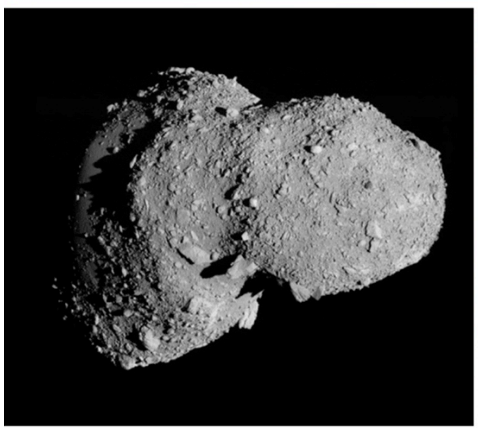
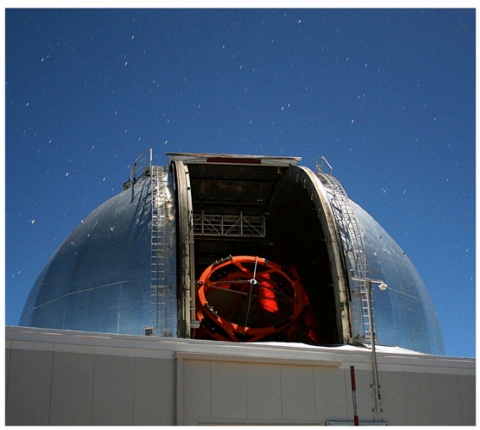
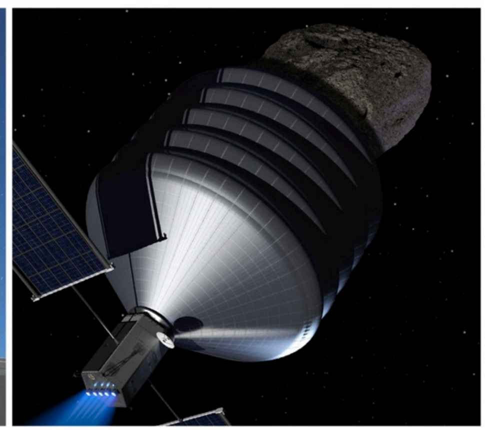
National Aeronautics and Space Administration

NASA’s Asteroid Redirect Mission

Moderator: William H. Gerstenmaier
NASA Associate Administrator for Human Exploration and Operations







September 11, 2013

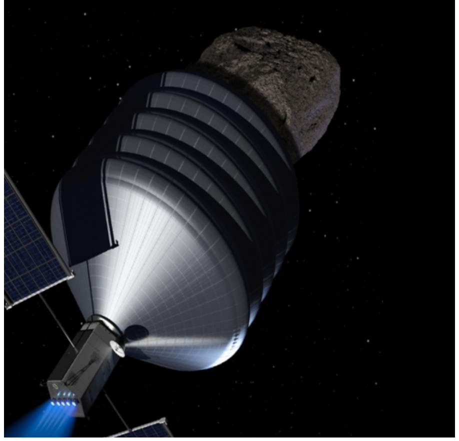
Overall Mission Consists of Three Segments

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

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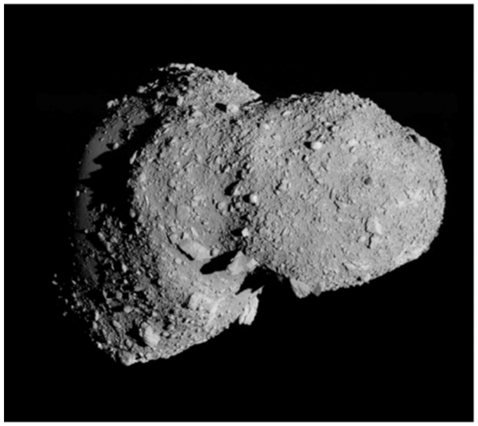
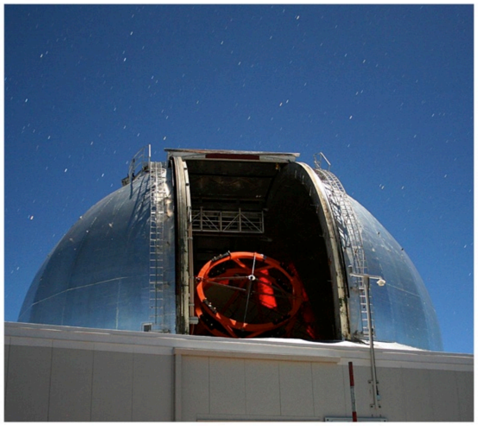
Asteroid Redirect Mission: Observation Campaign

