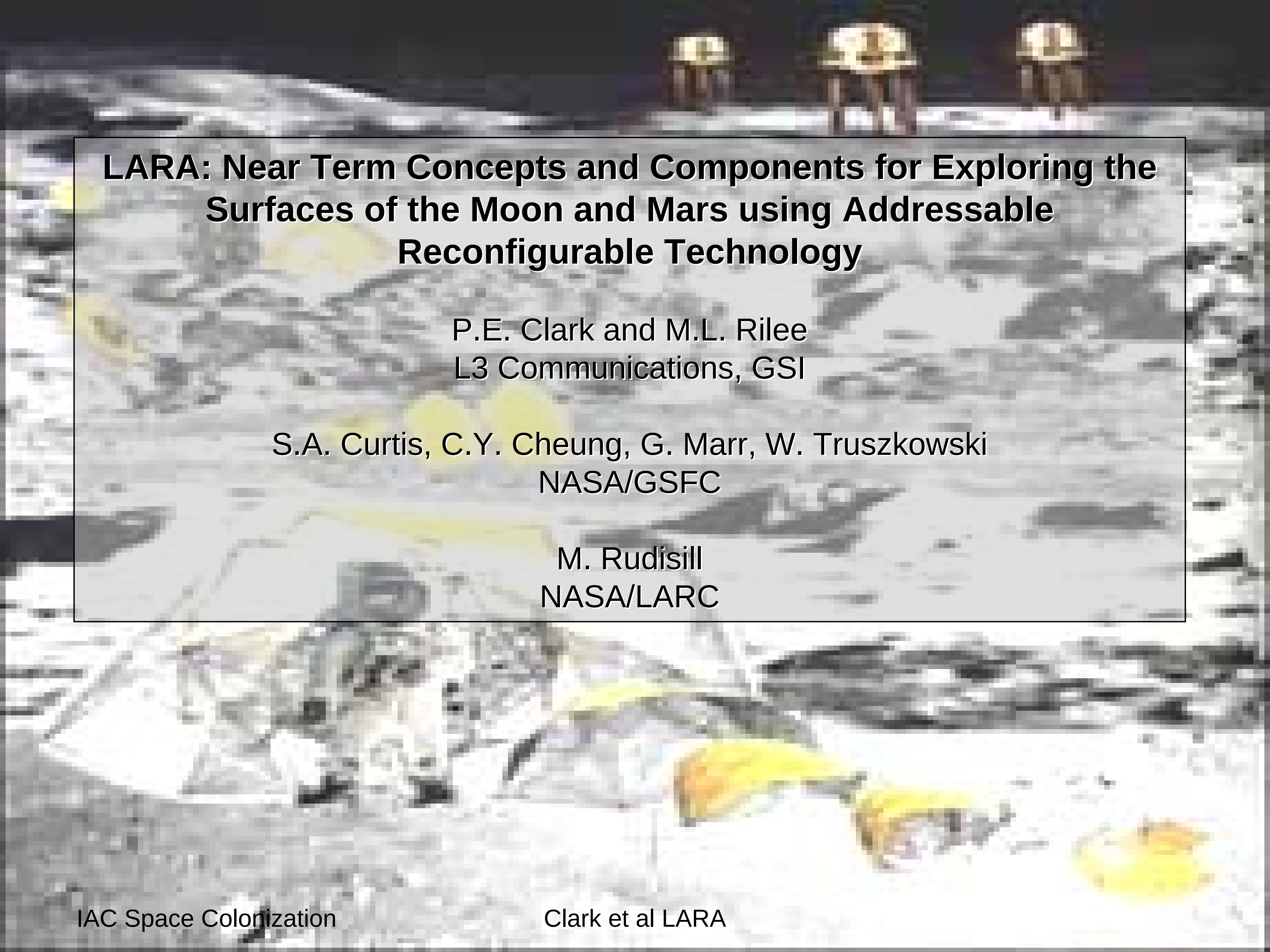

LARA: Near Term Concepts and Components for Exploring the Surfaces of the Moon and Mars using Addressable Reconfigurable Technology

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Exploration Initiative relevant to LARA

Lunar activities as ‘testbed’ enabling sustained human and robotic exploration of Mars and more remote targets.

Series of robotic missions begin in 2008 to prepare for later human exploration of lunar surface which begins in 2015-2020 time frame.

Lunar exploration missions make discoveries, develop new technologies and approaches, identify resources to support sustained activity in space.

