PDC2025
Stellenbosch, Cape Town, South Africa

☑ **Space Mission & Campaign Design**

THE ACCESSIBILITY OF POTENTIALLY HAZARDOUS ASTEROIDS FOR BALLISTIC RAPID RECONNAISSANCE FLYBY MISSIONS

Justin Atchison[(1)], **Rylie Bull**[(2)]
[(1)] *The Johns Hopkins University Applied Physics Lab (JHUAPL), 11100 Johns Hopkins Rd., Laurel, MD 20723 USA, 240-228-1488, Justin.Atchison@jhuapl.edu*
[(2)] *JHUAPL, 11100 Johns Hopkins Rd., Laurel, MD 20723 USA*

Keywords: *asteroid flyby, rapid reconnaissance*

ABSTRACT

Rapid reconnaissance flyby missions represent the fastest means of characterizing a potentially hazardous asteroid in a planetary defense scenario. Flyby trajectories can often reach the asteroid with launches every year and cruise durations as short as months. In these scenarios, the design, fabrication, and testing of the spacecraft is the longest duration event in the overall timeline. In an effort to achieve a faster response capability and shorten this timeline, we could consider developing the spacecraft and instrument suite in advance of the asteroid's discovery. This would even offer an opportunity to test and demonstrate the spacecraft prior to a critical threat when any mission failures could be catastrophic.

This study seeks to characterize the mission design requirements and trade-space for a flyby spacecraft capable of performing reconnaissance of an as-yet undiscovered threat. Our goal is to help define a set of requirements the spacecraft must meet in order to be applicable for some percentage (*e.g.* 90%) of the expected threat population.

Our approach is to use a synthetic population of threatening asteroids to represent the distribution of expected orbital properties. For each synthetic asteroid, we compute the set of feasible ballistic (no maneuver) spacecraft trajectories that reach the asteroid. This ensemble of trajectories is then post-processed to identify subsets of parameters that correspond to satisfy fractions of the asteroid population. As an example, spacecraft power engineers must size the solar arrays to the maximum solar distance the spacecraft will experience. With this set of trajectories, we can compute the maximum spacecraft aphelion solar distance that is compatible with feasible trajectories to 90% of the synthetic population. The same type of question can be addressed for most relevant mission design parameters: encounter flyby speed; encounter lighting geometry; solar distances; Earth distances; and angles between the Earth, Sun, and asteroid.

Many of these parameters are highly correlated. An example of this correlation is shown in Figure 1 for solar phase angle and encounter flyby speed. The colors indicate

the fraction of all synthetic targets that are reachable with at most the specified speed or angle. The dotted lines are contours of 80%, 90%, and 95% of the population.

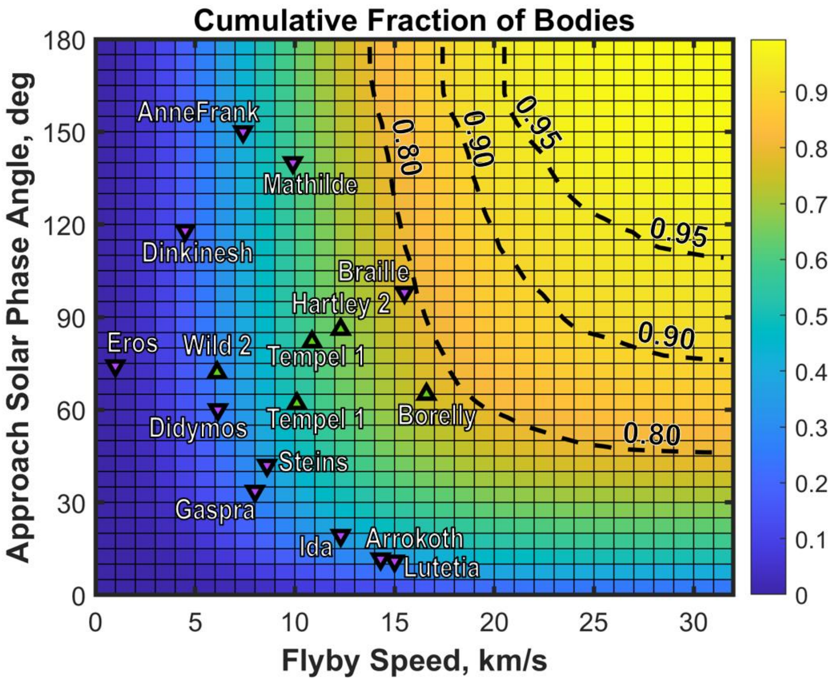

Figure 1: Approach solar phase angle versus flyby speed for the synthetic threat population. Previous asteroid (upside down pink triangles) and comet (green triangles) flybys are also plotted. This figure also appears in [1].

It turns out that there are multiple combinations of requirements that are compatible with 90% of the population. Table 1 gives one such set of parameters. Any individual flyby is unlikely to require all of the listed conditions. However, we don't know which conditions a newly discovered asteroid will require in advance. That is, the spacecraft is overdesigned for any single asteroid.

Table 1. Sample set of flyby conditions for >90% completeness [1].

Parameter	
Maximum time of flight	2.5 yrs
Minimum solar distance	0.9 AU
Maximum solar distance	2.0 AU
Maximum approach solar phase angle	90°
Maximum flyby speed	25 km/s
Maximum launch C3	30 km^2s^{-2}

We conclude by presenting different sets of parameters that achieve 90% completeness, and identifying which parameters are most driving.

REFERENCES

[1] Chabot, N., J.A. Atchison, R.A. Bull, et. al., "A Mission to Demonstrate Rapid-Response Flyby Reconnaissance for Planetary Defense", International Astronautical Congress, Milan Italy, IAC-24-E10.1.1, 2024.

****

Comments:
Prefer oral presentation