Paul Chodas, NASA NEO Program Office





NASA's NEO Search Programs

~60%

~30%

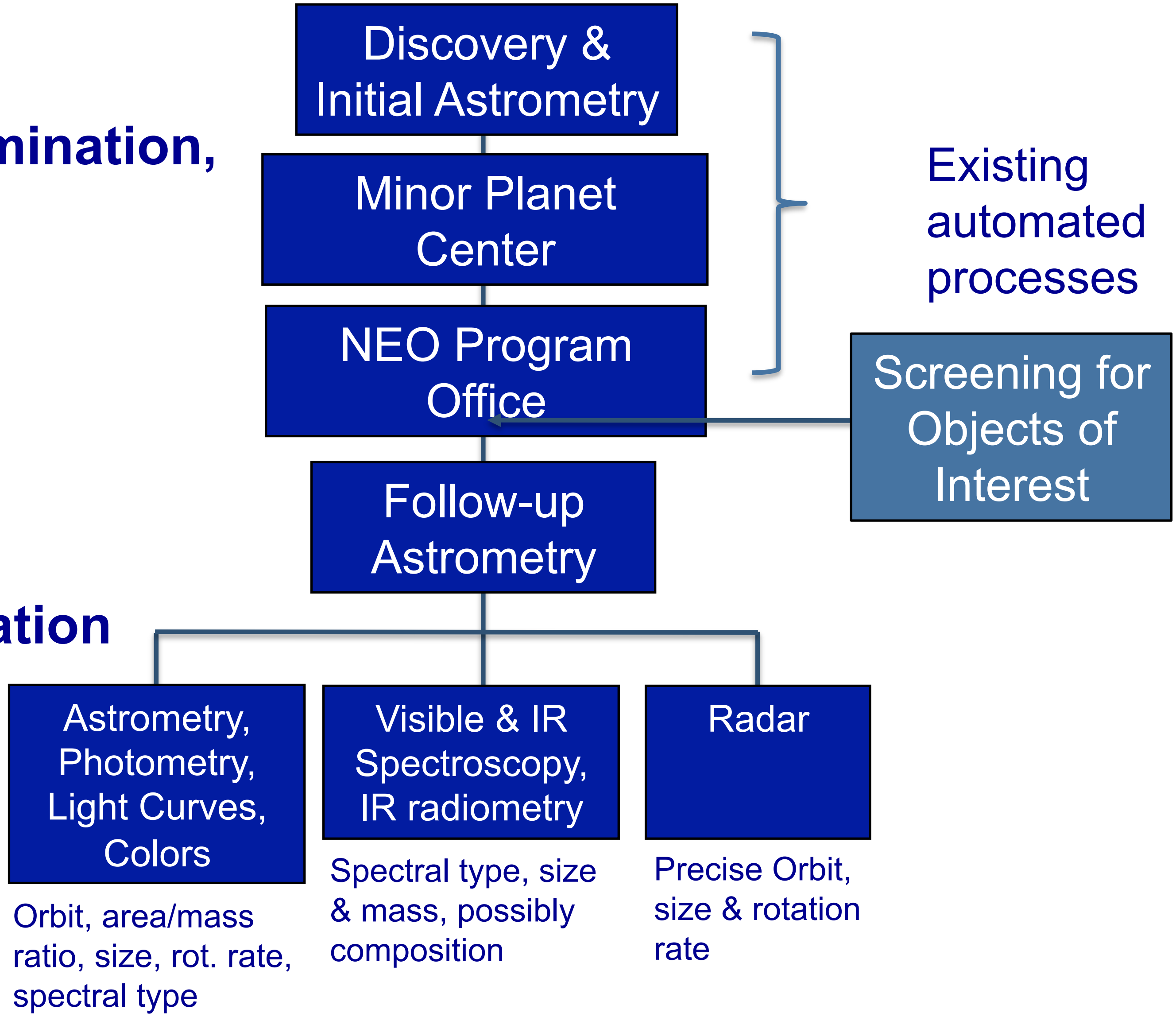
~3%

- 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

Physical Characterization



ARM Candidate Targets

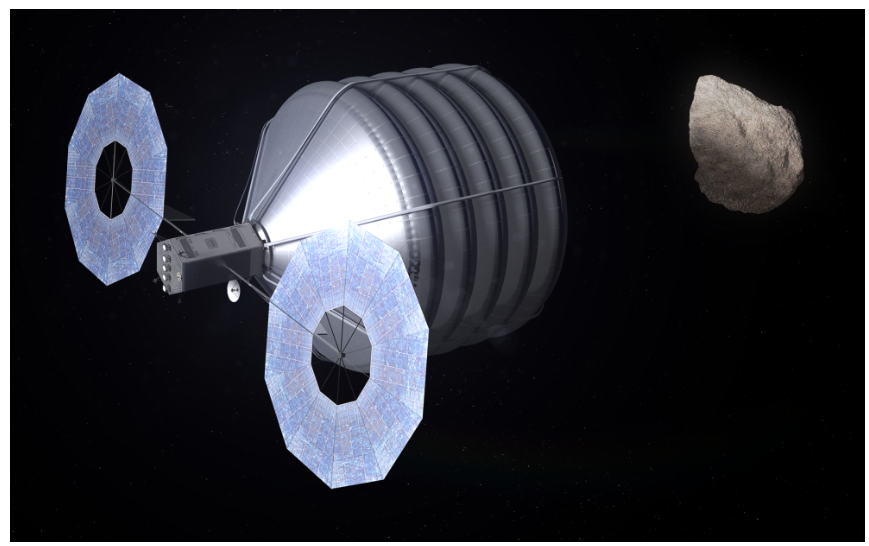
- Requirements:
  - Earth-like orbit about the Sun.
  - Close Earth approach in the early 2020s.
  - Size constrained to ~7 to ~10 meters (~20 to ~30 feet).
  - Slow to moderate spin rate (less than 2 rpm).

- 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.

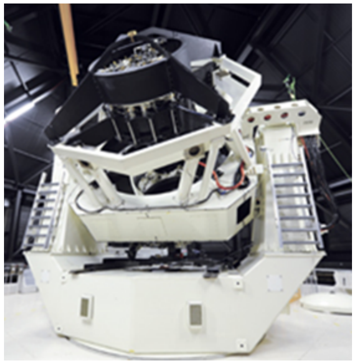
- Sizes of 2 of the candidates could be characterized within a year, and another in 2016.

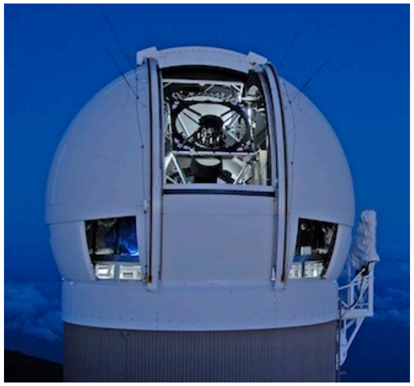
- Rapid response will be used when possible for future candidates to characterize size and spin rate immediately after discovery.

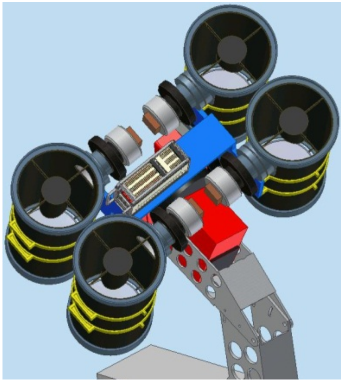


Enhancements for ARM Candidate Discovery

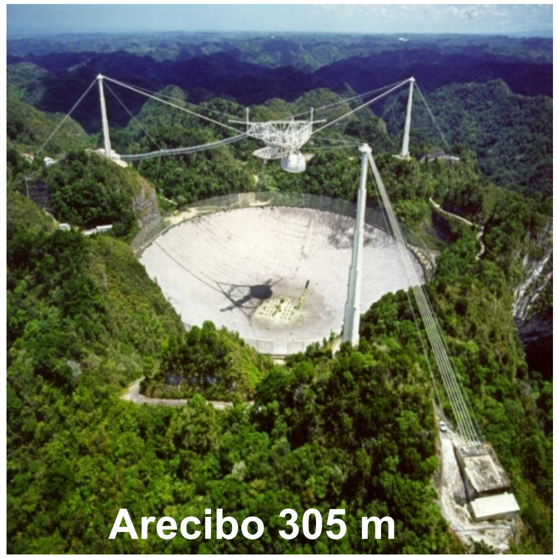
- **NEOs on DARPA Space Surveillance Telescope**
  - Built for DoD Space Situational Awareness.
  - Testing of NEO detection capability: Sep 2013.
- **Enhancing Pan-STARRS 1, Completing Pan-STARRS 2**
  - Increase search time to 100% on PS1: Early 2014.
  - Complete PS2 (improved copy of PS1): Late 2014.
- **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.**

