Target NEO 2 Workshop: Summary and Findings

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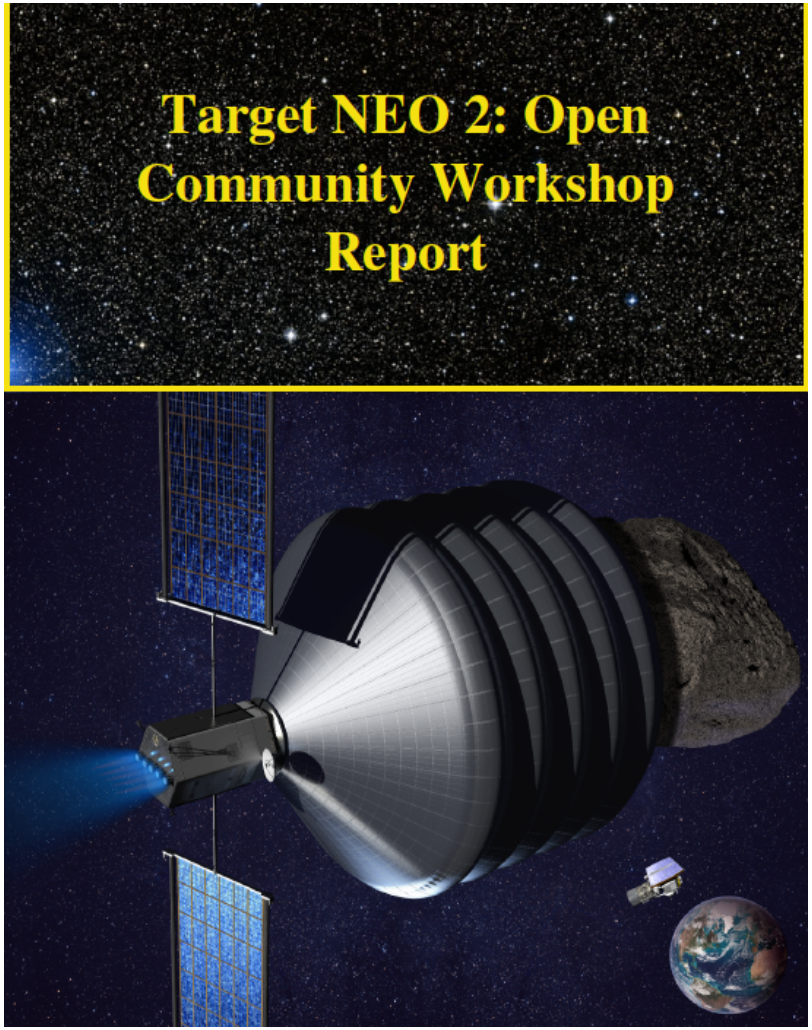
Outline

- Workshop overview
- Workshop agenda/organizers/panelists
- Community briefings and interaction
- Key findings and recommendations
  - Programmatic considerations
  - Target detection and characterization
  - Mission design for the ARRM
  - System design for the ARRM
  - Cost and schedule considerations
- Recommendations

Workshop Overview

- Target NEO 2: A broad community workshop held July 9, 2013 in Washington, D. C. at the National Academy of Sciences Auditorium
  - Follow-on to Target NEO 1 (Feb. 2011)
- Purpose: Support development of a robust human exploration program by ensuring that technical viewpoints of experts in fields pertinent to robotic and human NEO exploration are provided and documented
- Over 160 participants from academia, industry, NASA, international
- Key questions:
  - What are the technical challenges of, and key new capabilities needed for, the ARRM?
  - What technical information is still needed?
  - Are there any alternative approaches?
- Product: Written report and community briefings and discussion

http://targetneo.jhuapl.edu



Community Briefings and Interaction

Key objectives of the Target NEO 2 workshop and subsequent report are to provide input to community stakeholders and engage in discussion and debate on the readiness for and implications of the ARRM and the broader asteroid initiative

- Discussions to date:
  - 9th Meeting of the NASA Small Bodies Assessment Group (SBAG): July 10, 2013
  - Future In-Space Operations (FISO) Working Group: August 28, 2013
  - AAS Division for Planetary Sciences (DPS): October 14, 2013
  - National Research Council (NRC) Human Spaceflight technical panel: October 15, 2013
- Upcoming opportunities:
  - 10th Meeting of the NASA SBAG: January 8—9, 2014
  - 45th Lunar and Planetary Science and Conference: March 17—21, 2014

Workshop Agenda/Organizers/Panelists

- **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

Programmatic Considerations

Report Section 1: Update to the Flexible Path Vision

The ARRM is a key element of NASA's new Asteroid Initiative and is proposed as the first step for future human exploration beyond Low Earth Orbit

- The ARRM may help fulfill NASA's goal of a human asteroid mission by 2025
- However, feed-forward of the ARRM to future human space exploration, especially Mars, is unclear
  - Useful context for human mission experience and exercises key systems, but:
  - Limited direct applicability of most ARRM technologies to future mission goals
  - Insufficient study of potential alternatives and development of metrics for evaluation
  - Limited relevance to planetary defense due to the small size of target NEA
- Key aspects of the ARRM remain undefined, resulting in lack of clear requirements and the potential for high cost risk
  - *Must* establish success criteria and rigorous requirements flow-down that demonstrate how the mission contributes to future human space exploration
  - Designation as a "tech demo mission" does not appear to be consistent with the high cost or programmatic significance of the ARRM
- ARRM studies have not yet engaged international partners, and compressed schedule may limit options for international participation

