Capture algorithms are being used to develop the synthetic neural system.

Effective gait selection, maneuvering and navigation will require feedback from other systems being developed as well: a multichannel laser altimetry system for near (maneuvering relative to obstacles) and far (navigating relative to target) scene characterization, combined with touch and motion sensors (accelerometers), miniature transmitter/receivers, and central node camera.

References: [1] Clark, P.E. et al, The next generation of tetrahedral rovers, in Space Technology and Applications International Forum (STAIF-07), edited by M.S. El-Genk, AIP Conference Proceedings, 880, 711–718, 2007. [2] Clark, P.E. et al, ALI(Autonomous Lunar Investigator): Revolutionary Approach to Exploring the Moon with Addressable, Reconfigurable Technology, Lunar and Planetary Science XXVI, 1217.pdf