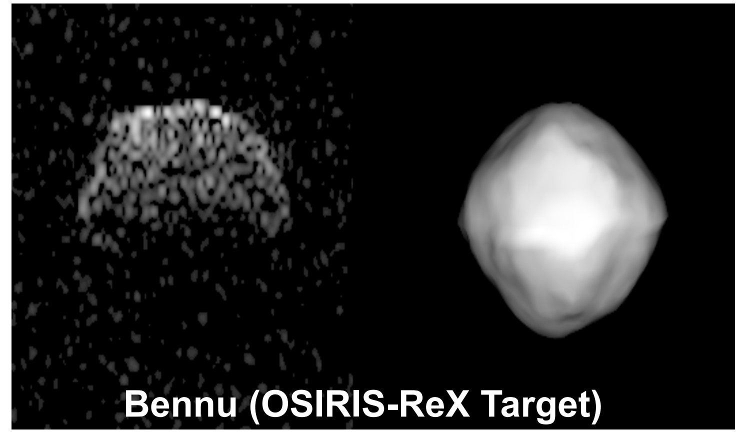


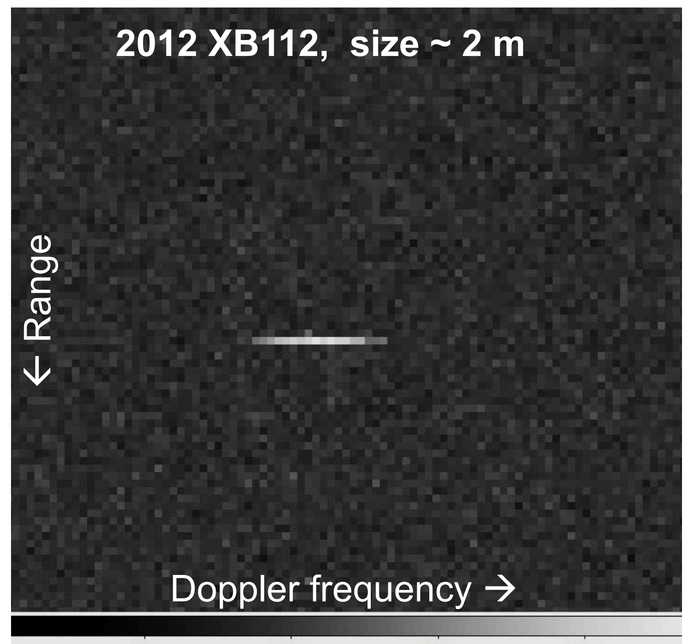




Radar Observations of NEAs





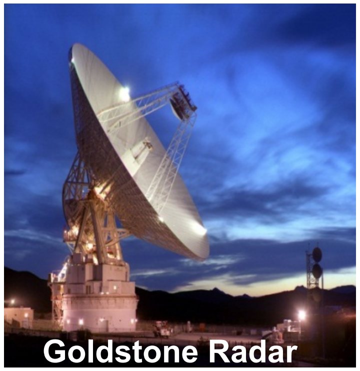


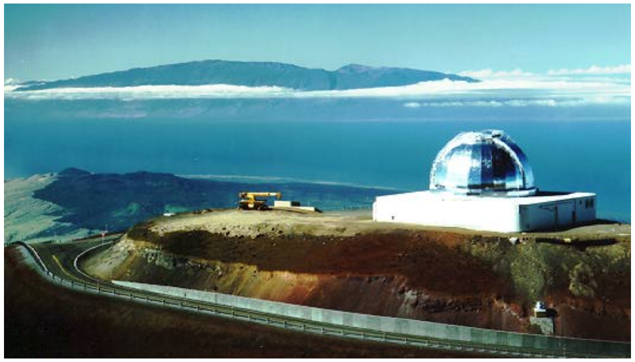
- 70-80 NEOs are observed every year.
- 10-m-class NEAs observable out to ~5 lunar distances; ~80% of the ARM candidates should be radar observable once detected.
- Radar observations can provide:
  - Size and shape to within ~2 meters.
  - High precision orbit data.
  - Spin rate, surface density and roughness.

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 (in work)

•~3 year warm phase dedicated to NEO Search/Characterization data collection.

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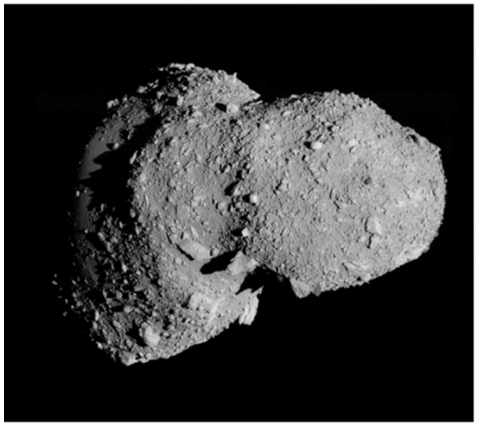
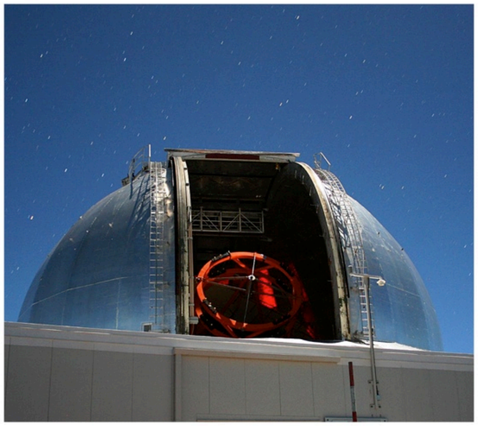
Asteroid Redirect Robotic Mission (ARRM)

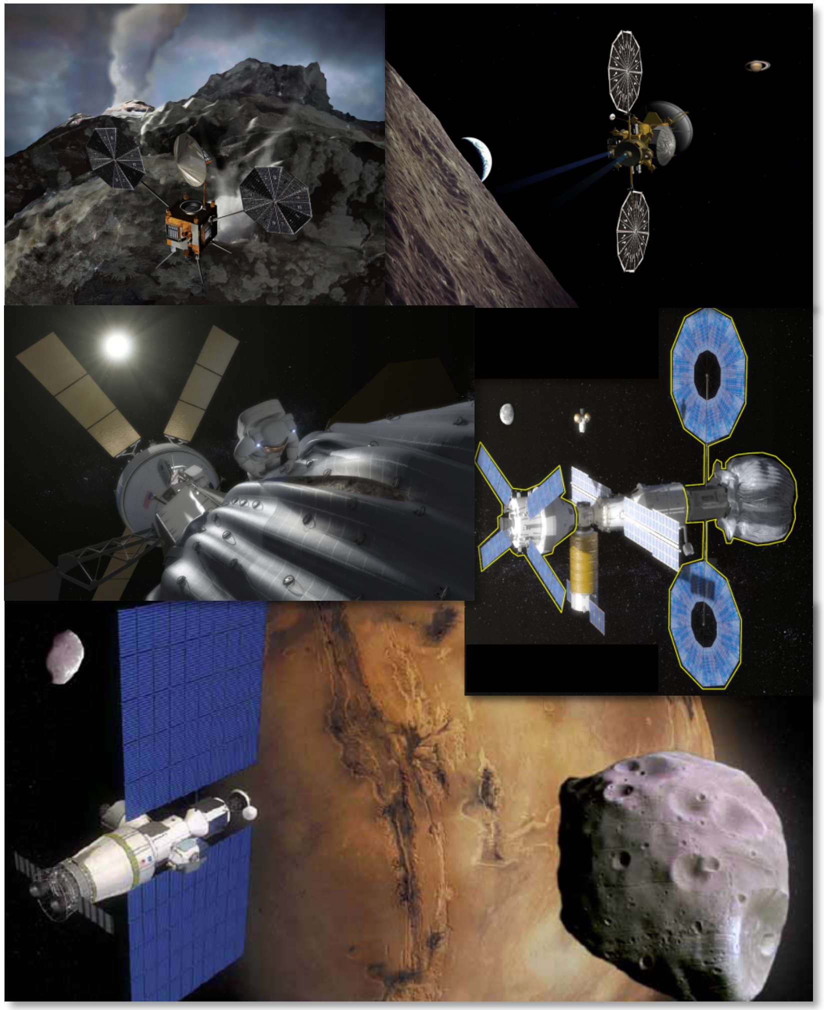
Contributing NASA Centers:
JPL, GRC, JSC, LaRC, MSFC, KSC, GSFC

