NASA’s Asteroid Initiative
Asteroid Redirect Mission and Grand Challenge

Robert Lightfoot, NASA Associate Administrator
September 30, 2013

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NASA’s Asteroid Initiative

• NASA is leveraging relevant portions of science, space technology, and human exploration capabilities toward a first-ever mission to capture and redirect a near Earth asteroid to earth-moon space, followed by a human exploration and sampling mission.

• The mission will demonstrate technologies for deep space exploration, advance efforts in planetary defense, and engage new industrial capabilities and partnerships. There are other benefits.

• NASA will also lead a broad effort to find all asteroid threats to human populations and know what to do about them: a “Grand Challenge”

• These two activities are mutually supporting, and both leverage ongoing activities.

• This initiative includes a parallel, forward-looking mission development approach, partnership opportunities (nationally and internationally), open innovation, and participatory engagement.

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Both sets of activities leverage existing NASA work while amplifying participatory engagement to accomplish their individual objectives and synergize for a greater collective purpose.
Agency Grand Challenges

• Large-scale effort that requires activities and contributions nationally and ideally globally

• High impact, multi-disciplinary collaborations and public private partnerships

• Leverages a variety of sources of partnership and outside collaboration (interagency, international, industry, academia, NGOs, citizens, particularly non-traditional partners)
Asteroid Grand Challenge

Find all asteroid threats to human populations and know what to do about them

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Grand Challenge Methods

Public-Private Partnership

Incentive Prizes

Crowdsourcing

Citizen Science

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Leveraging Capabilities for an Asteroid Mission

• NASA is aligning key ongoing activities in Science, Space Technology, and Human Exploration and Operations Mission Directorates
  – Asteroid identification and characterization efforts for target selection
  – Solar electric propulsion for transport to and return of the target asteroid
  – Autonomous guidance and control for proximity operations and capture
  – Orion and Space Launch System (SLS) vehicles for asteroid rendezvous
  – Technologies for astronaut extra-vehicular activities

• Each individual activity provides an important capability in its own right for human and robotic exploration

• We are working to utilize all of these activities to
  – Identify and redirect a small asteroid to a stable orbit in the lunar vicinity;
  – Test human spaceflight systems and operations beyond LEO; and
  – Investigate and return samples with our astronauts using the Orion and SLS assets.

• The FY14 budget supports continued advancement of the important individual elements and furthers the definition of the overall potential mission.
Overall Mission Consists of Three Main Segments

**Identify**

**Asteroid Identification**
Ground and space based NEA target detection, characterization and selection

**Redirect**

**Asteroid Robotic Redirection Mission**
Solar electric propulsion (SEP) based robotic asteroid redirect to trans-lunar space

**Explore**

**Asteroid Redirect Crewed Mission**
Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid

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### First Steps to Mars and Other Destinations

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Mission</th>
<th>Current ISS Mission</th>
<th>Asteroid Redirect Mission</th>
<th>Long Stay In Deep Space</th>
<th>Humans to Mars Orbit</th>
<th>Humans to Surface, Short Stay</th>
<th>Humans to Surface, Long Stay</th>
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Alignment Strategy

Asteroid Identification Segment

- 2013: SST
- 2014: PS-2
- 2015: Enhanced ground assets & Initial candidates for further development
- 2016: Potential GEO-hosted payload detection
- 2017: Final target selection

Asteroid Redirect Segment

- 2018: Mission launch & SEP demo
- 2019: Asteroid rendezvous & capture
- 2020: Asteroid maneuver to lunar vicinity

Orion & SLS Crewed Asteroid Exploration Segment

- 2021: First flight of Orion
- 2022: EM-1: Un-crewed Orion test beyond the Moon
- 2023: EM-2: Crew on Orion beyond the Moon (to asteroid depending upon timeline of asteroid redirect)

THIS SEGMENT TIMELINE NOTIONAL- BASED ON REFERENCE MISSION

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## Decision and Engagement Strategy

<table>
<thead>
<tr>
<th>Year</th>
<th>Asteroid Identification Segment</th>
<th>Asteroid Redirect Segment (Reference Mission Timeline)</th>
<th>Orion &amp; SLS Crewed Asteroid Exploration Segment</th>
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<tbody>
<tr>
<td>FY2013</td>
<td>Studies &amp; Trades</td>
<td>Industry and Partner Day, RFI release</td>
<td>Studies &amp; Trades</td>
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<td>2014</td>
<td>Ideas Synthesis</td>
<td>Mission Concept Baseline</td>
<td>SST and SBAG Wkshp</td>
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<td>2015</td>
<td>MFR Risk and Programmatic Feasibility</td>
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<td>2016</td>
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### Important Dates:
- **2016**: Mission launch & SEP demo
- **2017**: Target selection need date
- **2018**: Potential GEO-hosted payload detection
- **JANUARY 2019**: Orion test beyond the Moon
- **NOVEMBER 2021**: Orion test beyond the Moon
- **JUNE 2022**: Orion test beyond the Moon

