Low Cost Multiple Near Earth Object Missions.

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Introduction: There is much interest in asteroid exploration, especially Apophis, because of it's predicted close approach in 2019. This event has fueled further conversations regarding the concepts and designs of man made deflection maneuver missions. One of these techniques is the 'Yarkovsky effect' where the differential radiation of thermal emissions causes a slight recoil force to the asteroid. This effect is very, very small, so a crewed mission to deposit additional material has been suggested. The recent Augustine Commission Report included manned asteroid missions as a possible target for NASA to adopt as part of the "Flexible Path" option for Human Spaceflight. Manned missions would support both scientific and planetary defense purposes. Robotic precursor missions including sample return would increase the manned mission success probability by characterizing the potential candidate asteroids composition and local environment. In either case, we must be able to better constrain asteroid physical properties. Moreover, the scientific results for returned samples would be very important to the classification of asteroids, our understanding of solar system origin and history, and asteroid resource potential. The idea presented is to investigate a low cost approach to acquiring tbis data in a timely and cost effective manner. A commercially available spacecraft that has both liquid and solar electric propulsion as part of the standard configuration was used as the baseline for the analysis. This spacecraft can be used to bring back samples from three (3) asteroids in with a 2016 launch. The mission was modeled after the the JPL Nearer mission that returned samples to the Earth after an asteroid encounter. Spaceflightsolutions (Jerry Horsewood) method of optimizing these missions with added constraints uses Hilltop to search for the optimum solutions.

Index	Designation	Semi-axis	Eccentricity	Inclination
10302	1989 ML	1.2725	0.13661	4.3779
28066	1998 QA11	1.9802	0.09475	5.6986
68278	2001 FC7	1.4358	0.11446	2.6206
99942	Apophis	0.92244	0.1912	3.3314
103066	1999 XO141	1.6705	0.17448	2.9367
137799	1999 YB	1.3212	0.07497	6.7906
138911	2001 AE2	1.3496	0.08152	1.6606
141424	2002 CD	0.9796	0.17673	6.8795
156716	2002 RK27	1.9642	0.15243	3.7196
157082	2004 CW50	1.9882	0.1519	5.0895
162173	1999 JU3	1.1896	0.19036	5.8834
163000	2001 SW169	1.2484	0.05151	3.5549
189829	2002 VQ6	1.6431	0.13799	5.3314
209215	2003 WP25	0.99	0.12102	2.5601
215197	2000 SN42	1.797	0.11857	4.37084
89136	2001 US16	1.3558	0.2529	1.9059

Preliminary results indicate that for mission objectives we can visit Apophis and any other 2 asteroids on this list or any other 3 asteroids listed. The asteroids selected for this mission are Apophis, WP25 and US16.

We have considered only the low thrust approach to accomplish mission objectives since the characteristic velocity is high, at 8 km/sec. We assumed a science payload mass of 270 kg, power up to 300 W, and s/c bus pointing as good as 12 arc sec.

Conclusion: Our Commercial spacecraft are available with efficient high power solar arrays and hybrid propulsion systems (Chemical and Solar Electric) that make possible multiple Near Earth Object Missions within Discovery budget limits. Our analysis is based on the converged low thrust assumptions:

- Escape from Earth at a C3 of 11.5 km^2/sec^2, rendezvous with 3 asteroids and collect samples, returning to Earth after each rendezvous to drop 100 g samples.
- Launch between 2016 and 2025
- Total trip time less than 10 years
- Minimum stay time of 60 days at each asteroid
- Initial spacecraft mass less than 2,725 kg, launched from a an Atlas 401
- Maximum thrust of 0.165 N and Isp of 3,550 s
- Only EGA missions allowed (Rmin = 6,871 km)