Mars robotic exploration goals include searching for evidence of life, understanding solar system formation, preparing for human exploration.

Develop key capabilities suppoting long duration combined human and robotic exploration, including power generation, life support, transportation.

Human exploration of Mars begins after robotic missions have completed reconnaissance of planet and human presence on Moon becomes sustainable.

Moon and Mars Exploration Lessons

We can deliver a human crew to another body, keep them on the surface for at least a short time, and return them safely.

A human crew provides a more effective surface exploration tool than rovers alone.

Exploration with humans is much more costly than with rovers alone.

We can deliver and keep rovers elsewhere indefinitely.

With present technology, rovers could move to, collect samples and send back analyses from relatively easy targets selected through human telepresence.

With present technology, rovers have limited coverage and limited flexibility for dealing with the range of challenging terrains.

How could we increase cost effectiveness of human crews and effectiveness of rovers?

LARA Solution

Mission component design based on Addressable Reconfigurable Technology (ART) developed as part of ANTS architecture.

Robust, ‘form follows function’ vehicles transform providing all key functions: transportation in space and on the ground, communication, shelter, resource identification and capture.

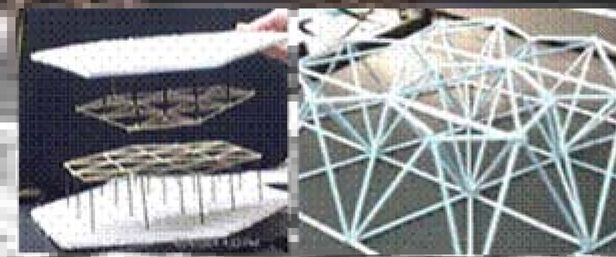
LARA systems deployable from Earth/Earth orbit, Space Station, or Moon/Lunar orbit and operate autonomously as robotic mission or through interface to support human exploration.

LARA rover capable of operating in terrains with high and variable relief and roughness inaccessible to appendaged vehicles through capability to continuously change scale, motion, and gait with many degrees of freedom.

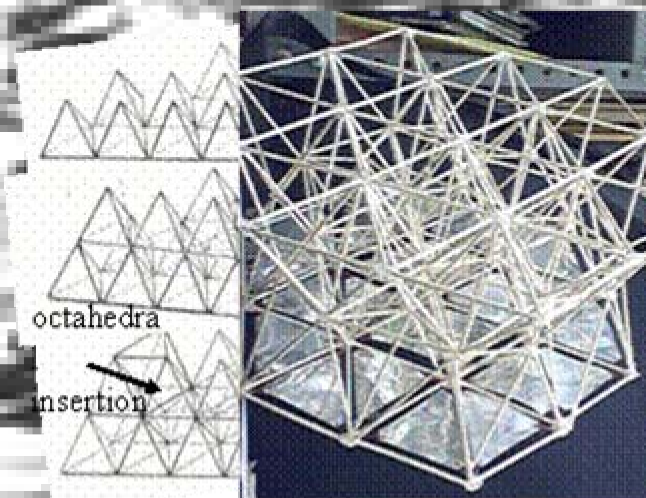
LARA Characteristics

* Support, sustain robotic or human exploration
* Operate autonomously, singly or collectively, with or without human partners
* Key functions include lander, rover, antenna, reconnaissance, shelter
* Surface targets by preselection or opportunity
* Search for resources, evidence for life
* Cover many kilometers/day on ground.
* Operation on any surface
* Propulsion in Space: Mini Chemical Thruster
* Propulsion on Ground: Node and Strut
* Power: solar or nuclear batteries

LARA Vehicle Design:
Reconfigurable landers, rovers, antennas



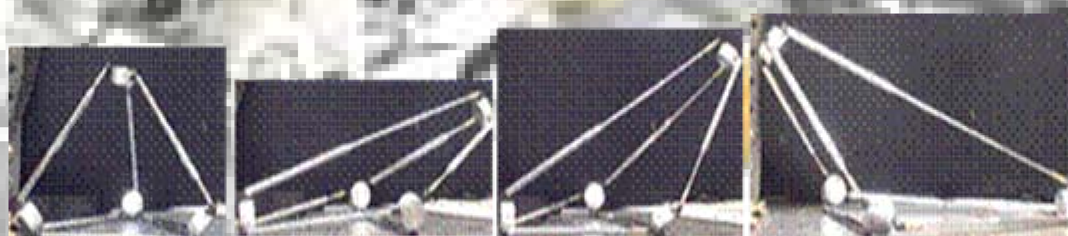
Based on tetrahedron as ‘building block’, acting singly, or connected in continuous network, where apices act as nodes from which struts reversibly deploy.