Brian Muirhead, ARRM Study Lead

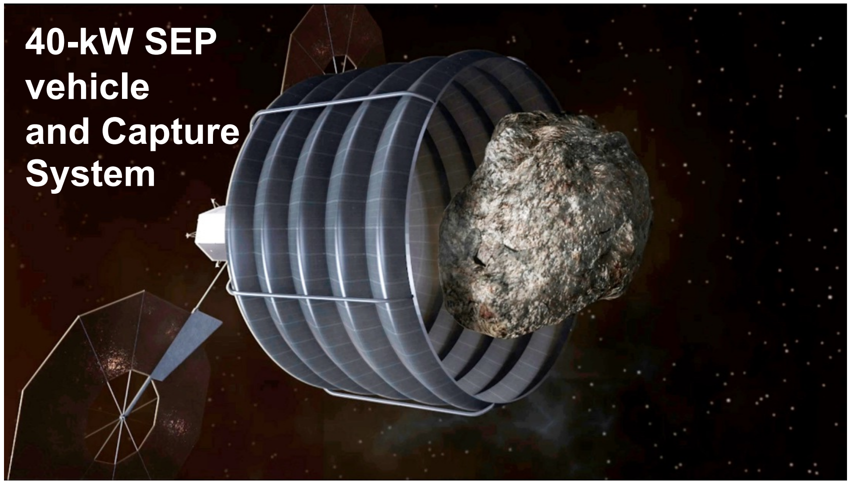
ARRM Architecture

- 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

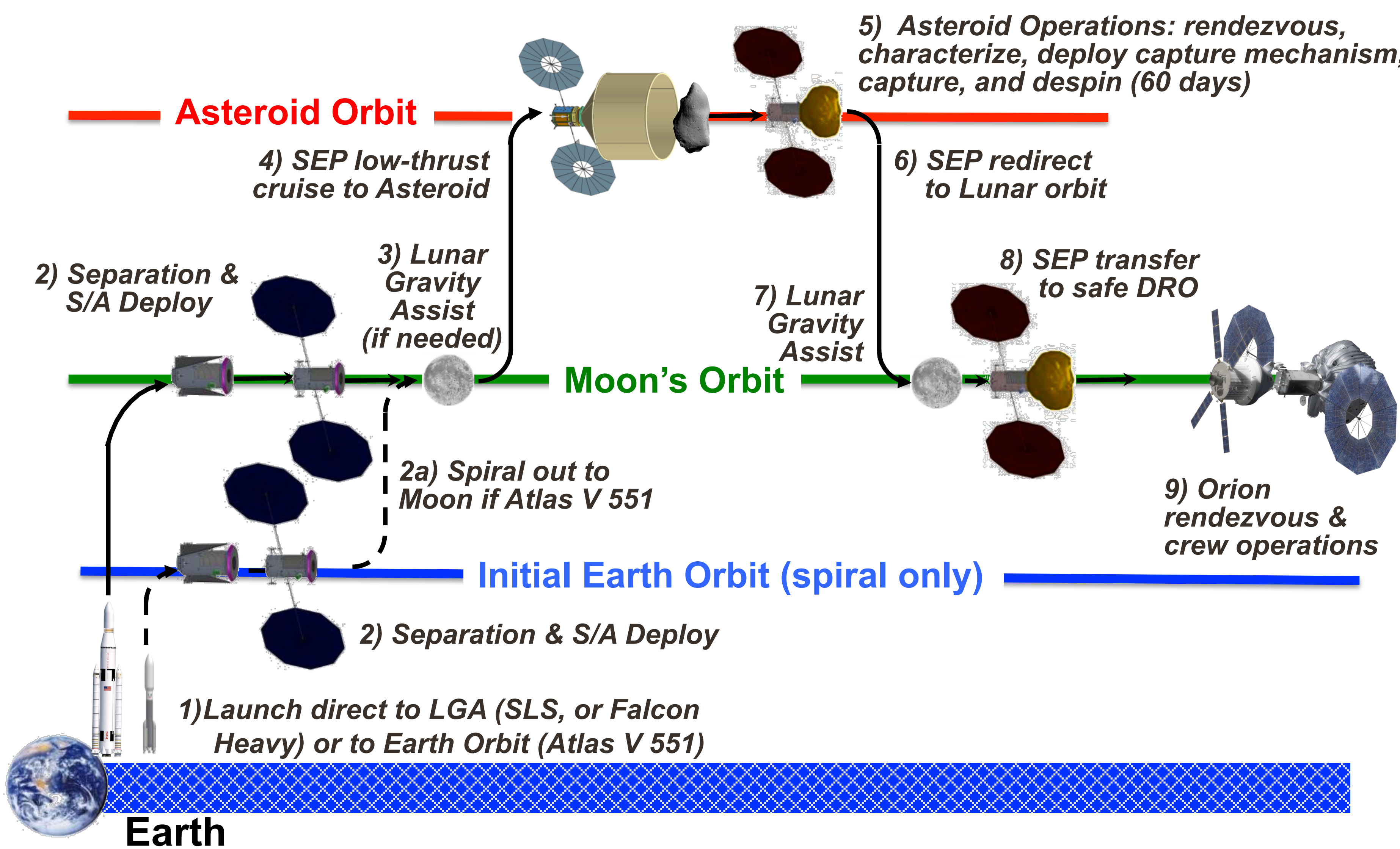


Small Asteroid Mission Concept

- 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

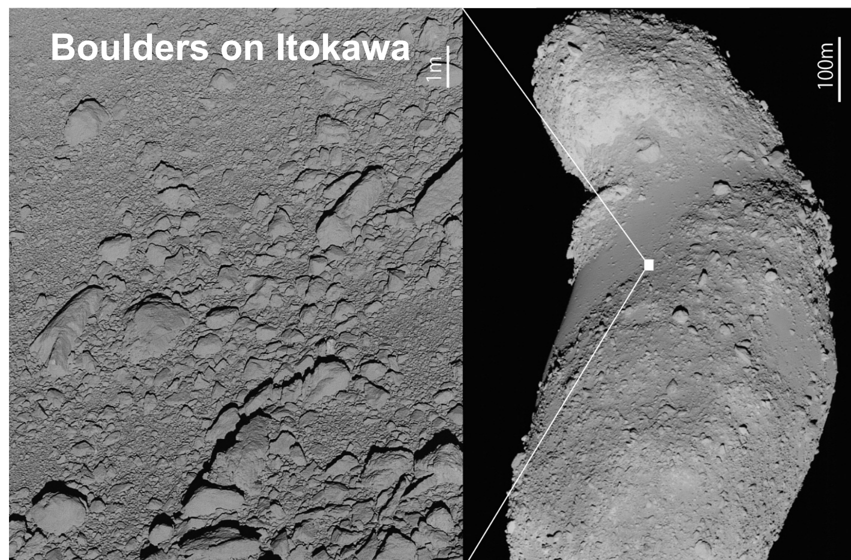


Small Asteroid Mission Mission Design



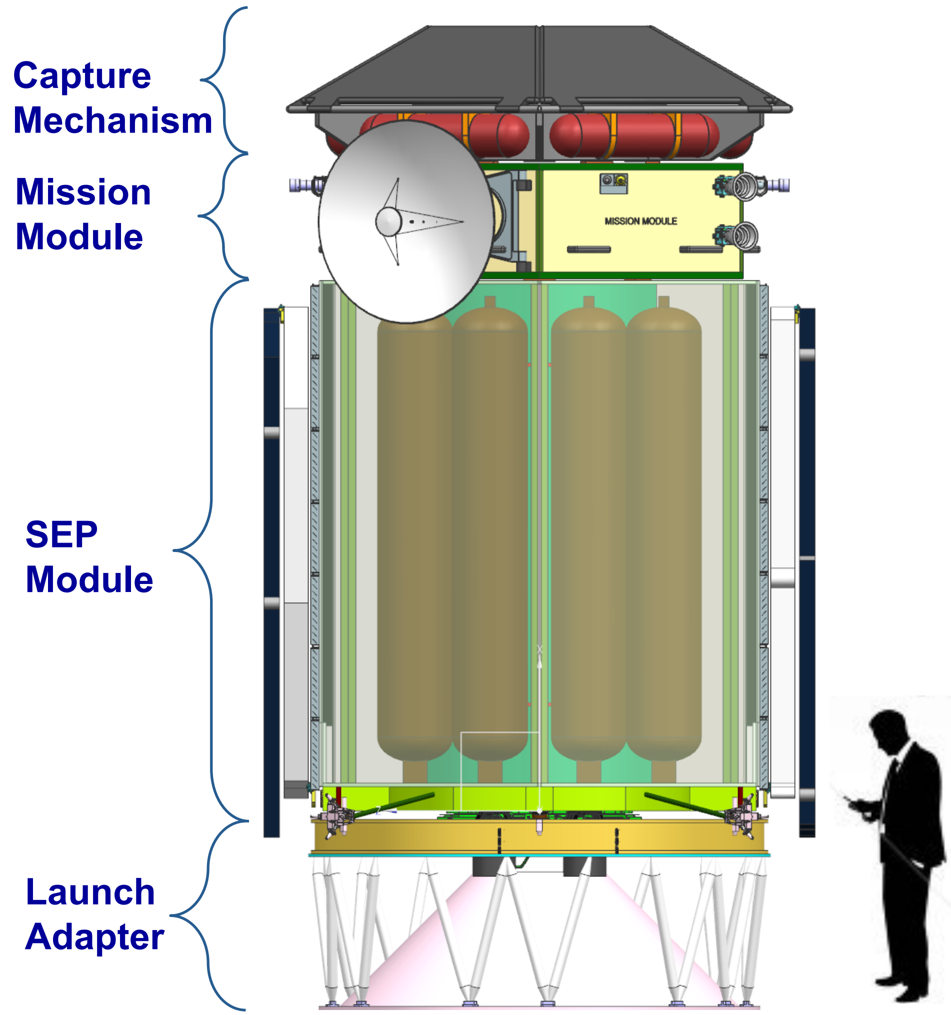
Large Asteroid Mission Concept

- Rendezvous with a large (~100+m) NEA
