Session 2 Summary: The Small (<10 meters) NEA Population

Al Harris (More Data!): *Population estimates of Small NEAs*

Andy Rivkin (APL): *Small NEA Characteristics: Albedo, Composition, Spin, and Mechanical Properties*

Bill Bottke (SwRI): *Modeling Capabilities and Uncertainties*

Paul Chodas (JPL): *Estimated ARM candidate Target Population and Projected Discovery rate of ARM Candidates*

Session chairs: Mark Sykes (PSI) and Dan Britt (UCF)

Session 2 Summary

ARM Target Characteristics (Chodas)

- Orbit: $V_{infinity}$ relative to Earth < 2 km/s desired, <2.6 km/s required.
- Orbit: Natural return to Earth. Orbit-to-orbit distance (MOID) < 0.03 au, Natural return to Earth in early 2020s (2020-2026) (i.e., close approach within 0.3 au)
- Mass: <1,000 metric tons (upper bound varies according to $V_{infinity}$)
- Rotation State: Spin period > 0.5 min. Upper bound on angular momentum: ~$1x10^6$ kg-m^2/s. Non-Principal-Axis rotation can be accommodated
- Size and Aspect Ratio: 4 m < mean diameter < 10 m (roughly, 27 < H < 31). Upper limit on max dimension: ~15 m. Aspect ratio < 2:1
- Spectral Class: Known Type (C-type with hydrated minerals desired)

Session 2 Summary (Continued)

Projected Discovery Rate of ARM Candidates (Chodas)

- The ARM candidate discovery rate will almost certainly increase due to enhancements to existing surveys and new surveys coming online.
- Current detection of targets meeting ARM dynamical and magnitude constraints is ~2.8/year. Expanding existing and new ground-based facilities may double this.
- With at least another 3-4 years to accumulate ARM candidate discoveries, at least ~15 more ARM candidates are expected to be discovered; favorable mission design trajectories should be available for at least half of these.

Q&A

- *Fraction of dynamic/magnitude ARM candidates that meet size/mass requirements is not known.*
- *Question about small number of Pan-STARRS ARM target detections (3) to which models are constrained.*

Session 2 Summary (Continued)

ARM Population Uncertainties and Options (Bottke)

- Most Asteroid Redirect Mission (ARM) Candidates, objects on very Earth-like orbits, are from the main asteroid belt.
- There are probably many thousands to many tens of thousands of ARM candidates.
- Our existing NEO models, developed for large NEOs, may break down for small NEOs.
- Estimates suggest our NEO models may be missing as much as a factor of 8-10 of the ARM Candidate population. Possible explanation (Harris): Possible sources of ultra-low v_∞ NEAs are Lunar ejecta (most), space debris (some), Main-belt asteroids (almost none), Mars ejecta (almost none).
- Minimoons are NEOs that have been temporarily captured in the Earth-Moon system. Bottke argues they provide superior targets for future human missions.
- A minimoon mission may allow NASA astronauts to reach an NEO by 2025 at lower cost and risk than other prospective missions.

Session 2 Summary (Continued)

Uncertainties of Potential ARM Target Physical Characteristics

- Albedo uncertainties for a given brightness lead to factor of ~3 uncertainty in size → factor of ~25-30 in mass. Albedo/size measurements are imperative. (Rivkin)
- Range of likely-seeming porosities from zero (*if* monolith) to 50% (if like larger asteroids, high end of TC3 estimate) → Densities from ~1 g/cm^3 - ~3 g/cm^3 → another factor of 3 in mass (*irreducible prior to S/C visit?*). (Rivkin)
- Great uncertainty in understanding overall population composition because of (unconstrained?) fraction of low albedo X-complex asteroids. Expect >~5% of NEOs to have hydrated minerals. (Rivkin)
- Rotation rates likely < 5 minutes (Rivkin). Many small objects are tumblers (Harris).
- Regolith cohesion can result in a 10m rubble rapidly rotating < 0.5 RPM with >mm grains on the surface (Scheeres & Sanchez).

Session 2 Summary (Continued)

Uncertainties of Potential ARM Target Physical Characteristics

- *In choosing a very low v_∞ target, you need to have very good physical characterization of the object if you want to be sure you aren't bringing a piece of the moon back to its home, or even an old rocket body. (Harris)*

- *Size/mass determinations are essential as it can easily push a dynamic/magnitude compliant candidate beyond the ARM target requirement range.*

- *Is it possible to adequately characterize all potential ARM targets in the time period after their discovery?*

- *A rapidly rotating cohesive rubble pile may represent a source of risk against interacting with the surface (intentionally or unintentionally).*