Asteroid Initiative Idea Synthesis

Asteroid Redirection Systems
(Held on September 30, 2013)
Jim Reuter, Steve Sandford

Join the discussion and send questions to: #NASAasteroid
Purpose of Asteroid Redirection Systems Session

• Concepts for robotic spacecraft systems to enable rendezvous and proximity operations with an asteroid, and redirection of an asteroid into trans-lunar space

• Integrated sensing systems to support asteroid rendezvous, proximity operations, characterization, and capture

• Refinements of the Asteroid Redirect Mission concept and opportunities for dual use technology development
Selecting RFIs for Presentation

• 75 responses received; 16 responses selected for discussion at Workshop

• Consolidated into 13 presentations plus one “walk-on”

• Mix of industry, government (NASA), international, university

• Targeted responses for discussion that represented interesting/new ideas, system variations or added details, higher TRL technologies
# Session Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Presenter</th>
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<tr>
<td>1:30 p.m.</td>
<td>Session Introduction</td>
<td>JIM REUTER /NASA Marshall Space Flight Center</td>
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<tr>
<td>1:40 p.m.</td>
<td>Asteroid Retrieval Alternatives from the KISS Study (Status of Reference Configuration including technical risks and uncertainties)</td>
<td>JOHN BROPHY /NASA Jet Propulsion Lab</td>
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<tr>
<td>1:55 p.m.</td>
<td>Proposed Development Solutions for Asteroid Redirection Systems</td>
<td>SIMONA FERRARIS/Thales Alenia Space Italy <em>(Virtual)</em></td>
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<tr>
<td>2:10 p.m.</td>
<td>Asteroid Redirect Vehicle with Solar Electric Propulsion and Robotic Manipulator</td>
<td>ADAM MAHER /Space Systems Loral</td>
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<tr>
<td>2:20 p.m.</td>
<td>Alternative Mission Concepts and Summary of GSFC Technologies and Facilities Relevant to ARM</td>
<td>BENJAMIN REED /NASA Goddard Space Flight Center</td>
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<tr>
<td>2:30 p.m.</td>
<td>Leveraging Heritage Spacecraft Platforms and Subsystems to Reduce ARM Execution Risk</td>
<td>MIKE ELSPERMAN/Boeing and MANNY LEINZ/Boeing</td>
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<td>2:45 p.m.</td>
<td>Asteroid Redirect Systems - Integrated Sensing Systems and Solar Electric Propulsion System Concepts</td>
<td>JOHN RINGELBERG/Lockheed Martin</td>
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<td>3:00 p.m.</td>
<td>Enabling Technologies for Asteroid Redirection Systems</td>
<td>JOHNATHAN WROBEL/Honeybee Robotics <em>(Virtual)</em></td>
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<tr>
<td>3:10 p.m.</td>
<td>Integrated Sensing Systems to Support Asteroid Rendezvous, Proximity Operations, Characterization, and Capture</td>
<td>STEVEN WARWICK/Northrup Grumman</td>
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<tr>
<td>3:20 p.m.</td>
<td>Integrated Sensing Systems for Asteroid Missions</td>
<td>RICHARD DISSLY/Ball Aerospace</td>
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<tr>
<td>3:30 p.m.</td>
<td>In-situ Radar for Asteroid Characterization and Altimetry</td>
<td>MARK HAYNES/NASA Jet Propulsion Lab</td>
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<tr>
<td>3:40 p.m.</td>
<td>Integrated Sensor Systems and Applications of Satellite Servicing Technology to ARM</td>
<td>PAUL FULFORD/MDA Canada</td>
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<td>3:50 p.m.</td>
<td>Refinements of the Asteroid Redirect Mission Concept to Maximize Scientific and Commercial Value</td>
<td>DAVID GUMP/Deep Space Industries</td>
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<tr>
<td>4:00 p.m.</td>
<td>Earth’s Minimoons: New Prospective Targets for Human Exploration Minimoons: Discovery &amp; Retrieval Missions</td>
<td>BILL BOTTKE/Southwest Research Institute and ROBERT JEDICKE/University of Hawaii</td>
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<tr>
<td>4:25 p.m.</td>
<td>Discussion and Synthesis</td>
<td>OPEN DISCUSSION</td>
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Key Topics Discussed (Categories)