  - Collect ~2-4 m boulder (~10-70t)
  - 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 18t 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



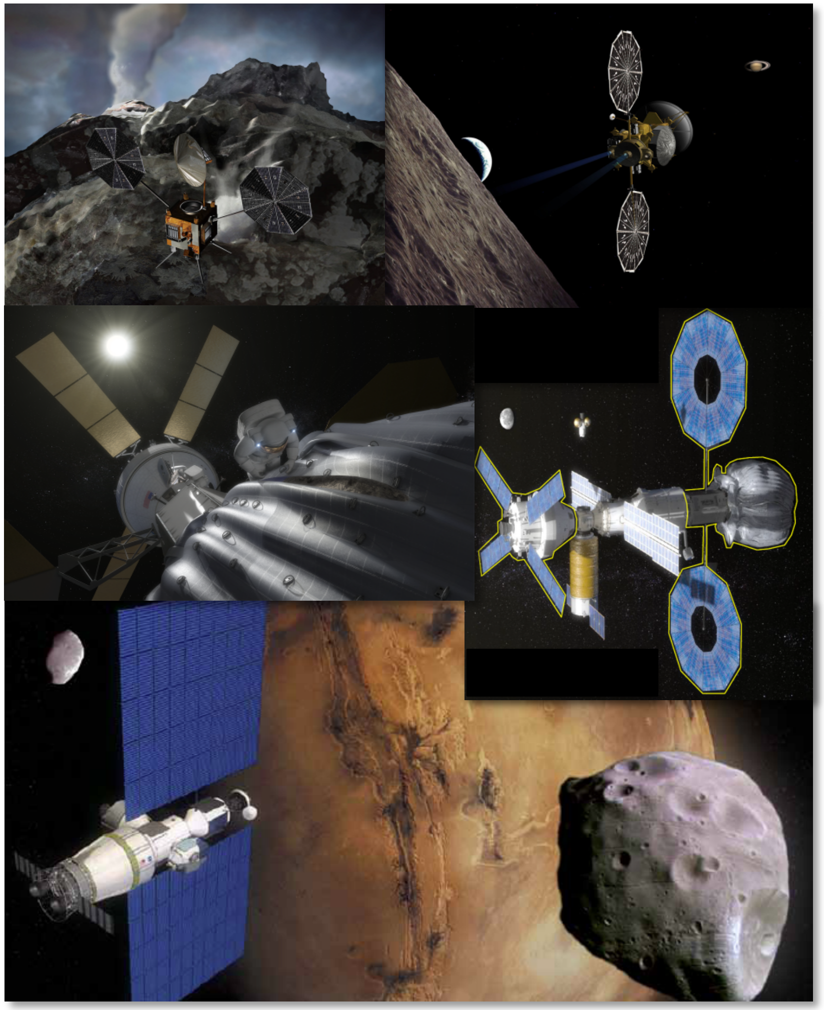
ARRM Flight System

- 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



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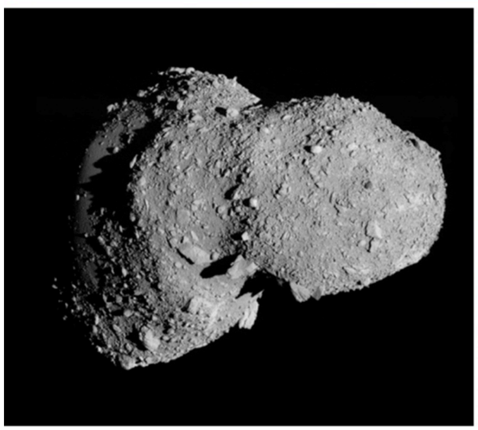
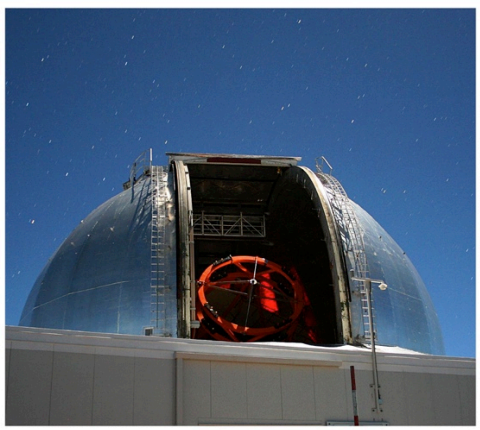
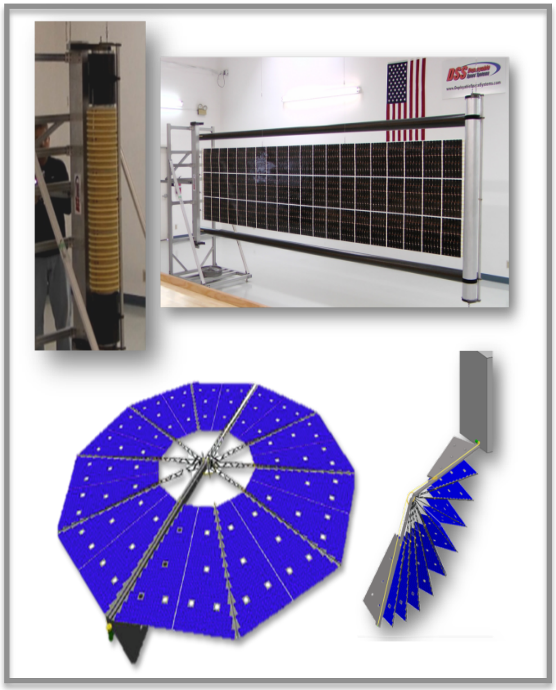
Space Technology & NASA's Asteroid Redirect Mission