Conformable tetrahedra are simplest space-filling form the way triangles are simplest plane-filling facets.

Single tetrahedra give high flexibility, move by controlled tumbling. Continuous networks give high degree of freedom resembling amoeboid movement.

Must be reusable, reconfigurable, and multi-functional to meet all mission subsystem needs.



LARA Mission Scenario: Forms follow Functions

Function	**Form**
Lander/Space Mobility	Flattened with mini-thrusters at sides, edges
Amorphous Rover/Surface Mobility	Size@terrain scale, Shape@required movement Gait@roughness e.g., rough:amoeboid, steep:slither, smooth:spheroid
Payload Carrier/Transportation	Same as Rover
Antenna/Communication	Beacon/Bowl shape, Single or arrayed
Shelter provider	Cover over natural enclosure or hut-like in open
Specialized Task/Reconnaissance	Form platform for measuring/collecting operation

IAC Space Colonization

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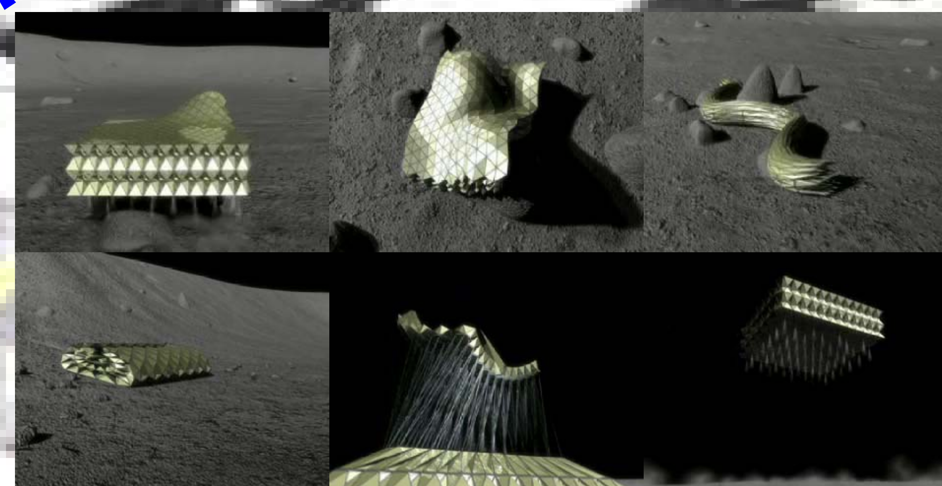