Target Detection and Characterization

Report Section 2: The Small (<10 meters NEA Population)
Report Section 3: Finding Small NEAs: Current Capabilities and Gaps

Early discovery, characterization, selection, and study of a target NEO is key to ensuring mission success with acceptable cost and risk

- Current detection rate of candidate targets meeting ARRM dynamical and magnitude constraints is ~2—3/year; may increase to ~5/year
  - Expect to have ~2 dozen acceptable candidate targets *(orbit, size, mass only)* by 2017
  - Very limited time for follow-up observations (few days for optical/IR, radar)
- Uncertainty in asteroid physical properties results in significant mission risk
  - No comprehensive plan to make the required observations
  - Existing observational assets are of limited utility for detailed characterization
  - Many limitations on follow-up are organizational rather than technical, e.g. time required for "radiation clearances" (radar)
- Radar characterization is essential to reducing uncertainties in size/mass/rotation state
- Must improve plans and capabilities for detailed characterization prior to final ARRM mission/ system definition
  - Improve procedures for more rapid characterization and establish a "clearing house" for coordination and data collection
  - Pursue new space-based telescopes for NEO detection and study
  - Consider small robotic precursor missions to fully close characterization risks

Mission Design for the ARRM

Report Section 4: Small NEA Mission Design Challenges

The ARRM design appears feasible in terms of mass, energy, and time, provided that a satisfactory target is identified and characterized early in development

- A lunar Distant Retrograde Orbit (DRO) is an innovative place to keep the captured asteroid; simplifies design of the ARRM and subsequent exploration
- Return of an *entire, cohesive* small NEO to the Earth-Moon system appears feasible, but many potential targets will impose additional complexities
  - "Rubble pile" or loosely bound NEOs may invalidate key mission decisions
  - Extracting a portion of a larger object (e.g., a "boulder") is not well understood
  - Differences in mission designs are extreme; decision must be made soon
- Propulsion technology (SEP) and techniques for proximity operations / capture can be available this decade
  - Ability to acquire a sufficient quantity of xenon must be established
  - Capture and de-spin of "principal axis rotators" appears feasible but tumbling objects (the more likely case) require additional analysis
  - Unusual force environment near small NEOs requires careful study of dynamics
    - Solar radiation pressure is a dominant force with implications for system design

System Design for the ARRM

Report Section 4: Small NEA Mission Design Challenges *(continued)*

Major ARRM system requirements remain undefined, resulting in high risk that would be unacceptable for most NASA missions

- Lack of clear success criteria and target characteristics make it impossible to design the ARRM flight system to NASA standards
  - Level 1 requirements and flow-down to system/subsystem specifications are vague and incomplete
  - Likely need to make key spacecraft decisions prior to target asteroid selection will result in overdesign or substantial technical risk, both leading to high cost
- The ARRM requires multiple significant technology developments and a complex implementation that lead to high mission risk
  - Propulsion, power, proximity operations, and capture mechanism all require substantial development
  - Flight system testability in a relevant environment ("test as you fly") is impractical
  - Capture system / human interactions with target asteroid is a major risk area

Schedule and Cost Considerations

Report Section 5: Panel Discussion

A firm cost cap and realistic development schedule are required before the community can fully evaluate or endorse the ARRM

- Any ARRM plan that proposes launch prior to 2019 is not credible
- Disparate unsubstantiated cost estimates (e.g., $1B--$5B) must be reconciled via a realistic and comprehensive cost assessment
  - Community support hinges on understanding the relative costs and benefits of the ARRM, and where the resources will come from
  - NASA must establish a realistic, independently assessed cost cap that fully accounts for all mission-related costs
  - Determine resources needed to upgrade key ground-based observatories to improve detection rate and follow-up characterization capabilities
- Utilizing the established processes of competition and peer review would enhance credibility and support

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, 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
- Fly a space-based NEO survey telescope
  - A cross-cutting agency asset supporting science, planetary defense, and exploration
  - A robust target set will always be a limiting factor for human NEO exploration
  - The NEO survey telescope should be the top precursor priority for a human mission to a NEO

Concluding Remarks

- The Target NEO 2 workshop was well supported and has been an effective mechanism for community input
  - Educated the community about the ARRM and the asteroid initiative
  - Ensured that broad technical expertise was provided and documented
  - Presentations and discussions have been well received and are continuing
- Many positive reactions to the general ARRM concept, but significant skepticism regarding cost, schedule, and technical risk (unknown unknowns)
- NASA must be clear about the ARRM goals and implementation plans, and must follow its own rules
  - The ARRM should not get a "free pass" on issues such as requirements, risk, and technology readiness
  - Peer review and competition can mitigate many community concerns
- Community acceptance would be enhanced by increased involvement and a broader comparison of alternatives
  - Are there other means of achieving the same technical/programmatic goals?