• Vehicle Systems
• Sensing Systems and Algorithms
• Mission Enhancements
• Extensibility
• Alternate Mission Scenarios/Concept of Operations
• Different Business Strategies
Key Topics Discussed (p. 1 of 4)

**Vehicle Systems**
- Key technology readiness (solar arrays, thrusters, power processing units, etc.)
  - Mostly Hall thruster focus but also had a discussion on lower TRL plasma based solar electric propulsion
- Adaptations of existing spacecraft bus’
- Balance between technology development for improved mission vs. use of low risk mature technologies (on-ramp vs. off-ramp philosophy) – preference for pushing technology up front where significant benefits seen
- Importance of being able to verify & validate system on ground
- Need for flexibility in the design to be able to accommodate surprises
- Key risk/development areas: asteroid characterization, rendezvous & capture system, solar arrays, high-power thrusters, power processing units, xenon tanks, dust & volatiles
**Key Topics Discussed (p. 2 of 4)**

- **Sensing Systems & Algorithms**
  - Wide range of sensor technologies discussed for various mission requirements: characterization, rendezvous, proximity operations, capture
    - Target size, shape, range, tumble dynamics, shape modeling
    - Closed loop control with uncooperative target – tracking, relative navigation, rate matching
    - Considerations for surface and subsurface characterization, crater detection/tracking, asteroid structural strength
    - Candidate sensor technologies include: visible/IR camera, LIDAR, laser altimeter, spectrometry, radar, tomography, etc.
  - Discussion of integrated systems and algorithm development
  - Hardware & software adaptation from heritage systems (OSIRIS-REx, DARPA Phoenix, Orbital Express, STORRM, ISS, XSS-10, etc.)
Key Topics Discussed (p. 3 of 4)

• Mission Enhancements
  – Robotic manipulators – enhanced asteroid characterization, dissimilar capture techniques; enabler for “pick up a rock” scenario
  – Cubesat class observation and sensor spacecraft
  – Contact excursion probes; surface samplers
  – Science potential
  – Take advantage of ~3 year ARRV transition to cislunar space

• Extensibility
  – Broader solar electric propulsion applicability
  – Satellite servicing missions – similarity in needs
  – Potential for commercial applications (e.g., ISRU, fuel for satellites)
  – Potential re-use as cargo tug for translunar assets
  – Planetary defense/asteroid deflection demonstration
  – Space debris removal
  – Potential value of remaining material – commercial follow-on
• Alternate Mission Scenarios/Concept of Operations
  – Benefits of obtaining multiple samples from rubble-pile asteroid
  – Precursors – considerable input on importance
  – Consider a campaign rather than “one-off”; visit more than one asteroid
  – Mini-moons
  – Separate transporter (main bus/SEP) and capture vehicles

• Different Business Strategies
  – COTS-like model for commercial partnership engagement
  – Possible industry partnership for precursors
  – Leverage existing industry assets; have NASA focus on innovation areas
Findings Relevant to the Mission

- Establish concise set of mission objectives and figures of merit
  - Includes extensibility/commercialization considerations
  - Weigh cost vs. mission objectives; launch vehicle concern
  - Understand how much asteroid mass is enough; quality vs. quantity
  - Top FOM should be sustainability; more than just a single mission

- Perform an assessment of the various mission concept options
  - Includes weighing technology on-ramp vs. off-ramp approach and mission enhancement options

- Focus risk-reduction activities consistent with mission concept approach – leverage RFI inputs
  - Address commercial utility of technology development areas (thruster performance, solar arrays) and technology transfer implications

- Consider follow-on studies for sensor technologies
  - Address potential for integrated sensing system that is able to support all mission phases and broader NASA exploration needs

- Improve coordination with the small body science community

- Address how to deal with business case/partnership opportunities