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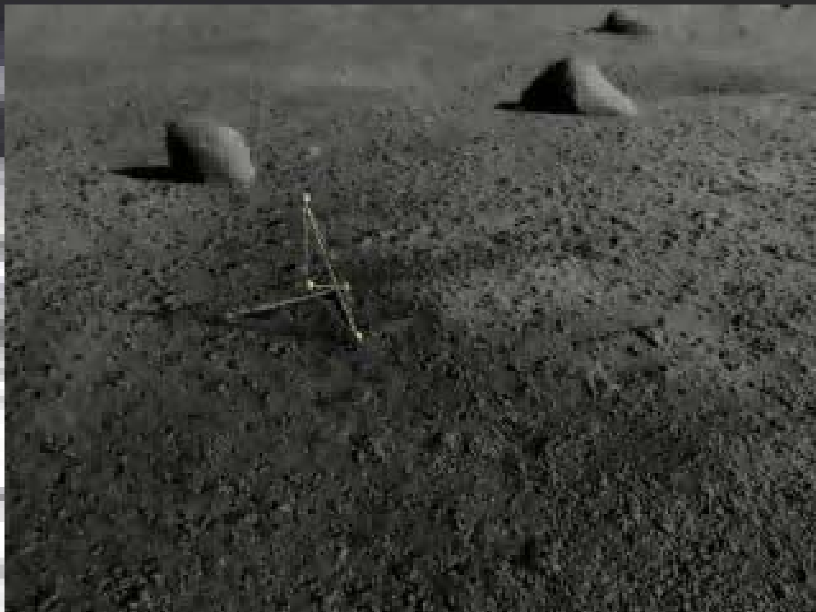
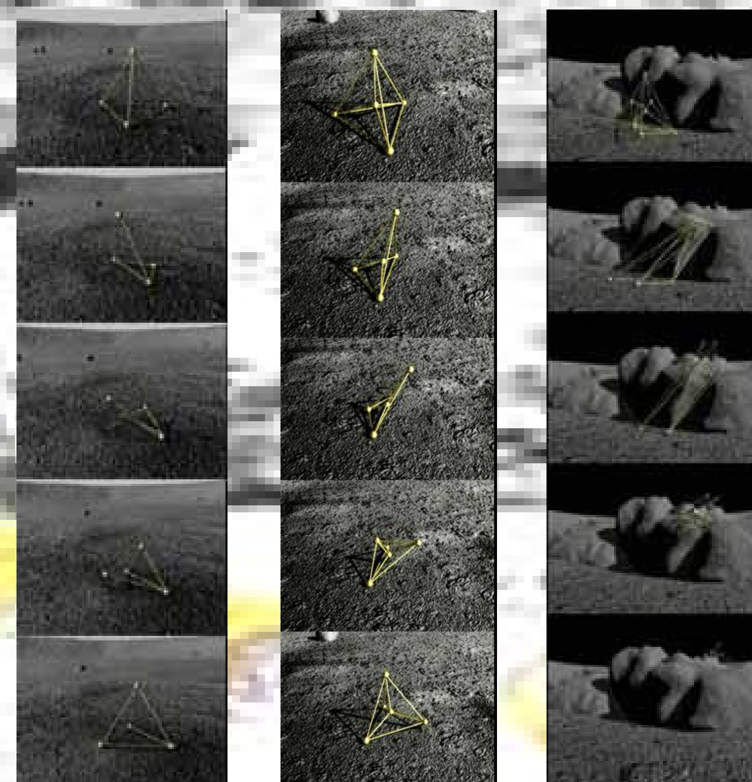
TetWalker Development Path

From simple tetrahedron walker, making punctuated tumbling movements, sized to navigate the level of roughness, to 4Tetrahedral walker, with an interior node for payload, with movement analogous to 1Tet, to a 12Tetrahedral Walker beginning to exhibit continuous motion. The 12Tet would perform adequately for LARA requirements.



IAC Space Colonization



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TetWalker Development Path

In a continuous or multi-tetrahedral structure, movements have a high degree of freedom, reminiscent of amoeboid movement. Thus continuous ‘shape shifting’ is possible, from flattened rectangle for stable landing function then conforming to surface, to tetrahedral amorphous rover shifting from slithering to rolling depending on surface, to concave surface formation for antenna function.

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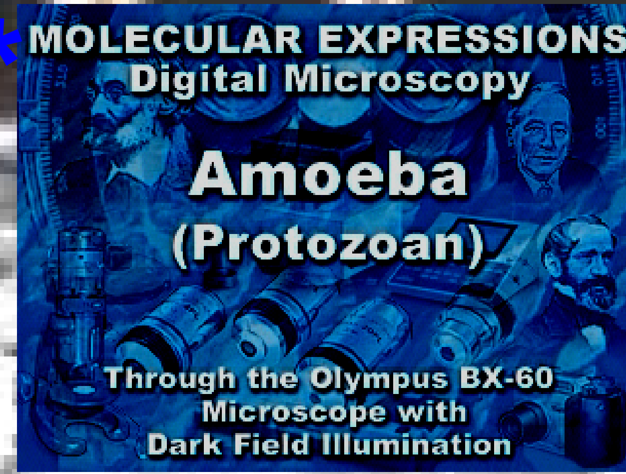

