EXPLORING WITH PAM: PROSPECTING ANTS MISSIONS FOR SOLAR SYSTEM SURVEYS. P. E. Clark[1], M. L. Rilee[1], and S. A. Curtis[2], [1]EER Systems, Inc., 3750 Centerview Drive, Chantilly, VA 20151(Pamela.Clark@gsfc.nasa.gov), [2]Code 695, NASA/GSFC, Greenbelt, MD 20771 (u5sac@lepvax.gsfc.nasa.gov).

Introduction: ANTS (Autonomous Nano-Technology Swarm), a large (1000 member) swarm of nano to picoclass (10 to 1 kg) totally autonomous spacecraft, are being developed as a NASA advanced mission concept [1, 2]. ANTS, based on a hierarchical insect social order, use an evolvable, self-similar, hierarchical neural system in which individual spacecraft represent the highest level nodes. ANTS uses swarm intelligence attained through collective, cooperative interactions of the nodes at all levels of the system. At the highest levels this can take the form of cooperative, collective behavior among the individual spacecraft in a very large constellation. The ANTS neural architecture is designed for totally autonomous operation of complex systems including spacecraft constellations. The ANTS (Autonomous Nano Technology Swarm) concept has a number of possible applications. A version of ANTS designed for surveying and determining the resource potential of the asteroid belt, called PAM (Prospecting ANTS Mission), is examined here.

Mission Context: PAM is consistent with the present strategic plan for the NASA mission and the HEDS (Human Exploration and Development of Space) enterprise. In this plan, completed survey of the solar system and automated discovery of space resources are envisioned as a building block for expanding the human presence in space. Survey the universe and solar system. A major breakthrough in our ability to find these resources will require survey of a representative cross-section of the mainbelt asteroid population to determine: 1) What is the nature of smaller, darker, more remote asteroids more difficult to observe from Earth? 2) How are elements, minerals, rocks distributed in asteroids and asteroid parent bodies in space and time? 3) What is the relationship between 'space weathering', regolith, underlying rock, and the original parent body material for asteroids? 4) What are the distributions and effective limits for compositional and dynamic properties?

Unique PAM Capabilities: Single Sensor/Multi-spacecraft missions are uniquely capable of providing measurements for a comprehensive asteroid survey. 1) Ground based or even Earth orbiting observatories, even with projected improvements in sensitivity, will be not be able to provide measurements for more remote, smaller, or darker asteroids, which must be observed by spacecraft. 2) Single spacecraft missions are useful in providing extensive documentation for one to a handful of previously observed asteroids, but are not designed for surveying a wide range of unexplored asteroids. 3) Multi-sensor spacecraft have flown before (NEAR) or are flying now to solar system bodies such as asteroids. Essential sensors, such as imagers, spectrometers, and altimeters, have very different optimal operational requirements for a) illumination conditions, b) pointing geometry, c) distance to target, and d) orbital configuration. This translates into constant compromising to meet sensor requirements and results in less efficient collection of high quality data, a problem that is magnified when a small, irregularly shaped object, such as an asteroid, is being explored. The ANTS/PAM concept calls for a fleet of single sensor spacecraft, working individually or as teams. Individual spacecraft can be flown to meet optimal instrument operational as well as science requirements simultaneously, reducing the time required to obtain a comprehensive of observations as well as increasing the quality of those observations, for each target. The PAM specialized sensor/multiple spacecraft concept lends itself to asteroid exploration. Targeting thousands of widely separated bodies, which will require hovering in a highly irregular gravity field, demands a very large autonomous constellation of specialized workers.

'Virtual Instrument Studies': ANTS can also, using built in reactivity and response capability, acquire simultaneous coverage of the same target, thus providing a comprehensive measurement set required to solve a particular scientific problem. Identical sensor or multiple sensor 'virtual instrument studies' could be performed. Particularly useful studies, and the approximate order in which they would go in, are: 1) **Asteroid Detector/StereoMapper** consisting of two wide field imaging spectrometers with enhanced navigational (location and pointing awareness) capability separated by distances varying from hundreds of kilometers to kilometers which would be used to detect and determine the orbit of potential targets at a distance, or move to within kilometers of a target to obtain astronomical classification, rough shape, and dynamic properties of more likely candidates for detailed studies. These are the 'point men'. 2) **Dynamic Modeler** consisting of an enhanced radio science instrument, altimeter, and wide field imager separated by tens of kilometers to kilometers which would be used to acquire detailed figure parameters (including shape model) and dynamic properties (spin, density, mass

distribution). 3) **Petrologist** consisting of X-ray, Near Infrared, Gamma-ray, Thermal IR, and wide field imager separated by tens of kilometers to kilometers which would be used to determine the abundances and distribution of elements, minerals, and rocks present, from which the nature of geochemical differentiation, origin, and history of the object, and its relationship to a 'parent body' could be inferred. 4) **Photogeologist** consisting of Narrow Field and Wide Field Imagers and Altimeter separated by tens of kilometers to kilometers which would be used to determine the nature and distribution of geological units based on texture, albedo, color, and apparent stratigraphy as expressed on the surface, from which the nature of the dynamic history and origin of the object could be inferred. 5) **Prospector** consisting of altimeter, magnetometer, Near Infrared, Infrared, and X-ray spectrometers separated by tens of kilometers to kilometers which could be used to determine the distribution of 'resources', including Fe/Ni and volatiles on preselected candidates for 'mining'.

Near Term Benefits: This concept can be tested, with smaller numbers of prototype low periapsis orbiters in vertical or planar array clusters, for targets near the Earth, allowing near real time analysis of the machine/human interface, in homogeneous (identical sensor) or heterogeneous (multiple sensors) mode. In homogeneous mode, ANTS could be flown in formation (to maintain consistent inter-sensor orientation) for 3D analysis of magnetic or gravitational field anomalies, or temporal/spatial variations in magnetospheres or ionospheres. In heterogeneous mode, ANTS could be flown in conjunction (to create comparable inter-sensor ground coverage) for site selection and/or characterization in regard to resource inventories.

References: [1] Curtis et al, *IAU Proceedings*, IAF-00-Q.5.08, 2000; [2] Rilee et al, *IAU Proceedings*, in press, 2003.