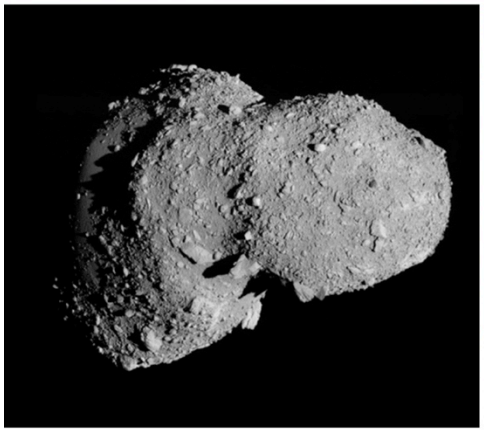
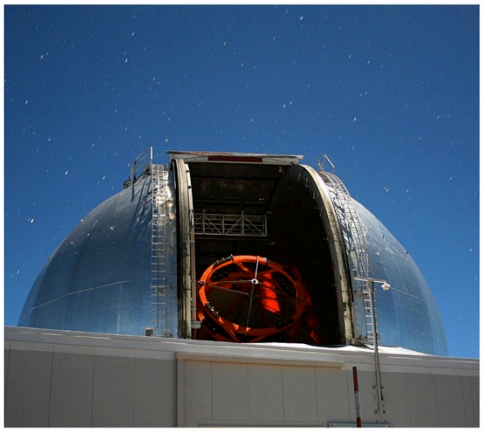
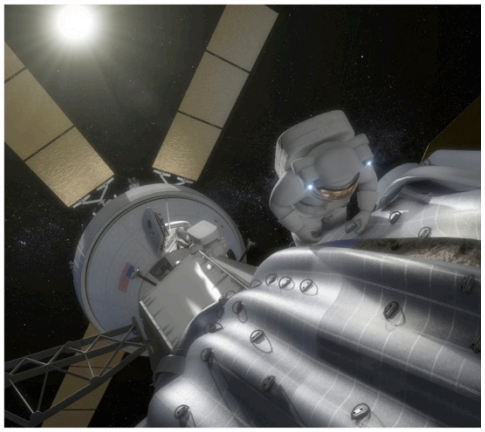
National Aeronautics and Space Administration

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

Time	Title	Presenter
1:30 p.m.	Session Introduction	JIM REUTER /NASA Marshall Space Flight Center
1:40 p.m.	Asteroid Retrieval Alternatives from the KISS Study (Status of Reference Configuration including technical risks and uncertainties)	JOHN BROPHY /NASA Jet Propulsion Lab
1:55 p.m.	Proposed Development Solutions for Asteroid Redirection Systems	SIMONA FERRARIS/Thales Alenia Space Italy**(Virtual)**
2:10 p.m.	Asteroid Redirect Vehicle with Solar Electric Propulsion and Robotic Manipulator	ADAM MAHER /Space Systems Loral
2:20 p.m.	Alternative Mission Concepts and Summary of GSFC Technologies and Facilities Relevant to ARM	BENJAMIN REED /NASA Goddard Space Flight Center
2:30 p.m.	Leveraging Heritage Spacecraft Platforms and Subsystems to Reduce ARM Execution Risk	MIKE ELSPERMAN /Boeing and MANNY LEINZ / Boeing
2:45 p.m.	Asteroid Redirect Systems - Integrated Sensing Systems and Solar Electric Propulsion System Concepts	JOHN RINGELBERG /Lockheed Martin
3:00 p.m.	Enabling Technologies for Asteroid Redirection Systems	JOHNATHAN WROBEL/Honeybee Robotics **(Virtual)**
3:10 p.m.	Integrated Sensing Systems to Support Asteroid Rendezvous, Proximity Operations, Characterization, and Capture	STEVEN WARWICK /Northrup Grumman
3:20 p.m.	Integrated Sensing Systems for Asteroid Missions	RICHARD DISSLY /Ball Aerospace
3:30 p.m.	In-situ Radar for Asteroid Characterization and Altimetry	MARK HAYNES /NASA Jet Propulsion Lab
3:40 p.m.	Integrated Sensor Systems and Applications of Satellite Servicing Technology to ARM	PAUL FULFORD /MDA Canada
3:50 p.m.	Refinements of the Asteroid Redirect Mission Concept to Maximize Scientific and Commercial Value	DAVID GUMP /Deep Space Industries
4:00 p.m.	Earth's Minimoons: New Prospective Targets for Human Exploration Minimoons: Discovery & Retrieval Missions	BILL BOTTKE /Southwest Research Institute and ROBERT JEDICKE /University of Hawaii
4:15 p.m.	Honeybee for Near-Earth Object Retrieval: Simpler, More Innovative, More Practical, More Useful	JOEL SERCEL /ICS Associates Inc.
4:25 p.m.	Discussion and Synthesis	OPEN DISCUSSION

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

Key Topics Discussed (p. 4 of 4)

- **Alternate Mission Scenarios/Concept of Operations**
  - Keck Institute study options: "Get-a-Whole-One", "Pick-Up-A-Rock", "Scoop-Up-Regolith", "Pre-deployment of Equipment"
  - 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**