Dr. James Reuther

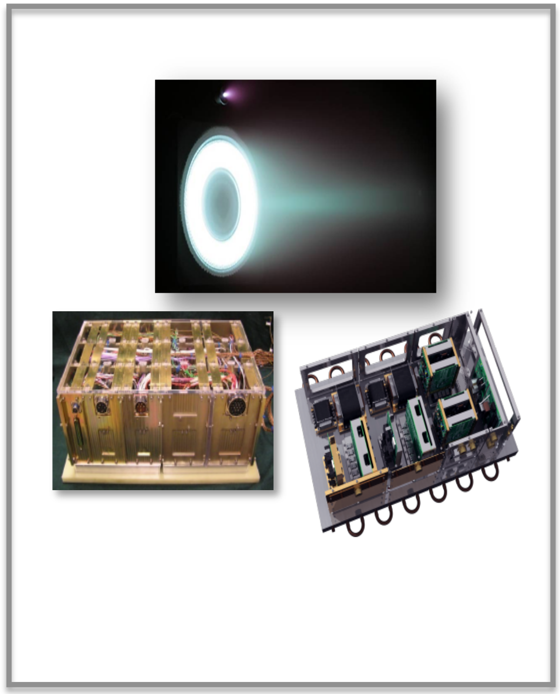
Deputy Associate Administrator for Programs,
Space Technology Mission Directorate

High-Powered Solar Electric Propulsion



Solar Arrays

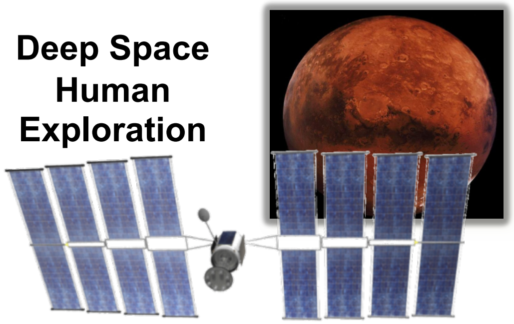


Thruster and Power Processing Unit (PPU)

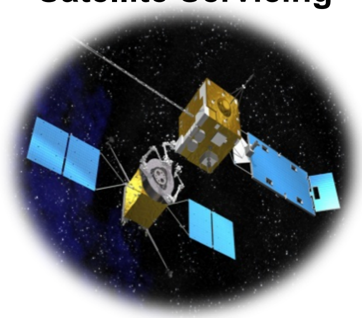
Propellant Feed System and Storage Tanks

High-powered SEP Enables Multiple Applications

Deep Space Human Exploration

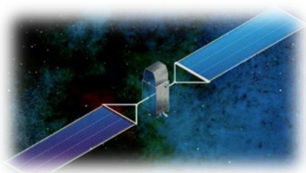


Satellite Servicing



Payload Delivery

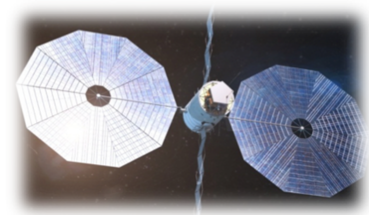
Commercial Space Applications



ISS Utilization

Orbital Debris Removal

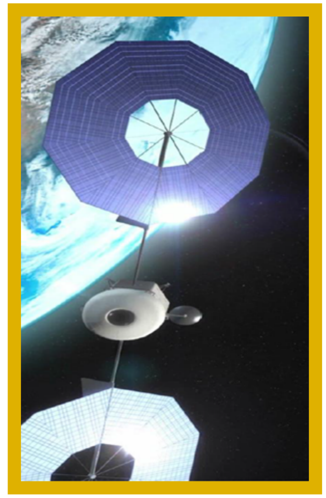
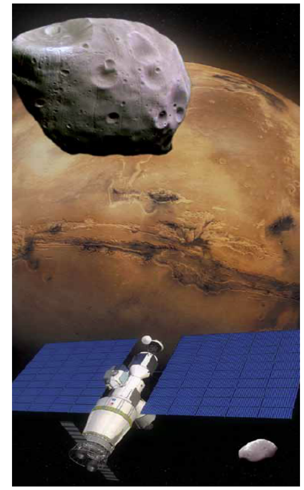
Space Science Missions



OGA Missions

Advancing Solar Electric Propulsion Technology



Deep Space 1 1998	Dawn 2007	AEHF Recovery 2010	Asteroid Redirect Mission	Far-term Exploration Missions circa 2030's
Technology Demonstrator	Deep-Space Science Mission	Satellite orbit established with Hall Thrusters	Robotic Mission to Redirect Asteroid to Trans-Lunar Orbit	Crewed mission beyond Earth space
2.5 kW power system 2kW EP system	10 kW power system 2.5kW EP system	~16kW-class power ~4.5kW-class EP	50kW-class power system 10 kW-class EP	350kW-class power system 300kW-class EP

