Target NEO 2: Open Community Workshop

Executive Summary

July 25, 2013

Introduction to Workshop

- NASA's *Asteroid Initiative* has prompted much community discussion on both the science value and the technical and programmatic challenges involved with this campaign. Specifically, much of this discussion has centered around the prospect of an asteroid redirect mission.

- The **Target NEO 2 Workshop** was a community-driven activity to discuss these challenges, and to provide technical input from experts in fields pertinent to robotic and human NEO exploration, to identify areas of potential risk and help inform ARRM mission formulation. It was structured around a series of technical and programmatic topics, and was not a forum for broader policy discussions.

- The Workshop was held July 9, 2013, at the National Academy of Sciences Auditorium, in Washington, DC. In attendance were over 140 people in person, and over two dozen via WebEx, representing academia, NASA, industry, and the international space exploration community.

- The Workshop presentations and discussion were focused around a few key questions:
  - *What are the technical challenges involved and what new capabilities are needed for the newly proposed Asteroid Robotic Redirect Mission (ARRM)?*
  - *What technical information is still needed?*
  - *Are there any alternative approaches?*

- All presentations from workshop are uploaded to website: **http://targetneo.jhuapl.edu**

Workshop Agenda

Session 1: Update to Flexible Path Vision

- *Overview of NASA's New Asteroid Initiative* (Bill Gerstenmaier, NASA HQ, AA HEOMD)
- *NRC Human Exploration Study Update* (Michael Maloney, SSB)
- *Global Exploration Roadmap Update, ISECG Perspective* (Kathy Laurini, NASA HQ)

Co-chairs: Doug Stetson (Independent) & Cheryl Reed (APL)

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

- *Population Estimates of Small NEAs* (Al Harris, More Data!, Inc.)
- *Small NEA Characteristics* (Andy Rivkin, APL)
- *Modeling Capabilities and Uncertainties* (Bill Bottke, SwRI)
- *Estimated ARM Candidate Target Population and Projected Discovery rate of ARM Candidates* (Paul Chodas, JPL)

Co-chairs: Mark Sykes (PSI) & Dan Britt (UCF)

Session 3: Finding Small NEAs – Current Capabilities and Gaps

- *Tutorial on Process of Finding Small NEAs* (Tim Spahr, MPC)
- *Follow-up Characterization Needs and Issues* (Lance Benner, JPL)
- *Existing and Near-Term Ground-Based Capabilities and Gaps* (Steve Larson, U of Arizona)
- *Discovery Process for Finding ARM Targets Using PS2 and Atlas* (Eva Schunova, U of Hawaii)
- *Existing and Near-Term Space-Based Capabilities and Gaps* (Amy Mainzer, JPL)

Co-chairs: Paul Abell (JSC) & Rich Dissly (Ball)

Session 4: Small NEA Mission Design Challenges

- *End-to-End Mission Design Trajectory Optimization* (Damon Landau, JPL)
- *Proximity Operations and Characterization/Nav/Control* (Steve Broschart, JPL)
- *Docking, Grappling, Capture, Control, and Alternative Approaches* (Carlos Roithmayr, LaRC)
- *Maintaining a Safe, Stable, and Human Accessible Parking Orbit* (Dave Folta, GSFC)
- Defining Key Technology Requirements (John Dankanich, MSFC)

Co-chairs: Brent Barbee (GSFC) & Steve Chesley (JPL)

Session 5: Technical Value of ARM, Panel Discussion

Panel

- Gentry Lee, JPL
- Doug Cooke, AA NASA (Retired)
- Tom Jones (FIHMC, former astronaut)
- Jim Bell (ASU)

Co-chairs: Dan Mazanek (LaRC) & Faith Vilas (PSI)

Session 6: Session Summaries and NASA Response

- Session 1-5 Co-Chairs
- Jim Green, NASA HQ
- Greg Williams, NASA HQ

Summary of Key Findings

- ARRM has the potential to be a unifying, cohesive endeavor across NASA directorates and may be the only way to fulfill NASA's goal of a human asteroid mission by 2025.
- Key aspects of ARRM remain undefined, resulting in lack of clear requirements and success criteria and the potential for high cost and schedule risk.
- ARRM requires multiple significant technology developments and a complex implementation that present significant schedule and cost risk
- The difficulty in discovering targets that can be fully characterized with existing observational assets presents a major schedule risk.
- Uncertainty in asteroid physical properties (size, mass, spin state, mechanical properties) translates to significant mission risk, and there is at present no comprehensive plan for the observations required to refine these properties.
- ARRM will have limited applicability to planetary defense due to the small size of the target NEA. However, it may provide some marginal benefit from the systems, capabilities, and operational experience that can be leveraged.
- A firm cost cap and realistic development schedule are required before the community can fully evaluate or endorse ARRM as a step in the exploration architecture.