Join the discussion and send questions to: #NASAasteroid
• RFI released June 18; responses due July 18

• Areas of request:
  – Asteroid Observation
  – Asteroid Redirection Systems
  – Asteroid Deflection Demonstrations
  – Asteroid Capture Systems
  – Crew Systems for Asteroid Exploration
  – Partnerships & Participatory Engagement

• 402 responses received

• Ideas Synthesis Meeting Sept 30 - Oct 2
  – Transparently explore the 96 highest rated responses
  – International, industry, science will be specifically invited
  – Meeting structured to provide input to planning
Currently, most Near-Earth Asteroid discoveries are made by: Catalina Sky Survey (60%), Pan-STARRS-1 (30%), and LINEAR (3%).

Data correlation and orbit determination is done by the IAU Minor Planet Center. Precision orbital analysis is performed by the NEO Program Office at JPL.

Enhancements and new surveys can come online in the next 2 years.

These improvements will increase capabilities to find hazardous asteroids as well as ARRM candidate targets.
Primary Enhancements Planned for the Initiative

• **NEO Time on DARPA Space Surveillance Telescope**
  - Large 3.6m telescope, first light: Feb 2011, now in testing.
  - Eventual operations by AFSPC for DoD Space Situational Awareness.

• **Enhancing Pan-STARRS 1, Completing Pan-STARRS 2**
  - Increase NEO search time to 100% on PS1: Early 2014.
  - Complete PS2 (improved copy of PS1): Late 2014.
  - Simulations suggest the ARRM candidate discovery rate for PS2 alone at 100% will be ~5 per year.

• **Accelerated Completion of ATLAS**
  - Set of small telescopes with extremely wide fields of view covering the entire night sky every night, but not as deeply.
  - Final design selection soon. Completion: Early 2015.
  - Simulations suggest the ARRM candidate discovery rate for ATLAS will be ~10 per year.

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NEO Characterization Enhancements

Radar (Goldstone and Arecibo)
- Increase time for NEO observations.
- Streamline Rapid Response capabilities.

NASA InfraRed Telescope Facility (IRTF)
- Increase On-call for Rapid Response.
- Improve Instrumentation for Spectroscopy and Thermal Signatures.

Reactivate NEOWISE
- ~3 year warm phase dedicated to NEO Search/Characterization data collection.

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Space Technology and the Asteroid Initiative

• Early Stage programs will foster innovation in
  – Asteroid detection, characterization and mitigation for planetary defense and asteroid retrieval mission target selection
  – Asteroid proximity operations and resource utilization techniques

• The redirect mission leverages high powered SEP demonstration capability
  – SEP is the primary propulsion for the robotic asteroid rendezvous and redirection
  – The redirect mission is not possible without SEP
  – SEP component technologies serve commercial needs
  – SEP is also enabling for deep space human exploration

• Asteroid Robotic Redirect Mission will serve as a critical technology demonstration of a high-power SEP system

• Key high-power SEP system components include
  – 30kW – 50kW advanced solar arrays
  – 10kW to 15kW magnetically shielded Hall thrusters
  – Power Processing Units (PPUs)
  – Xenon propellant tanks
1. Launch (2 Options)
   1a. Atlas V – Low Thrust Trajectory to Moon
   1b. SLS or Falcon Heavy – Direct Launch to Moon or to Asteroid

2. Lunar Flyby to Escape (If Needed)

3. Low Thrust Trajectory to Asteroid

4. Low Thrust Trajectory with Asteroid to Earth-Moon System

5. Lunar Flyby to Capture

6. Low Thrust Trajectory to Storage Orbit

7. Orion Rendezvous
Mission and Flight System Concept
Executive Summary

• Key Driving Objective:
  – Minimize the cost and technology development risk with extensibility to future missions
• Balanced risk across major elements
  – Asteroid discovery and characterization
  – SEP technology development
  – Proximity operations and capture approach
• Developed a baseline flight system and conops approach
  – Modular Flight System: SEP Module, Mission Module, Capture System

Flight system concept is feasible and includes appropriate margins

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Capture Sequence

• S/C approaches and matches spin along projected asteroid spin vector
• When asteroid is centered in the bag, close top diaphragm, and at the moment spin is matched, inflate air bags w/pressure <<1 PSI to limit loads on surface of asteroid, achieving controlled capture quickly
• Mechanism provides elasticity to control loads to solar arrays

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**Alternate Approach: Robotic Concept**

- **Concept:** Demonstrate planetary defense (PD) and retrieve coherent/monolithic boulder(s) from a larger NEA