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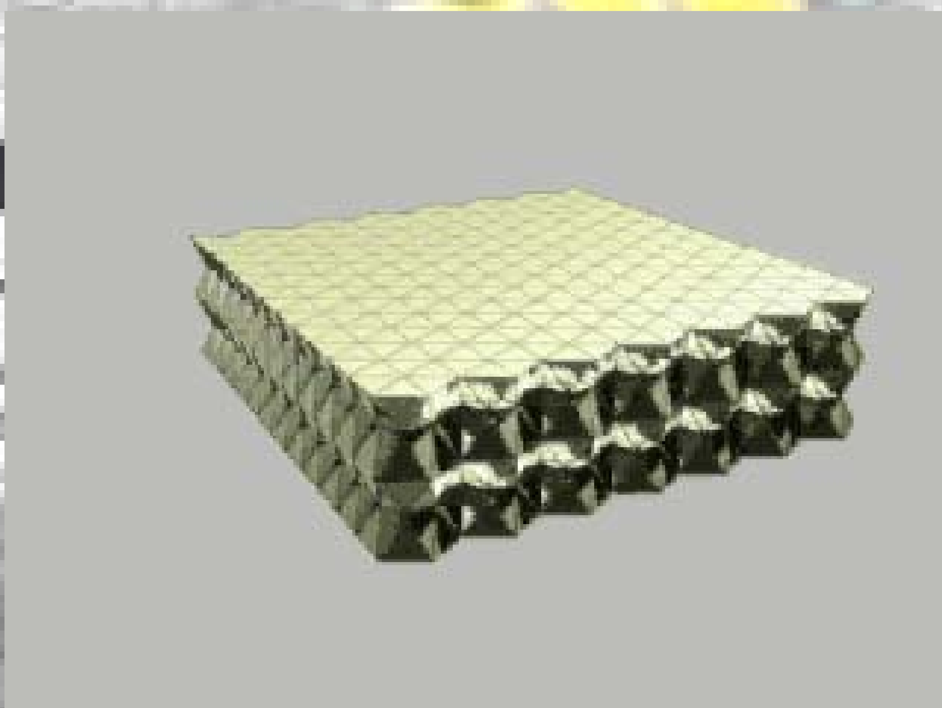

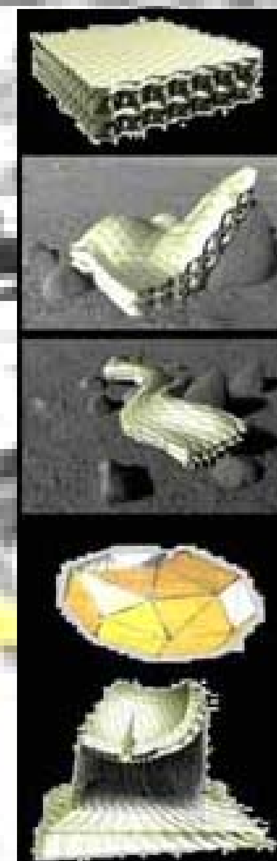

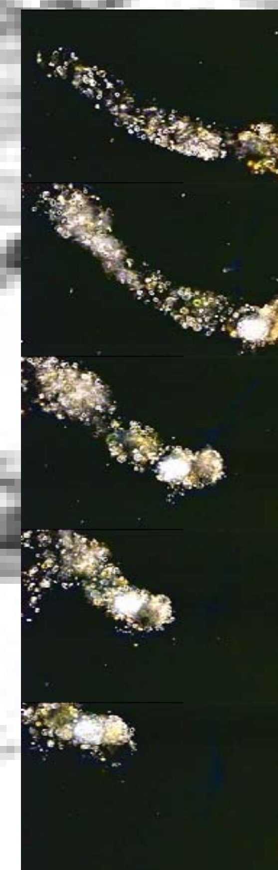

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LARA Requirements

Launch Date: 2010-1015
Duration: Months or even years
Location: 1.0-2.0 AU
Spacecraft Mass: 10-50 kg
Spacecraft Materials: 10-100 g/cm^2
Power system: Solar Cells or Nuclear Batteries
Power system mass: 5 kg
Power requirement: 10-30 Watts
Torque at node:
Space Propulsion system: Chemical Mini-thruster
Ground Propulsion system: Node and Strut
Operations:

- Autonomous or through link with crew
- Individual or collective operation
- Cover tens of kilometers per day
- No single point failure
- Robust to minor faults and major failure

