NASA’s Asteroid Redirect Mission

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Overall Mission Consists of Three Segments

Identify

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

Redirect

Asteroid Redirection Segment:
Solar electric propulsion (SEP) based robotic asteroid redirect to trans-lunar space

Explore

Asteroid Crewed Exploration Segment:
Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid
Asteroid Redirect Mission: Observation Campaign

Paul Chodas, NASA NEO Program Office
• NEO = Near Earth Object (99% are NEAs, Near-Earth Asteroids)
• Since 1998, NASA’s NEO Observation Program has led the international NEO discovery and characterization effort.
• ~95% of 1-km and larger NEAs have been discovered.
• Total number NEAs now known: 10,090; increasing at ~1,000 per year.
Discovery & Characterization Processes

Discovery, Orbit Determination, Rough Size Estimation

- Discovery & Initial Astrometry
- Minor Planet Center
- NEO Program Office

Physical Characterization

- Astrometry, Photometry, Light Curves, Colors
  - Orbit, area/mass ratio, size, rot. rate, spectral type
- Visible & IR Spectroscopy, IR radiometry
  - Spectral type, size & mass, possibly composition
- Radar
  - Precise Orbit, size & rotation rate

Existing automated processes

Screening for Objects of Interest
ARM Candidate Targets

- Requirements:
  - Earth-like orbit about the Sun.
  - Close Earth approach in the early 2020s.
  - Size constrained to ~7 to ~10 meters (~20 to ~30 feet).
  - Slow to moderate spin rate (less than 2 rpm).

- Estimated number of suitable candidates: ~10,000, but hard to detect.

- 14 have been discovered so far by current surveys (2-3 per year), but sizes of most of these were not accurately characterized when discovered.

- Sizes of 2 of the candidates could be characterized within a year, and another in 2016.

- Rapid response will be used when possible for future candidates to characterize size and spin rate immediately after discovery.
Enhancements for ARM Candidate Discovery

• **NEOs on DARPA Space Surveillance Telescope**
  • Built for DoD Space Situational Awareness.
  • Testing of NEO detection capability: Sep 2013.

• **Enhancing Pan-STARRS 1, Completing Pan-STARRS 2**
  • Increase search time to 100% on PS1: Early 2014.
  • Complete PS2 (improved copy of PS1): Late 2014.

• **Accelerated Completion of new survey ATLAS**
  • Extremely wide field, covering entire night sky every night, but not as deeply. Detects NEAs close to Earth.
  • Completion: Early 2015.

• **With these and other enhancements, the ARM candidate discovery rate should increase to at least 5 per year.**

• **These enhancements will also increase capability for finding hazardous asteroids in general.**
Radar Observations of NEAs

- 70-80 NEOs are observed every year.
- 10-m-class NEAs observable out to ~5 lunar distances; ~80% of the ARM candidates should be radar observable once detected.
- Radar observations can provide:
  - Size and shape to within ~2 meters.
  - High precision orbit data.
  - Spin rate, surface density and roughness.
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 (in work)
• ~3 year warm phase dedicated to NEO Search/Characterization data collection.
Asteroid Redirect Robotic Mission (ARRM)

Contributing NASA Centers:
JPL, GRC, JSC, LaRC, MSFC, KSC, GSFC

Brian Muirhead, ARRM Study Lead
• NASA has been performing architecture-level trade studies to establish the feasibility of missions to small and/or large near Earth asteroids, including:

  – Demonstrate high-power, extensible SEP

  – Returning an asteroid (10m, 1000t class) or a part of an asteroid (3 m, 20t class) to a lunar DRO for crew exploration

  – Conducting a planetary defense demonstration at the asteroid
Small Asteroid Mission Concept

- Rendezvous with small (<10m mean dia.) near Earth asteroid (NEA)
  - Examine opportunities and proof of concept
  - Capture <1000t spinning NEA and despin
  - Maneuver to stable, crew accessible lunar orbit (e.g. DRO)

- Candidate target is 2009 BD, which is <500t
  - Other targets to be discovered and characterized by radar
  - Primary constraints are target V-infinity, size, mass, spin rate, and launch date and launch vehicle
1) Launch heavy mission
2) Separation & S/A Deploy
3) Lunar Gravity Assist (if needed)
4) SEP low-thrust cruise to Asteroid
5) Asteroid Operations: rendezvous, characterize, deploy capture mechanism, capture, and despin (60 days)
6) SEP redirect to Lunar orbit
7) Lunar Gravity Assist
8) SEP transfer to safe DRO
9) Orion rendezvous & crew operations

Initial Earth Orbit (spiral only)

Earth
Large Asteroid Mission Concept

- Rendezvous with a large (~100+ m) NEA
  - Collect ~2-4 m boulder (~10-70 t)
  - Perform planetary defense demonstration(s) & track to determine effect
  - Return boulder to stable, crew accessible lunar orbit (e.g. DRO)

