SHOTPUT Sample Return: Examining the Compositional Gradient of Small-Body Objects

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Introduction

A unique trajectory opportunity exists that will allow a view of the compositional gradient of small-bodies in our solar system with a New Frontiers-class mission. The 2008 JPL Planetary Science Summer School design calls for a launch in 2015 to begin a seven year mission visiting a variety of small-body objects. With impactors and instruments onboard, this mission provides the chance to visit the main-belt asteroid (108144)) 2001 HM10, Jupiter Trojan contact binary (624) Hektor with companion S/2006 and the possibly active Centaur 39/P Oterma. In this paper, we expand on this mission by considering the addition of a third impactor for additional science at (108144) 2001 HM10 as well as carrying the Stardust / Genesis canister for an asteroid impactor sample return.

Mission

The SHOTPUT mission provides the first visit to Trojan and Centaur class asteroids as well as the visiting of a main-belt asteroid. This mission will provide the first in-situ investigation of small bodies across the solar system, from the mid to the outer system. As this mission was designed to fulfill the New Frontiers requirements, two impactors were included to study the composition of (624) Hektor and 39/P Oterma.

The mission has several objectives: to measure fundamental properties and composition while investigating the origins and evolution of small body objects. Onboard dead impactors, based on the Deep Impact [1] mission, but designed as 75 kg tungsten spheres will be used to view inside the asteroid bodies. Instrumentation on the SHOTPUT spacecraft includes a multi-spectral imager, a dust secondary ion mass spectrometer, a thermal infrared spectrometer, an ultra-violet imaging spectrograph, a wide angle camera and the radio science package.

This mission can be expanded, however, by taking advantage of the 300 km Earth fly-by after the main-belt asteroid encounter. In the original design, (108144) 2001 HM10 was a bonus and a chance to calibrate the instruments and encounter strategy before reaching the main small body objectives. But the original mission also managed to use an Atlas V 531 rocket, well within New Frontiers requirements. We propose to expand the launch vehicle to the Atlas V 541, allowing an extra 215 kilograms to be place onboard. A third impactor can be added in addition to the Stardust / Genesis [2] [3] sample return canister to provide internal samples of the main belt asteroid. Release of the impactor less than an hour before the close encounter will allow significant particles to escape the path of the spacecraft while dust will still be available for collection. The analysis at the 8 km/sec flyby speed, showed a dust plume lasting approximately 1 hour at the altitude of the spacecraft. This filled canister can be returned to Earth upon the Earth flyby.

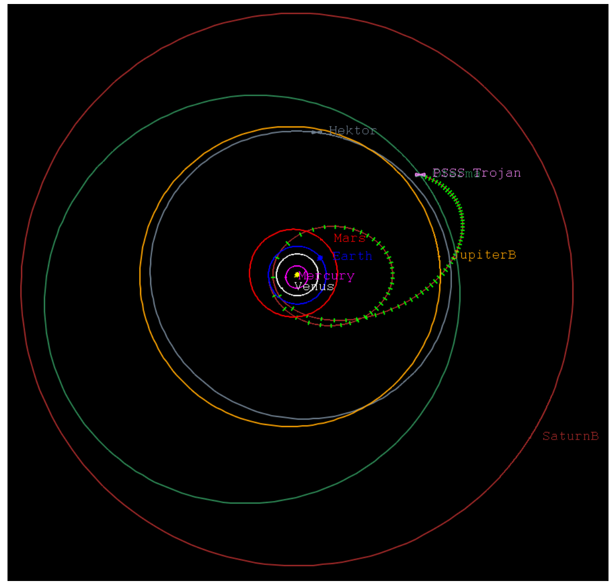

Figure 1: The final trajectory of the SHOTPUT mission upon encounter with Oterma [4], [5], [6].

Earth Flyby and Canister Re-entry

Earth flyby will occur on May 17, 2018 at a mere 300km altitude. The passive flyby was designed to change the ecliptic inclination of the spacecraft to align for the Hektor encounter. While the majority of the seven year mission is in a quiescent cruise stage, the flyby was planned to calibrate the instrumentation with the Earth and the moon. Thus the additional operational burden of releasing the sample return canister will not require additional operations time.

The canister will re-enter Earth's atmosphere with an encounter velocity similar to that of the Stardust mission, approximately 12 km/sec. Though the heat of re-entry will be extreme, the canister was designed for these high speeds. Similar helicopter retrieval and analysis methods may be used

Expected Science Return

As with Stardust, this sample return mission will provide samples of "fresh" asteroid particles able to be analyzed. Here, primitive samples from the interior of an asteroid will be provided allowing for both the composition and possible evolution of the main-belt asteroid to be studied.

As the canister and acquired particles will be similar to that of Stardust and Genesis, the scientific aparatus is already established for the analysis of this data. The use of heritage equipment will provide a reduction in mission cost and improve the overall already outstanding science return.

Table 1: SHOTPUT Sample Return Mission Timeline

Event	**Date**
Launch	March 27, 2015
(108144) 2001 HM10 Encounter	January 13, 2016
Deep Space Maneuver	June 14, 2016
Earth Flyby / Sample Return	May 17, 2018
(624) Hektor Encounter	March 25, 2020
Deep Space Maneuver	March 25, 2020
39/P Oterma Encounter	October 30, 2022

Summary and Concluding Remarks

The trajectory presented and used in both the SHOTPUT and SHOTPUT Sample Return missions is unique in that it allows several morphologically different small bodies to be investigated with in-situ instrumentation. Here, the trajectory and encounter strategies will be presented as well as the sample-return mission changes enabling the greater scientific gain. Sample mission scenarios will be examined and parallels given to heritage missions.

While the trajectory allows for several unique opportunities, work must begin soon to take advantage of the alignment of these particular objects. Other main belt asteroids may be available (though (108144) 2001 HM10 is the closest to the Hektor / Oterma trajectory), but the scientific gain of visiting a contact binary with companion and seeing a possibly active Centaur in the same mission is incredible. Further mission study is recommended to take advantage of this intriguing opportunity. Furthermore, though a sample return from the Oterma and Hektor encounters is unlikely (closest approach to Earth happens in 2037, but is still 1e8 km), the use of an Atlast V 541 allows the possibility for additional propellant to be added onboard for possible additional sample return capsules.

Acknowledgements

The initial mission design without sample return was completed as part of the 2008 Planetary Science Summer School at the NASA Jet Propulsion Laboratory. For further information about the original mission, see [4].

References

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