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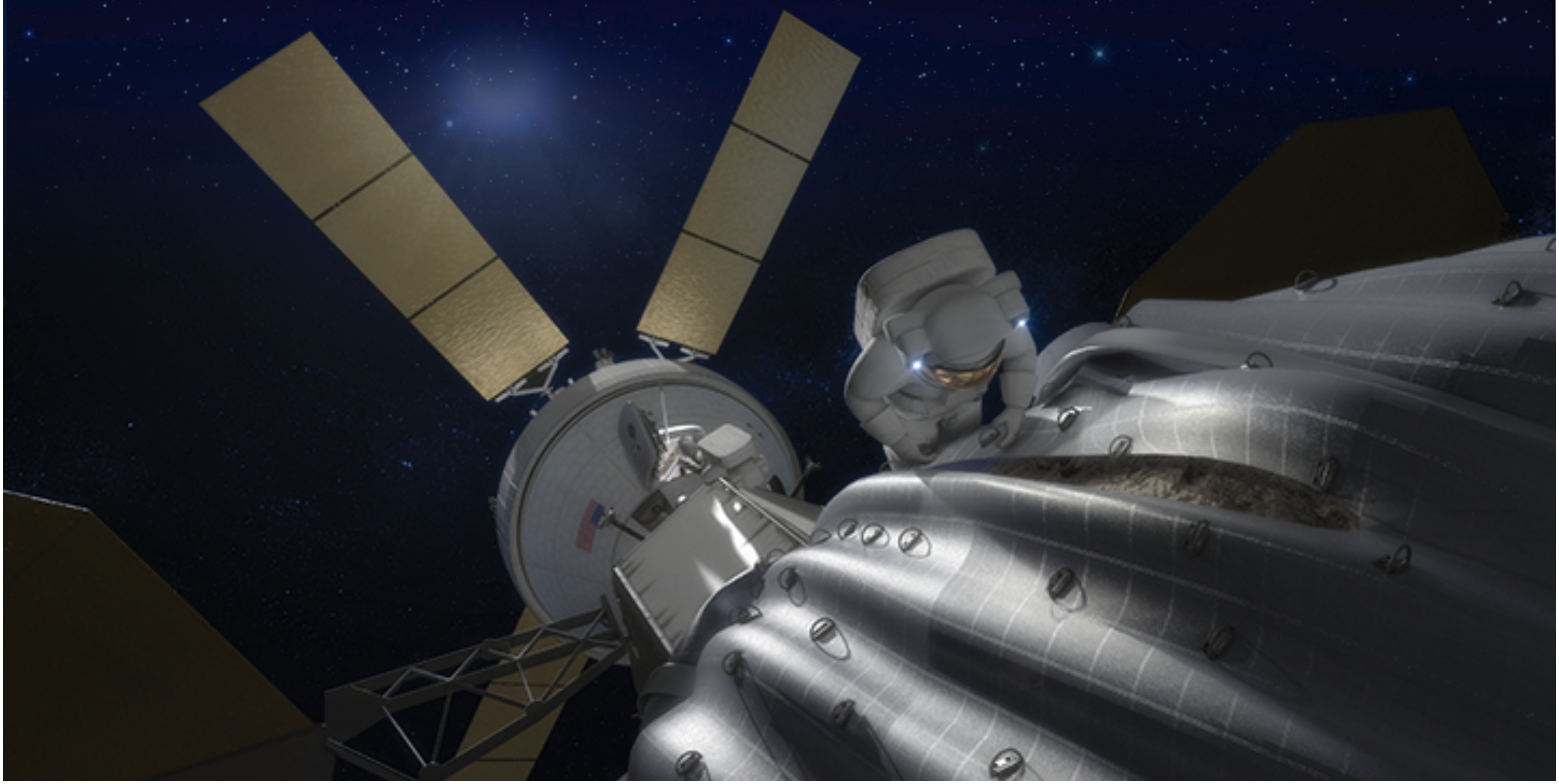
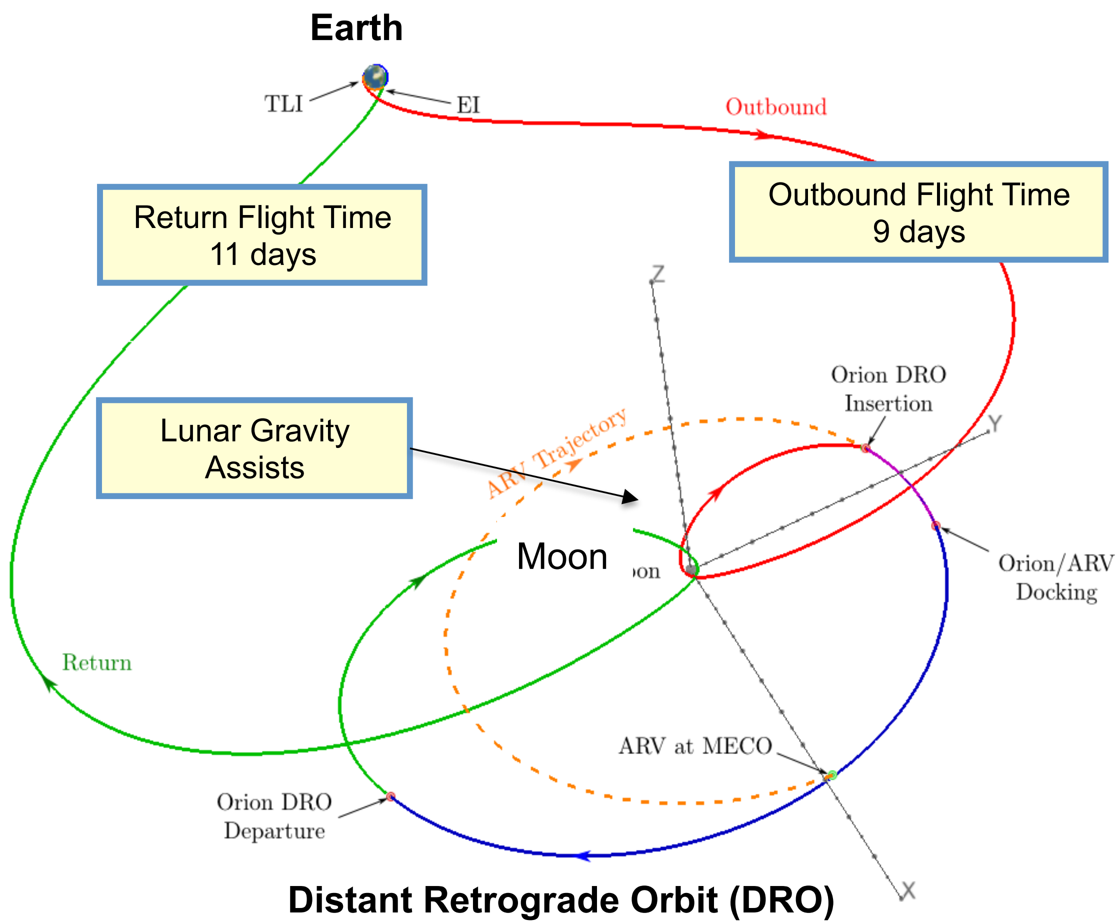
Crewed Mission Segment

Steve Stich – Deputy Director, JSC Engineering



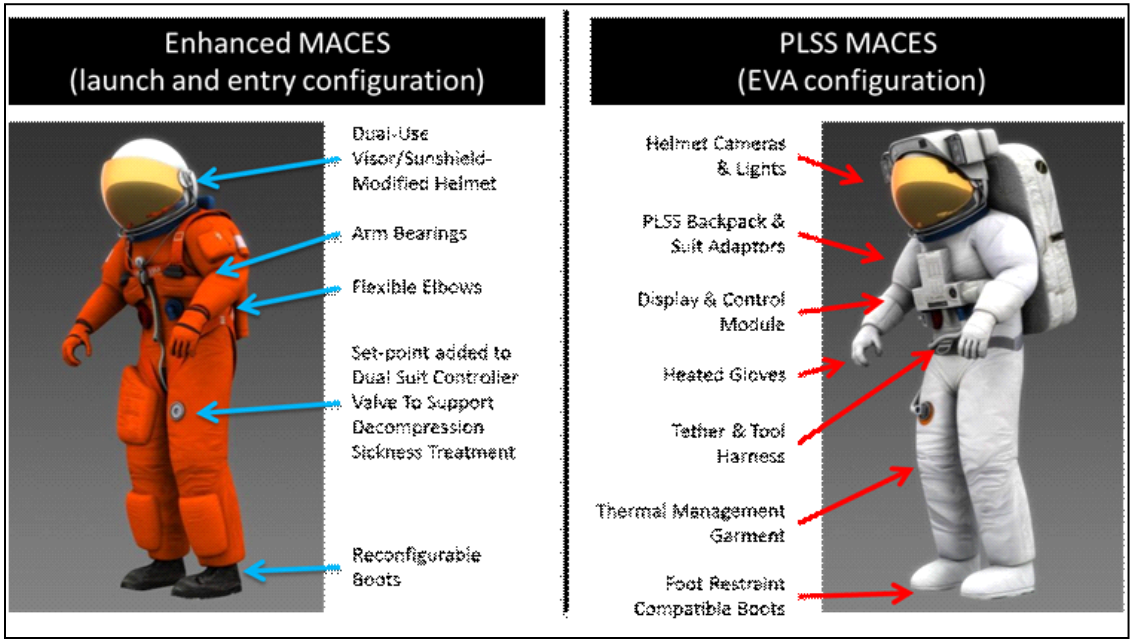
Reference Trajectory: Earliest Mission for 2009BD