- Candidate target Itokawa, could return 18 t boulder in August 2023
  - Other targets to be characterized by radar or direct observation (e.g. Bennu by OSIRIS-Rex & 1009 JU3 by Hayabusa 2)
  - Primary constraints are NEA V-infinity, launch date and launch vehicle, and size, mass, and retrievability of boulders
ARRM Flight System

• Key Driving Objectives:
  – Demonstrate high power, 40 kW, SEP technology in deep space
  – Cost driven paradigm

• Balance risk across major elements
  – Uncertainties in asteroid/boulder characteristics
  – SEP technology development
  – Proximity operations and capture approach

• Modular design
  – SEP: 4 Hall thrusters, 10t of Xe
  – High heritage avionics
  – Capture system
ARRM Versatility and Extensibility

• Studies to date have identified a suite of technically and programmatically feasible capabilities that can be integrated in different ways to enable a broad class of missions
  √ Asteroid Redirect Missions
  √ Planetary Defense demonstrations
  √ Science Missions
  √ Exploration Missions

• Mission provides key technologies—SEP, mission design, prox-ops—that are affordable stepping stones to missions requiring large payloads to the lunar surface and/or Mars
High-Powered Solar Electric Propulsion

- **Solar Arrays**
- **Thruster and Power Processing Unit (PPU)**
- **Propellant Feed System and Storage Tanks**
High-powered SEP Enables Multiple Applications

- Solar Electric Propulsion
- Satellite Servicing
- Payload Delivery
- ISS Utilization
- OGA Missions
- Space Science Missions
- Deep Space Human Exploration
- Commercial Space Applications
- Orbital Debris Removal
Advancing Solar Electric Propulsion Technology

Deep Space 1 1998
Technology Demonstrator 2.5 kW power system 2kW EP system

Dawn 2007
Deep-Space Science Mission 10 kW power system 2.5kW EP system

AEHF Recovery 2010
Satellite orbit established with Hall Thrusters ~16kW-class power system ~4.5kW-class EP

Asteroid Redirect Mission
Robotic Mission to Redirect Asteroid to Trans-Lunar Orbit 50kW-class power system 10 kW-class EP

Far-term Exploration Missions circa 2030’s
Crewed mission beyond Earth space 350kW-class power system 300kW-class EP
Crewed Mission Segment
Steve Stich – Deputy Director, JSC Engineering
Reference Trajectory: Earliest Mission for 2009BD

- **Outbound**
  - Flight Day 1 – Launch/Trans Lunar Injection
  - 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 – 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.
Mission Kit Concept Enables Affordable Crewed Mission

Enhanced MACES (launch and entry configuration)
- Dual-use Visor/Ballistic-Modified Helmet
- Arm Bearings
- Flexible Elbows
- Set-point added to Dual Suit Controller Valve To Support Decompression Sickness Treatments
- Reconfigurable Boots

PLSS MACES (EVA configuration)
- Helmet Camera & Lights
- PLSS Backpack & Suit Adapters
- Display & Control Module
- Heated Gloves
- Tether & Tool Harness
- Thermal Management Garment
- Foot Restraint Compatible Boots

Tools & Translation Aids

Sample Container Kit
EVA Communications Kit
Repress Kit
Mission Kit Concept Enables Affordable Crewed Mission

- Docking System - Leverages International Space Station development of International Docking System Standard

- Relative Navigation Sensor Kit based on Space Shuttle Flight Tested Orion Sensors

Relative Navigation Sensor Kit

Robotic Spacecraft Passive Half of Docking Mechanism

Orion Active Half of Docking Mechanism (extended)
Extravehicular Activity (EVA) Details

- Orion-based EVA with two Crewmembers
- Two EVAs + One Contingency
- Short Duration (~4 hours)
Accommodations for Crewed Mission

**Extra Vehicular Activity (EVA) Translation Booms**
- Translation Booms for Asteroid EVA

**EVA Tether Points**
- Hand-over-hand translation
- Temporary tool restraint
- Management of loose fabric folds

**Pre-positioned EVA Tool Box**
- Tool box stores 85 kg tools

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

**Hand Rails**
- Translation path to capture bag
- Ring of hand rails near capture bag
## First Steps to Mars and Other Destinations

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Asteroid Redirect Mission builds upon Orion/SLS to enable Global Exploration Roadmap

Asteroid Exploitation Missions

Lunar Surface Missions

Deep Space Missions
• NASA received over 400 ideas from the Asteroid Initiative RFI.

• 96 ideas were selected for discussion at the workshop to help NASA formulate plans for the Asteroid Initiative.

• Everyone is welcome to participate virtually: www.nasa.gov/asteroidinitiative