

☑ NEO Characterization

**MASS MEASUREMENT TECHNIQUES FOR HIGH-SPEED FLYBY
RECONNAISSANCE MISSIONS OF POTENTIALLY HAZARDOUS ASTEROIDS**

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Rapid reconnaissance flyby missions are the fastest means of obtaining asteroid characterization data in a planetary defense scenario. However, the small masses of potentially hazardous asteroids (PHAs) require unreasonably or impossibly close flyby distances to achieve useful mass measurements with ground-based tracking, the current state of practice. This capability gap limits the value of rapid reconnaissance flyby missions and means that decision makers are missing critical information in a PD scenario (National Science & Technology Council, 2018).

Recent research has identified that relative tracking between multiple spacecraft can significantly increase flyby mass measurement sensitivity (e.g., Christensen 2021, Bull 2021, Walker 2021). In these approaches, the flyby spacecraft deploys one or more trackable test-masses prior to the flyby. These test-masses are intended to pass very close to the asteroid, within 1-3 body radii of the surface. The short range of the test-mass to the asteroid produces a large perturbation to the test-mass's trajectory. The relatively short distance between the host spacecraft and the test-mass (10's of km) provides a high accuracy measurement of this perturbation, allowing for a more sensitive mass determination.

This study evaluates a selection of concepts to achieve this relative tracking, including: passive optical tracking, active RF tracking (range and Doppler), and precise laser ranging. We also consider the impact of adding attitude control and maneuvers to the test-masses. These techniques are modeled in the context of two reference scenarios: the 2025 PDC hypothetical asteroid and a very high speed (35 km/s) hypothetical encounter.

This paper expands on former studies by modeling the full encounter concept-operations with representative spacecraft models. We model ground tracking

throughout cruise and flyby operations, optical navigation (when the asteroid is detectable), pointing constraints, approach targeting maneuvers, and a practical spacecraft and measurement schedule.

Given that the measurement is very sensitive, the simulations were conducted using two independent orbit determination tools: the commercial tool Orbit Determination Tool Kit (ODTK) and the NASA JPL tool MONTE.

Based on this research, we will update and expand Figure 1, which shows the sensitivity of flyby mass determination as a function of asteroid diameter and flyby speed, for each of the measurement techniques. Historically, asteroid flybys have been to much larger targets than we expect in a planetary defense encounter (100's of meters). Once updated, this figure will provide a reference for quickly determining what techniques are viable for a given flyby encounter. This is intended to be a guide for flyby reconnaissance mission design.

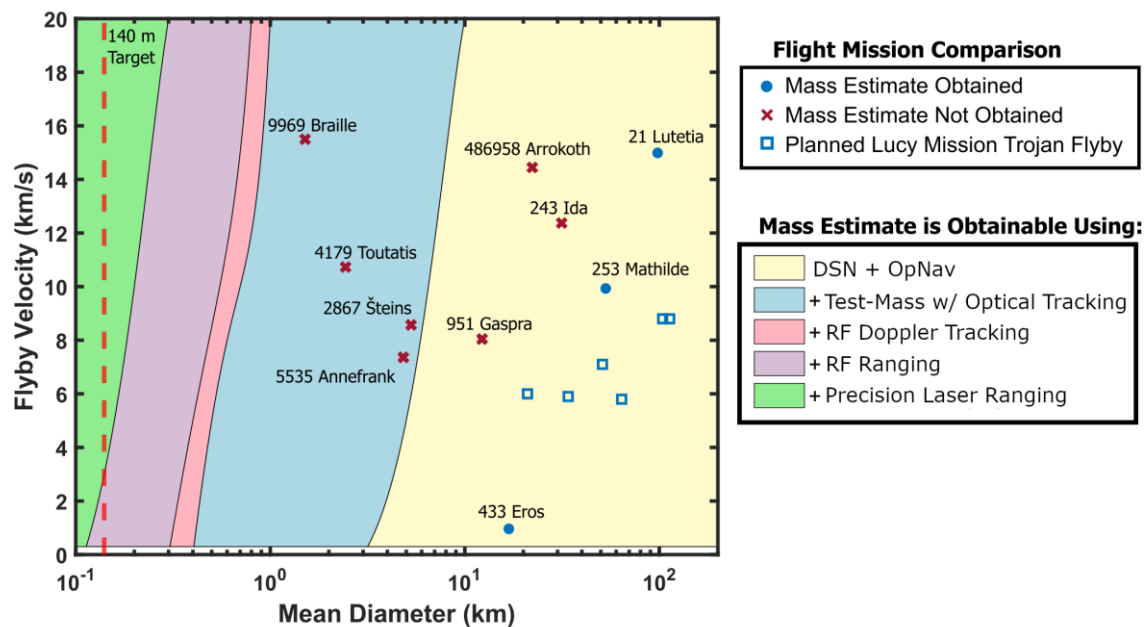


Figure 1: Expected mass determination performance based on simulation for all four architectures overlaid with results from historical missions and planned Lucy mission targets. Here, mass is considered obtainable if the post-flyby mass uncertainty is better than 25% 1σ . (This figure is currently in draft form.)

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Comments:

Oral presentation preferred.

This could appear in the Space Mission & Campaign Design section if that were preferable.