Scientific Exploration of Near-Earth Objects via the Crew Exploration Vehicle

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CONSTELLATION

Introduction

The concept of a crewed mission to a near-Earth object (NEO) has been previously analyzed several times in the past [1-5]. A more in depth feasibility study has been sponsored by the Advanced Projects Office within NASA's Constellation Program to examine the ability of a Crew Exploration Vehicle (CEV) to support a mission to a NEO. The notional mission profile would involve a crew of 2 or 3 astronauts on a 90 to 120 day mission, which would include a 7 to 14 day stay for proximity operations at the target NEO.

Scientific Rationale

Piloted missions to NEOs will have the capability to conduct an in-depth scientific investigation of NEOs. Essential physical and geochemical properties of NEOs can best be determined from dedicated spacecraft missions. Although ground-based observations can provide general information about the physical properties (rotation rates, taxonomic class, size estimates, general composition, *etc.*) of NEOs, spacecraft missions to NEOs are needed to obtain detailed characterizations of surface morphology, internal structure, mineral composition, topography, collisional history, density, particle size, *etc.* For example, the *Hayabusa* spacecraft encounter of asteroid Itokawa revealed an object with some unexpected physical characteristics (Fig. 1). Such missions are vital from a scientific perspective in order to further our understanding of the solar system.

Precursor Missions and Objectives

Robotic missions would be required in order to maximize crew safety and efficiency of mission operations. In addition to characterizing potential mission targets for the CEV, the data obtained would add to the knowledge about NEO physical properties. Some of the main objectives of precursor missions to NEOs are:

- Obtain basic reconnaissance to assess potential hazards that may pose a risk to vehicle and crew.
- Determine and survey NEO parameters such as surface morphology, gravitational field structure, rotation rate, pole orientation, mass/density, and general composition.
- Assess potential terrains for planning proximity operations and sample collection by the CEV and its assets.
- Aid in CEV navigation to the NEO, while refining orbit motion determination (Yarkovsky effect), and rotation rate changes (YORP effects) over time by deploying a transponder to surface.
- Deploy a small science package for a surface environment and material properties study to be retrieved later by the CEV.
- Observe a high kinetic energy experiment at the end of planned CEV activities at the NEO to investigate cratering formation, ejecta processes, seismic propagation, and momentum transfer.

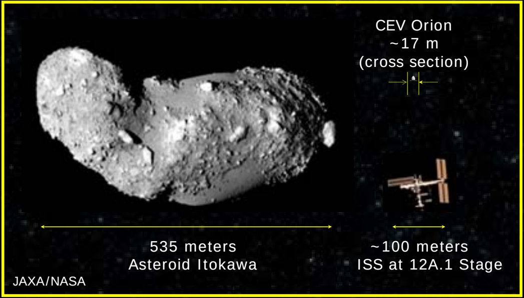

Fig. 1: Asteroid Itokawa, International Space Station, and CEV shown to scale.

CEV NEO Science Capability

Robotic spacecraft have limited capability for dynamic scientific exploration, and may not adapt as readily to certain conditions encountered at a particular NEO. A human crew is able to perform tasks and react quickly in a micro-gravity environment, faster than any robotic spacecraft could (rapid yet delicate maneuvering has been a hallmark of Apollo, Skylab, and Shuttle operations). The CEV could precisely deploy/re-deploy relatively small scientific packages and astronauts to the surface of a NEO during proximity operations (Fig. 2).

In addition, a crewed vehicle is able to test several different sample collection techniques, and to target specific areas of interest via extra-vehicular activities (EVAs) much more readily than a robotic spacecraft. The ability for the crew to traverse and collect macroscopic samples from specific terrains on the surface of an NEO is the most important scientific aspect of this type of mission. Having a human being interacting in real-time with the NEO surface material and sampling various locales in context would bring a wealth of scientific information on NEO physical properties.

CEV NEO Mission Objectives

Such capabilities that have been listed above greatly enhance any scientific return from these types of missions to NEOs. Some of the main scientific and engineering objectives of a CEV mission to a NEO are:

- Collect macroscopic samples (several tens to hundreds of kg) from various terrains on the surface of a NEO via astronaut EVAs. This would enable sample collection to be obtained in geological context.
- Utilize supplemental telerobotic collection of samples (from different, or difficult to reach sites on the NEO via an EVA of the crew) to expand the sample suite compared with only astronaut EVAs.
- Identify and collect other materials that are not indigenous to the NEO, which may have originated from other parent bodies (asteroids/comets).
- Investigate and determine the interior structure of the target NEO to place some constraints on the macroporosities that may be found among this population of objects (radar tomography and/or seismic studies).
- Investigate and experiment with possible techniques to attach science payloads, engineering structures, EVA equipment, and spacecraft for surface operations under micro-gravity regimes.
- Emplace and operate a resource collection device to demonstrate water production or metal extraction (even if in token quantities).
- Retrieve science package(s) left on the NEO for longer duration surface studies left behind by the precursor mission for analysis on Earth.

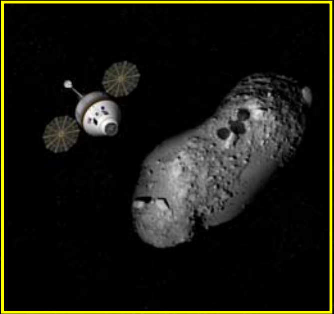

Fig. 2: Artist's concept of the CEV at a NEO.

Expected Benefits/Returns

With the ability to collect pristine samples from known objects within the solar system, scientists can start to "map outcrops" and glean new insights into the compositions and formation history of NEOs. Such knowledge will aid in a better understanding of our solar system, and also has the potential for more practical applications such as resource utilization (water, precious metals, oxygen, *etc.*) and NEO hazard mitigation (material properties, internal structures, macro-porosities, *etc.*). Some of the expected benefits and returns from sending the CEV to a NEO are:

- Provide ground truth to the vast set of data within the terrestrial meteorite collections, ground-based telescope observations, and spacecraft investigations of asteroids and comets (*e.g.*, geochemistry, thermal histories, isotope analyses, mineralogy, surface alteration, thermal inertias, source regions, *etc.*).
- Obtain extremely pristine samples for sensitive material analyses (*e.g.*, identification of pre-biotic materials).
- Gain understanding of the interior of NEOs that will be useful for planning possible mitigation techniques that may be required in the future, and for estimating the destructive potential of a NEO of a given size, composition, and structure.
- Identification of materials for *in situ* resource utilization. Both in terms of volatiles and silicates/metals that may prove useful for future exploration and commercial ventures.
- Identification of techniques and materials in attaching equipment under micro-gravity regimes that could be researched in more detail for subsequent spacecraft missions.
- Identification of mining and mechanical engineering methods to extract material for *in situ* resource utilization.

Conclusions

Such scientific, commercial, and hazard mitigation benefits, along with the programmatic and operational benefits of a human venture into deep space, make a mission to a NEO using Constellation systems a compelling prospect.

The Ten Second Review

- A study has been sponsored by the Advanced Projects Office within NASA's Constellation Program to examine the feasibility of sending a Crew Exploration Vehicle (CEV) to a near-Earth object (NEO).
- Precursor robotic missions would be required in order to maximize crew safety and efficiency of mission operations.
- A human being interacting in real-time at the surface of a NEO, collecting samples in geological context, would provide a wealth of scientific and practical data on NEO physical properties.

References:

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