A SIMPLE MISSION CONCEPT FOR SURFACE IMAGING OF APOPHIS PRIOR TO EARTH ENCOUNTER.

R. W. Dissly[1], M. S. Veto[1], R. N. Schindhelm[1], D. Chan[1], and S. J. Mitchell[1], [1]Ball Aerospace (1600 Commerce St, Boulder, CO 80301, Richard.Dissly@ballaerospace.com).

Introduction: The close flyby of 99942 Apophis with Earth in April 2029 is a unique opportunity to witness the effect of such a major planetary encounter on rubble pile asteroids. While deformation of the body is predicted to be minimal, tidal torques exerted on Apophis are expected to alter its rotation state [1] and possibly excite seismic waves that lead to surface disturbances [2]. Observations of surface modifications resulting from the encounter will constrain seismic wave accelerations and amplitudes, currently unknown on rubble pile asteroids, but important in understanding how these objects evolve, and key to mitigation planning for planetary defense. Short of directly measuring surface seismicity, surface change detection from a known perturbation is perhaps the next best (and simplest) method that can be employed to improve our understanding of rubble pile asteroid geophysical properties.

The possible rendezvous of the OSIRIS-REx (O-REx) spacecraft with Apophis after the latter passes by the Earth has the potential to measure the degree of surface modification due to seismic shaking by mapping the entire sunlit surface to spatial resolutions of <10cm, as done on Bennu [3]. However, change detection would only be inferred without knowledge of the surface prior to Earth closest approach; O-REx only gives us half the picture. Mapping of the surface prior to Earth encounter is needed to understand what changed. This presentation outlines a low-cost mission concept to provide this needed data.

Mission Concept: Rendezvous mission architectures that follow Apophis through the full Earth encounter have been formulated [4], [5]. While such concepts would provide maximum science return by monitoring surface changes and even seismicity in real-time, the delta-V to execute the mission is high (>2km/s), likely making these Discovery-class in complexity and cost. With a launch needed before 2028 to enable rendezvous well-before April 2029, the time window to initiate such a new start is now – making such a mission very unlikely.

As an alternative, we suggest that Apophis flybys prior to Earth encounter be considered, to map as much of the surface as possible. Two flybys could easily be phased so that both hemispheres are observed, and the flyby phase angle can be refined to either maximize the visibility of the sunlit hemisphere (high phase angle) or maximize the surface contrast for both boulder and local slope mapping (intermediate phase angles). The primary payload would be a broadband visible imager to map the sunlit surface. Other payload options include spectrometers with spectral band passes similar to OVIRS or OTES on O-REx to optimize the comparison of the surface before/after Earth closest approach.

The capability of the visible imager will be a limiting factor for this flyby concept. The flyby velocity of the spacecraft relative to Apophis will be on the order of 6-7 km/s, dominated by the relative encounter velocity of Apophis with the Earth. For a simple imager with a pixel IFOV of 0.5mrad, a 1 km flyby distance will yield images of ~1m spatial resolution. Fast exposure times are needed to mitigate blur, as the flyby velocity traverses a projected pixel in ~75 usec. This is readily achievable with current flight camera designs, although the frame rate will be limited by the time it takes to read out the detector.

The flight system for this concept fits within the resource envelope provided by an ESPA rideshare, enabling low-cost access to space. However, as a rideshare this would be subject to launch slips that could easily compromise the mission. To alleviate this time constraint, we suggest utilizing lunar rideshare missions as the launch opportunity, placing the flyby spacecraft into any number of “parking” orbits in cis-lunar space (e.g., high lunar orbit, distant retrograde orbits, E-M Lagrange orbits). This widens the rideshare launch window to months/years prior to the Apophis encounter, adding significant resiliency to the schedule. Initial analysis suggests that a delta-V budget of ~100m/s is sufficient to include the initial parking orbit emplacement (depending on the launch destination), and the burns required to target an Apophis flyby several days prior to Earth closest approach.

Conclusion: A rideshare solution of 1-2 spacecraft to a cis-lunar parking orbit can enable a low-cost solution for flyby reconnaissance of Apophis prior to Earth encounter. Imagers and/or spectrometers performing flyby mapping the surface prior to the encounter can then be compared to the probable OSIRIS-REx encounter mapping to provide a much more robust assessment of change detection than O-REx alone.

References:

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