LARA Scenarios

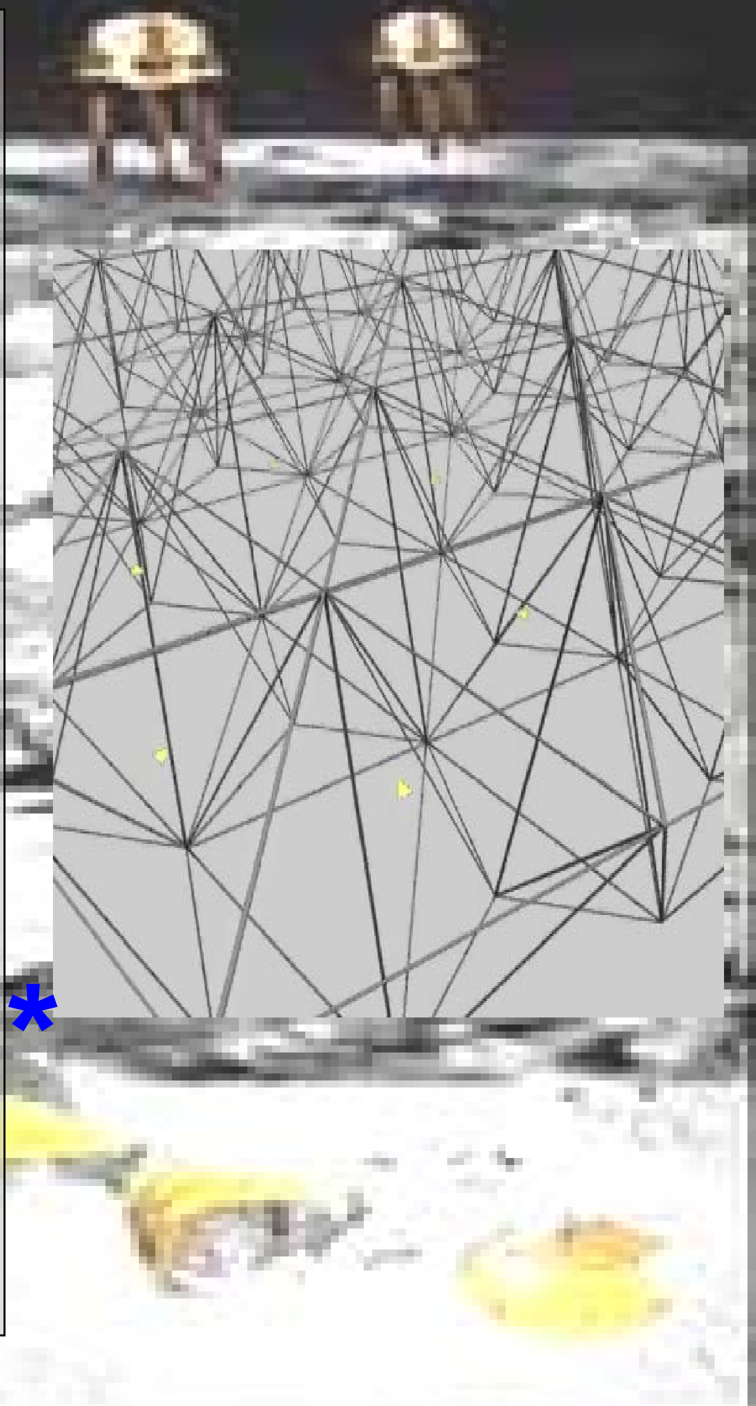
Land payloads autonomously, then form roving 'advance reconnaissance teams', mapping, gathering and analyzing samples and images of the terrain for use in site selection.

Analysis of samples, to determine elemental, mineral, water, biogenic material, or rock abundances, or terrains, to determine stratigraphy, morphology, age, would inevitable lead to the identification of sites with important clues on the origin of planets, the solar system, or life itself.

Single or networked rovers transform into antenna to transmit findings and receive instructions.

Rovers transform to provide shelter, by creating, seeking, and enclosing natural semi-enclosed formations, identifying and collecting environmental materials for use construction.

Networked rovers form a temporary or permanent communication, navigation, or observatory facilities.



Conclusion: Addressable Reconfigurable Technology is feasible

Autonomous navigation without appendages is currently being developed through simulation of tetrahedral movement, construction of tetrahedral walker prototype, design of 4, 12, and continuous tetrahedral structures, planned field test which involves development of 3D control and command interface for 1TET and 4TET walkers (See the official ANTS website [1]).

The potential flexibility and adaptability of ANTS architecture demands a **high level of artificial intelligence** we are in the process of developing through our role in ST-8 COTS High Performance Computing and Multi-agent Simulations using Beowulf clusters.

Carbon-based materials will ultimately be required to form structures and surface in order to minimize deployment, mass, and power requirements. Specially manufactured thin sheets of this carbon film on fiber material with shape memory have already been manufactured. A particular area of concern for our application would be deployment of surfaces with ability to 'retain' memory over potentially millions of deployments, and the power expenditure requirement to hold the material at partial deployment.