  - Target a ∼100+ m size NEA (hazardous size, but not necessarily a PHA)
  - Demonstrate PD techniques and measurably alter the trajectory of the NEA Capture a 1-10 m boulder (coherent rock) and return it in the 2020-2025 timeframe
  - Assess options for planetary defense demonstrations and delivery of other payloads
    - Take advantage of solar electric propulsion spacecraft capabilities and/or captured mass, as well mission capability for kinetic impact demonstration at the end of mission
    - Payload(s) emplaced prior to capture operations in case of failure and/or left behind before spacecraft departure
  - Identify required NEA stay time to perform proximity and surface operations

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Multiple Options for Boulder Retrieval

Capture System Option Examples

- A variety of capture system options and technologies are applicable for retrieving a coherent/monolithic boulder – optional bag for containment
- Specialized robotic tools and end effectors can be utilized
  - Manipulator or spacecraft mounted
  - Grapple, anchor, push/pull, sample, position, cut, drill, etc.
- In the unlikely event that a suitable boulder or boulders could not be retrieved, a contingency capability to collect regolith can be included (surface contact pads, OSIRIS-REx sample collector, etc.)

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Reference Trajectory Concept: Earliest Mission for 2009BD

- Outbound
  - Flight Day 1 – Launch/TLI
  - Flight Day 1-7 – Outbound Trans-Lunar Cruise
  - Flight Day 7 – Lunar Gravity Assist
  - Flight Day 7-9 – Lunar to DRO Cruise
- Joint Operations
  - Flight Day 9-10 – Rendezvous
  - Flight Day 11 – EVA #1
  - Flight Day 12 – Suit Refurbishment, EVA #2 Prep
  - Flight Day 13 – EVA #2
  - Flight Day 14 – Departure Prep
  - Flight Day 15 – Departure
- Inbound
  - Flight Day 15 – 20 – DRO to Lunar Cruise
  - Flight Day 20 – Lunar Gravity Assist
  - Flight Day 20-26 – Inbound Trans-Lunar Cruise
  - Flight Day 26 – Earth Entry and Recovery

Mission Duration and timing of specific events will vary slightly based on launch date and trajectory strategy.

Outbound Flight Time: 8 days, 9 hrs
Return Flight Time: 11 days, 6 hrs
Rendezvous Time: 1 day
DRO Stay Time: 5 days

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Integrated Stack Flight Attitude

- Extensive shading in unbiased solar inertial attitude
- Biasing attitude allows for adequate EVA lighting and thermal conditions
- Orion required to maneuver integrated vehicle to EVA attitude

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Example Robotic Spacecraft Accommodations for Crewed Mission (Docking)

Docking Mechanism
- IDSS-compatible, passive side

Vehicle-to-Vehicle Comm
- Orion compatible low-rate S-band with transponder

Docking Target
- Augmented with features for relative navigation sensors
- Visual cues for crew monitoring

Reflectors
- Tracked by the LIDAR during rendezvous and docking

Power and Data Transfer
- Transfer through connectors already part of the docking mechanism design; Supports extensibility

LED Status Lights
- Indicate the state of the ARRV systems, inhibits and control mode

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EVA Tether Points
• Hand-over-hand translation
• Temporary restraint of tools
• Management of loose fabric folds

Pre-positioned EVA Tool Box
• Tool box to offset Orion mass (85kg tools)

EVA Translation Booms
• Translation Booms for Asteroid EVA

EVA Translation Attach Hardware
• Circumference of Mission Module at base of Capture System and ARRV-Orion Interface

Hand Rails
• Translation path from aft end of ARRV to capture bag
• Ring of hand rails around ARRV near capture bag

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EVA Concept

- Orion-Based EVA
- Two Crew per EVA
- Two EVAs + One Contingency
- Short Duration (~4 hr)
Benefits of Asteroid Initiative: Redirect Mission

- Makes progress toward NASA goals in human space exploration
  - Challenging near term mission operations for human exploration beyond LEO & Early integration of foundational capabilities for deep space exploration
    - SLS and Orion initial capabilities for deep space
    - Navigation and piloting operations of deep space vehicles for human missions
    - Mission Kits for in-space assembly (EVA, Docking and Rendezvous)
    - Life support and deep space habitability
    - Complex ground and space operations, and sampling of small objects

- Exercises collaboration between human and robotic missions of exploration

- Furthers science and technology
  - Enhanced small bodies observation and characterization
  - Advanced solar electric propulsion
  - Asteroid sample return - but this is not a science mission

- Strong commercial application
  - Advanced solar electric propulsion

- Future utilization of in space resources
• Facilitates broad engagement with a diverse set of collaborators

• Combines NASA’s complement of Open Innovation techniques towards a single cause
  – Public Private Partnership
  – Incentive Prizes
  – Crowd Sourcing
  – Citizen Science

• Focuses attention and work on a global problem we have the ability to resolve

• Leverages NASA resources in unique ways

Shared Benefits of Redirect Mission and Grand Challenge
Enhanced small bodies observation and characterization
Planetary defense interests

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