Near-Earth asteroid sample return missions

Conference or Workshop Item

NEAR-EARTH ASTEROID SAMPLE RETURN MISSIONS.

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Introduction The exponential increase in the rate of discovery of near-Earth asteroids (NEA), the success of Deep Space 1 (in particular solar electric propulsion and autonomous navigation - notwithstanding encounter difficulties), the success of NEAR-Shoemaker, and the pending ISAS's MUSES-C asteroid sample return mission, Stardust and the upcoming Contour, Deep Impact and other small body missions, suggest that sample return from near-Earth asteroids is now technically feasible [1]. Deep Space 1 and MUSES-C missions are technology missions, but it is now possible to consider NEA sample return for scientific purposes. A recent workshop in Houston considered NEA sample return from a variety of viewpoints [2]. Here we present our summary of the workshop.

The Scientific Case for Sample Return: Asteroids and the comets are an integral and uniquely important part of our solar system. Not only do they provide insights into the nature of primordial solar system material – the material from which the Sun and planets formed – but their impact onto planetary surfaces is one of the most important geological and biological forces for change. They are also a potential natural resource and target for human exploration and development of space. The NASA report "Mission to the Solar System: A Mission and Technology Roadmap" advocates sample return from small solar system objects and the NASA "Space Science Enterprise Strategic Plan" lists eleven goals of which seven can be uniquely addressed by NEA sample return.

- Primitive asteroids are relics of the formation of the Solar System and contain evidence for processes during planet formation. Many primitive asteroids are probably too weak to supply meteorite samples and atmospheric selection effects are clearly major. Spectral data suggest that NEAs are representative fragments of main belt asteroids.
- These asteroids may contain pre-solar grains that help us understand stellar evolution and the relationship between stars and planet formation.
- Some asteroids should contain organic compounds that can shed light on the origin of molecules necessary for life on Earth.
- By understanding the chemical processes that preceded life on Earth, we can better understand possibilities of life on other planets.
- Asteroids capture solar wind and solar energetic particles, so studies of their surface materials will contain a record of solar activity for bodies of known recent orbital history.
- The samples (and the data from the encounters) will help us to design devices to deflect potentially hazardous objects and predict the effects should they reach Earth's atmosphere.
- Robotic missions to NEA will be pathfinders for human missions that might use asteroid resources to facilitate human exploration and the development of space.

We have cosmic dust and meteorite samples, the latter probably come from asteroids although the match between specific types of asteroids and meteorites is not firmly established. The Main Belt asteroids and the NEAs show similar spectral class distributions, suggesting that the NEAs fairly represent the main belt, even though some NEAs may be cometary in origin. However, meteorites and cosmic dust are cosmic jetsam, and, as with terrestrial geology, we need to visit the outcrops.

In situ measurements are necessary for global geophysical and geochemical studies, but sample return is essential for a meaningful examination of the surface materials. Sample return has the advantage over *in situ* methods of an unlimited range of techniques, vastly superior precision, the ability to archive samples for future investigation as instrumentation is developed, and they permit flexible responses to surprise results. Isotopic analysis for dating and characterizing samples requires extensive preparation that can only be done in terrestrial laboratories. The Apollo program is an excellent case study of the impact which sample return can have on our understanding. A geologist exploring a new region on Earth maps, chooses sample areas, collects samples, returns them to the laboratory for sophisticated analysis. The asteroid equivalent is to obtain reflectivity spectra, select interesting asteroids, collect samples, return them to the laboratory for sophisticated analysis. It is a time-tested strategy.

New Insights into the Nature of Asteroid Surfaces and Implications for Sample return: The NEAR-Shoemaker mission to Eros has yielded an abundance of data that will take many years to assimilate and understand. Cratering has been important, but boulders are much more abundant than expected. There is abundant regolith although bedrock might be exposed in places, and there are long lineations that suggest Eros is a coherent object rather than a rubble pile. X-ray data suggest an LL chondrite composition, at least for the surface, although sulfur appears depleted. The NEAR-Shoemaker studies of Eros show that we cannot understand meteorite-asteroid links and the chemical and physical properties of asteroids without returned samples from the surfaces of such NEA.