Detailed Findings: Target Detection and Characterization

- The set of potential targets for ARRM is not yet robust. Additional targets are needed to ensure that a good subset meet mission selection criteria for size, spin state, and orbit, and to provide viable backup launch opportunities.
  - Ground-based assets offer the only realistic opportunity to substantially increase the number of candidates within the current development schedule of a launch in 2017-18. Planned observatory upgrades/additions need to be realized.
  - A Discovery-class infrared space-based observatory (e.g., NEOCam or Sentinel) may make significant contributions to the number of candidate targets; however, such an asset could not achieve operational status until at least 2018.
- Follow-up observations to refine target orbits and to characterize size, mass, and spin state are critical to lower the uncertainty of these parameters for mission design, and need a more deterministic approach.
  - Follow-up visible, IR and radar observations are mandatory to reduce trajectory, size, mass, and spin state uncertainty in potential targets.
  - The current follow-up approach is too ad hoc; stronger follow-up procedures with identified assets are needed.
- Uncertainties in the ARRM target population and the difficulty in discovering viable targets that can be fully characterized translates to significant schedule risk. It is not clear that a robust target set can be generated to meet the current ARRM schedule of a launch in 2017-18.
- There is a distinct possibility that some small, rapidly rotating asteroids may be rubble piles. For such objects, the forces holding them together may be quite small. Interaction with such an object during capture may represent a risk.

Detailed Findings: Technical Readiness of ARRM

- The key technology needs for ARRM include propulsion, power, proximity operations, and the capture mechanism. The lack of fully formulated mission requirements makes the technology development targets poorly defined. It is therefore unclear whether the needed technologies can be ready in time for a 2017-18 launch.
  - Traditional technology development practices (e.g., incremental advancement of TRL) and associated oversight may not be compatible with such an aggressive schedule. This creates additional challenges and risks.
- The uncertainties in the mass and other physical properties of any given candidate target NEA create multiple challenges. Paramount among these is the likely need to design to the worst-case of the potential range of insufficiently constrained properties (such as mass or size).
- Although there are indications that capturing a small NEA may be feasible, there remain substantial uncertainties regarding mission design that must be addressed. Further studies should concentrate on the translational maneuvers and mechanisms needed to capture any small free-flying NEA. These studies should include modeling of flexible structure dynamics and shearing inside the capture mechanism since the target could be monolithic, loosely bound, or a rubble pile.
- Additional trade studies are required to evaluate the mission concepts of capturing an entire small NEA versus collecting a small portion of a larger NEA. The latter option may be particularly difficult to design for without some a priori knowledge of the target structure.

Detailed Findings: ARRM Programmatics

- The feed-forward of ARRM to future human space exploration, including Mars, is unclear, and there has been insufficient study of potential alternatives that could achieve similar goals.
- Key aspects of ARRM remain undefined, resulting in lack of clear requirements and success criteria and the potential for high cost risk.
  - E.g., there is confusion as to whether the return of any asteroid sample to lunar orbit is a requirement.
- The ARRM schedule is too aggressive when coupled with technology development, mission complexity, multi-center implementation and funding uncertainties.
- The NASA-provided target cost (~$1B) is not substantiated.
  - Mission formulation studies and full-cost assessment are required.
  - NASA should consider competing ARRM to ensure sufficient technical scrutiny and peer review.
- Identification of ARRM as a “technology demonstration” is inconsistent with its high cost
- ARRM implementation planning/studies have not yet engaged international partners.
  - The compressed schedule may limit options for international participation.

Recommendations

- Establish clear ARRM requirements and success criteria that demonstrate how the mission contributes to future human space exploration.
- Establish a realistic and achievable schedule based on assessment of technical and programmatic requirements.
- Provide a realistic, independently assessed cost cap that fully accounts for all mission-related costs.
- Utilize the established processes of competition and peer review to define and assess the ARRM mission, to verify its feasibility within the established cost cap, and to determine and maximize the probability of mission success.
- Determine resources needed to provide upgrades to key ground-based observatories to improve detection rate and follow-up characterization capabilities.
- Improve remote characterization follow-up procedures with identified assets.
- Consider small robotic precursor missions to close characterization risks.

Target NEO 2 – Public Summaries and Next Steps

- Summary presented to SBAG on July 10, 2013
- Written report out by end of August
  - Open to community for inputs
  - Drafts will be available for comment on website
- Planned briefings at AAS/DPS, other meetings (e.g., GER 2)