SELF-ASSEMBLING MESH NETWORKS OF FEMTO-SCALE SENSOR MOTES FOR PLANETARY EXPLORATION A. H. Parker[1] and the Project ESPRESSO Team. [1]Southwest Research Institute, 1050 Walnut St. Suite 300, Boulder, CO, 80302 (aparker@boulder.swri.edu).

Introduction: Networks of sensors on planetary and asteroid surfaces can deliver unique measurements of processes active on these surfaces. However, simultaneously implementing a sensor network with significant longevity, simple deployment, low cost, and high sensitivity is a substantial technical challenge. Here we explore the role of highly-homogenous networks of sensor motes that employ existing mesh-network standards to create extremely low-cost, easy to deploy, self-healing sensor networks for short- to medium-term investigations, with particular focus on the potential for dense seismic networks for subsurface imaging near landing sites.

Mesh network standards: In a mesh network of sensor motes, each mote acts as a network node. All nodes are capable of directly communicating with nearby nodes and information can be relayed from node-to-node to endpoints over the local horizon. Nodes interact non-heirarchically, and the failure of any individual node does not endanger the overall performance of the network. Likewise, addition of new nodes can be handled gracefully. Network standards like Zigbee have been developed to enable broad deployment of sensor and device networks with mesh topologies with the goal of enabling the Internet of Things. However, these standards can be leveraged to rapidly and inexpensively develop and deploy mesh networked sensor motes for planetary applications.

A mesh-networked seismic sensor mote: Project ESPRESSO has developed a demonstrator femtosatellite-scale seismic sensor mote that can embed itself in a mesh network of similar sensors. The sensor mote is illustrated in Figure 1. The mote includes a C&DH computer, power-management system, battery, solar arrays, a 3-axis 2000 Hz IMU, and a long-range radio transceiver. It is assembled in a "caltrop" configuration, with four tetrahedrally-arranged magnetized feet extended on shock-absorber legs; this arrangement ensures that no matter the orientation at landing, three of four feet will come in contact with the surface and provide anchoring in magnetic regoliths. This arrangement is sufficient to anchor the mote to a vertical wall of simulated Phobos regolith even under laboratory 1g conditions. The entire magnetically-anchored seismic sensor mote has a mass of just 48 grams, yet can run on battery power alone for approximately one week and can transmit data at 250 kbps to another sensor mote in its network at a range of up to 500 meters.

Figure 1, Left: The fully-functional 48-gram seismic sensor mote, magnetically anchored to an irregular vertical wall of Phobos regolith simulant. Caltrop shape enables three of four legs to contact surface in spite of irregularity. Whip antenna also shown. **Right:** Interior of the seismic sensor mote, showing the tightly-packed electronics, which include the C&DH computer, battery and PMU, instrument, and radio transceiver. SSERVI pin is 25 mm in diameter.

Mote-to-parent spacecraft data link range can be made far greater with a lower-noise receiver and a high-gain antenna. Testing and design iteration ongoing with this and similar motes to deterime optimal confiugurations for ease of deployment, maximum longevity, maximum sensitivity, and lowest cost (both in terms of per-unit and full network costs).

Application Concepts: There are several potential concepts of operations for similar sensor motes. The existing mote has been designed to accomidate simple deployment of hundreds of motes across the surface of an asteroid from a parent spacecraft; each mote will anchor to boulders on the surface after being passively dropped by the parent. Motes will relay information between them selves and the most advantageously-positioned mote at any given time would then relay the full network's data to the parent spacecraft for processing. Strong seismic motion induced by subsquent operations (e.g., impact experiments) can be used to conduct tomography of the asteroid interior. An alternate concept of operations would be deployment by an astronaut or rover on the lunar surface; deployment would consist of simply scattering them across the surface, and the motes would then assemble into a functional network without need of further intervention. Seismic signals generated by other mission operations (rover driving, hammering, drilling, or take-off) could then be recorded to investigate sub-surface resources (e.g., lava tubes) or hazards.