New Experience in Maneuvering Spacecraft in the Vicinity of Small Asteroids: Our experience with NEAR-Shoemaker demonstrates a high degree of confidence in the new techniques required to maneuver spacecraft around asteroids. Theoretical treatments for a variety of maneuvers around small asteroids have been developed, including: close stable orbits, low-altitude flyovers, landing trajectories and hovering, stated in order of increasing difficulty. Asteroid shape, size, density, and rotation state are crucial parameters that must be known to implement these operations, thus these data must be available before detailed maneuvers can begin. Additionally, the design of the entire spacecraft and mission can be simplified if constraints on these asteroid parameters can be estimated early in the mission development phase.

Sample Collection Devices, Sample Containment and Planetary Protection Issues: A number of sample collection devices have been flown on previous missions, trowels/claws, drillers/corers, percussive devices, penetrators, and passive surfaces. MUSES-C uses a cone to collect ejecta from an artificial impact during its touch-and-go sequence onto the asteroid surface, taking advantage of its microgravity condition. Asteroids present new difficulties and new opportunities. Their small size, high rotation rates and irregular shape and the abundance of dust make landing difficult, but at the same time their microgravity on surface makes hovering feasible. Honeybee Robotics and Lockheed-Martin Astronautics are developing devices that can sample without landing.

There has been considerable progress in designing sample containment devices to prevent contamination of the asteroid by terrestrial organisms, the transfer of organisms to Earth or the contamination of one asteroid sample with another. Planetary protection issues have been well-addressed by NRC subcommittees, high-risk asteroids identified, and laboratory procedures for handling returned samples are well-defined. Although well-developed, these procedures require that such issues are addressed from the outset of mission planning. Experience with terrestrial ecosystems demonstrates that natural transfer is not equivalent to anthropogenic transfer; for example radiation doses experienced by meteorites during transfer may be high enough to destroy living material while this would not be true for samples returned by missions.

Human Exploration and Development of Space and Implications for Resource Utilization: NEAs represent an attractive target for human exploration of space and could be a useful way to test Mars-bound spacecraft. The missions would be of shorter duration (one year *vs.* three years), simpler (no gravity well or atmosphere), launch windows numerous, and lower energy requirements than for a missions to Mars.

The increasing numbers of NEAs means that their accessibility as natural resources has improved. Returned samples will enable a better evaluation of the objects as resources and their possible use as propellants, life-support fluids, or structures.

Impact Hazard Mitigation: The impact hazard is receiving increasing attention from scientific communities and governments and is one reason for the increased rate of detection of new NEAs. Many methods have been proposed for deflecting a potential impactor (deep, shallow or standoff nuclear explosions, lasers and others), but the optimal method depends knowing the chemical and mineralogical composition and mass and physical properties of the asteroid, which at the moment cannot be predicted with the required accuracy.

Recommendations from the NEA Sample Return Workshop: There was a widespread acknowledgement that we need data on orbits, spectral class, spin state and size for NEA, and that Δv should be reported in compilations, so that interested astronomers could prioritize asteroids. There was a strong sense that there should be international collaboration, and that we should be thinking in terms of programs that address the numerous scientific goals rather than a single mission. Such a program could obtain *in-situ* data with consistent instruments and to collect samples from asteroids of all major spectral types within a decade or so.

References: [1] Sears D. W. G. *et al.* (2000) A multiple near-Earth asteroid sample return mission called Hera. *Meteorit. and Planet. Sci*. 35, A145. [2] *Near Earth Asteroid Sample Return Workshop, December 11-12, 2000,* Lunar and Planetary Institute, Houston, Texas, LPI Contribution 1073.