

ANTS: Exploring the Solar System with an Autonomous Nanotechnology Swarm. P.E. Clark¹, S. Curtis², M. Rilee³, W. Truskowski⁴, and G. Marr⁵, ¹Catholic University of America, Physics Department, 600 Michigan Ave., Washington DC 20006, Pamela.Clark@gssc.nasa.gov, ²NASA/GSFC, Code 695, Greenbelt, MD 20771, ³Raytheon ITS, Greenbelt, MD 20771, ⁴NASA/GSFC, Code 588, Greenbelt, MD 20771, ⁵NASA/GSFC, Code 553, Greenbelt, MD 20771.

ANTS (Autonomous Nano-Technology Swarm), a NASA advanced mission concept, calls for a large (1000 member) swarm of pico-class (1 kg) totally autonomous spacecraft to prospect the asteroid belt [1]. As the capacity and complexity of hardware and software, and the sophistication of technical and scientific goals have increased, greater cost constraints have led to fewer resources and thus, the need to operate spacecraft with less frequent contact.

At present, autonomous operation of spacecraft systems allows great capability of spacecraft to 'safe' themselves and survive when conditions threaten spacecraft safety. To further develop spacecraft capability, NASA is at the forefront of Intelligent Software Agent (ISA) research, performing experiments in space and on the ground to advance deliberative and collaborative autonomous control techniques. Selected missions in current planning stages require small groups of spacecraft weighing tens, instead of hundreds, of kilograms to cooperate at a tactical level to select and schedule measurements to be made by appropriate instruments onboard. Such missions will be characterizing rapidly unfolding real-time events on a routine basis.

The next level of development, which we are considering here, is in the use of ISAs at the strategic level, to explore the final, remote frontiers of the solar system, potentially involving a large number of objects. Such missions will allow only infrequent contact possible, due to limitations in near-Earth and human resources. The most obvious candidates for these missions are mainbelt asteroids, a population consisting of more than a million small bodies.

Although a large fraction of solar system objects are asteroids, relatively little data [2] is available for them because the vast majority of them are too small to be observed for more than single point measurements except in close proximity. Orbit determination has been done for approximately 50,000 MBAs, light curves are available for approximately 5,000, and IR and/or visible spectra for perhaps two to three thousand. Detailed shape models on the other hand are available for approximately ten, provided by a combination of spacecraft, Space Telescope, or Earth-based radar observations.

Asteroids originated in the transitional region between the inner (rocky) and outer (solidified gases) solar system. Many have remained largely unmodified since formation, and thus have a more primitive com-

position which includes higher abundances of siderophile (metallic iron-associated) elements and volatiles than other planetary surfaces. Determination of the systematic distribution of physical and compositional properties within the asteroid population is crucial in the understanding of the solar system formation. In addition, there has been interest in asteroids as sources of exploitable resources. Far more reconnaissance is required before such a program is undertaken.

A traditional mission approach (to explore larger asteroids sequentially) is not adequate for determining the systematic distribution of exploitable material in the asteroid population. Our approach involves the use of distributed intelligence in a swarm of tiny spacecraft, each with specialized instrument capability (e.g., advanced computing, imaging, spectrometry, etc.) to evaluate the resource potential of the entire population. Supervised clusters of spacecraft will operate simultaneously within a broadly defined framework of goals to select targets from among available candidates and to develop scenarios for studying targets simultaneously. Spacecraft use solar sails to fly directly to asteroids 1 kilometer or greater in diameter. Selected swarm members return to Earth with data, replacements join the swarm as needed. We would like to acknowledge our students R. Watson, V. Cox, and F. Olukomo for their support of this work.

References: [1] Curtis et al, 2000, IAF-00-Q.5.08; (2) Clark Chapman, 2001, Personal Communication.