- **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



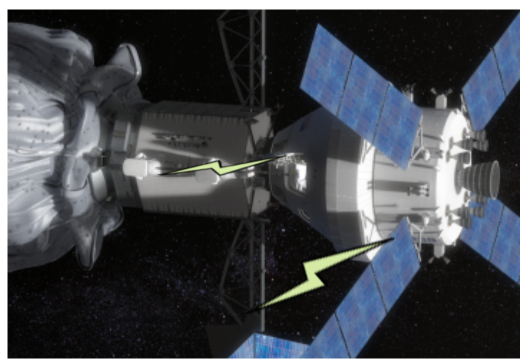
Mission Duration and timing of specific events will vary slightly based on launch date

Mission Kit Concept Enables Affordable Crewed Mission

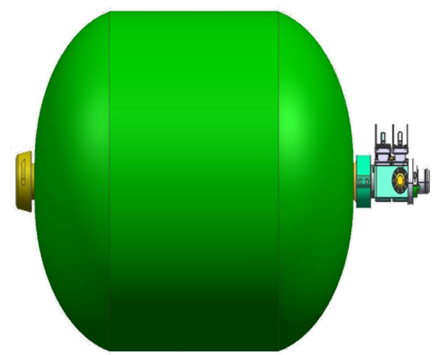


Tools & Translation Aids

Sample Container Kit



EVA Communications Kit

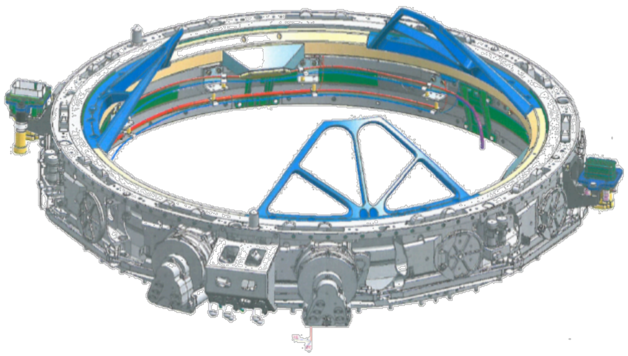


Repress Kit

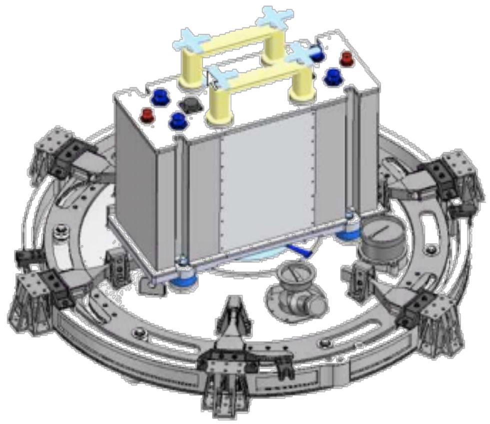
Mission Kit Concept Enables Affordable Crewed Mission

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

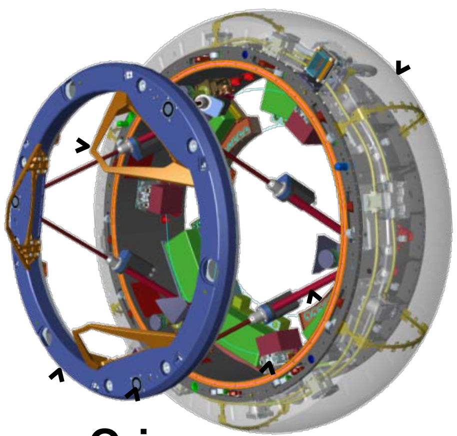
- Relative Navigation Sensor Kit based on Space Shuttle Flight Tested Orion Sensors



Robotic Spacecraft Passive Half of Docking Mechanism



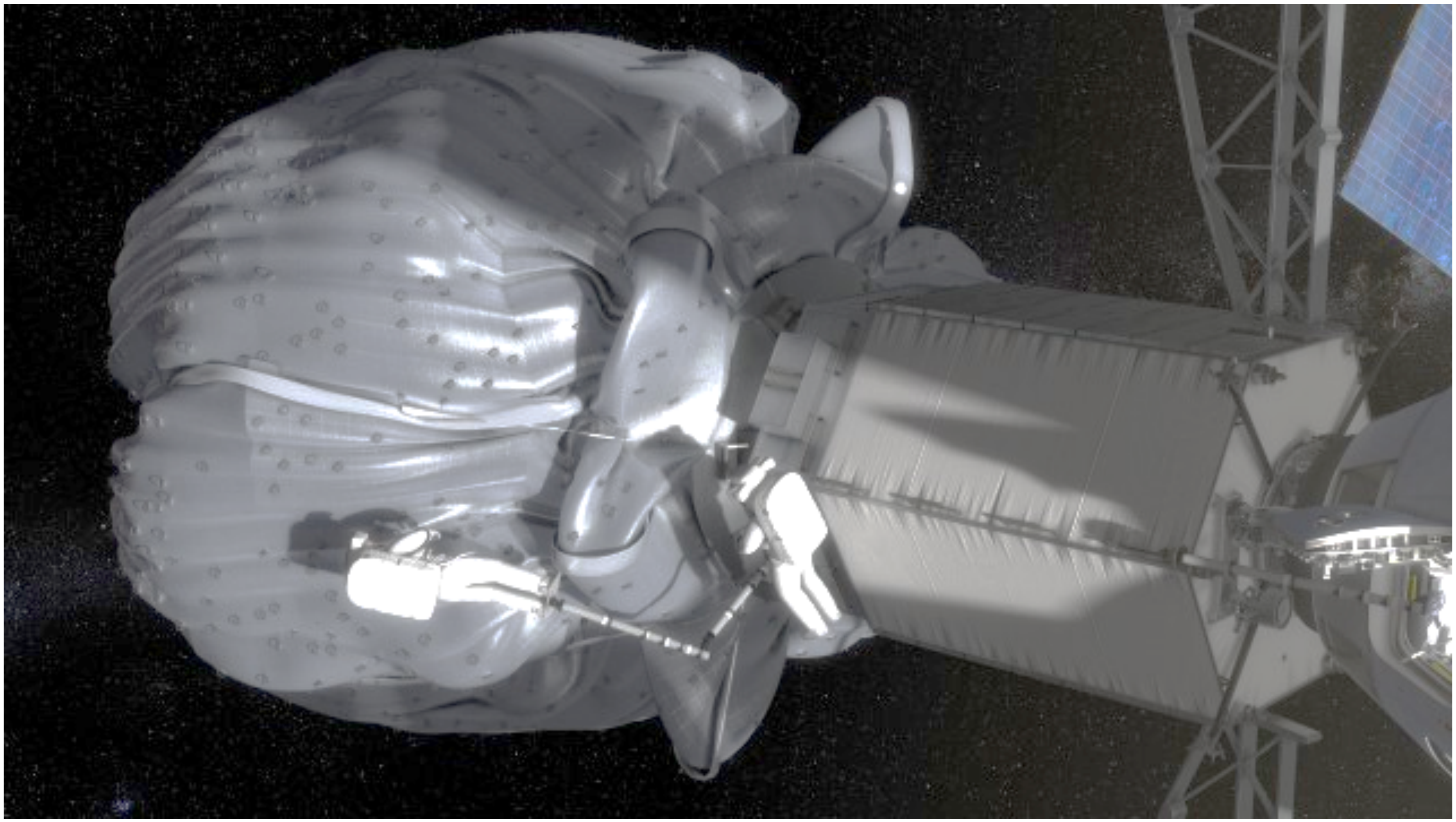
Relative Navigation Sensor Kit



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)

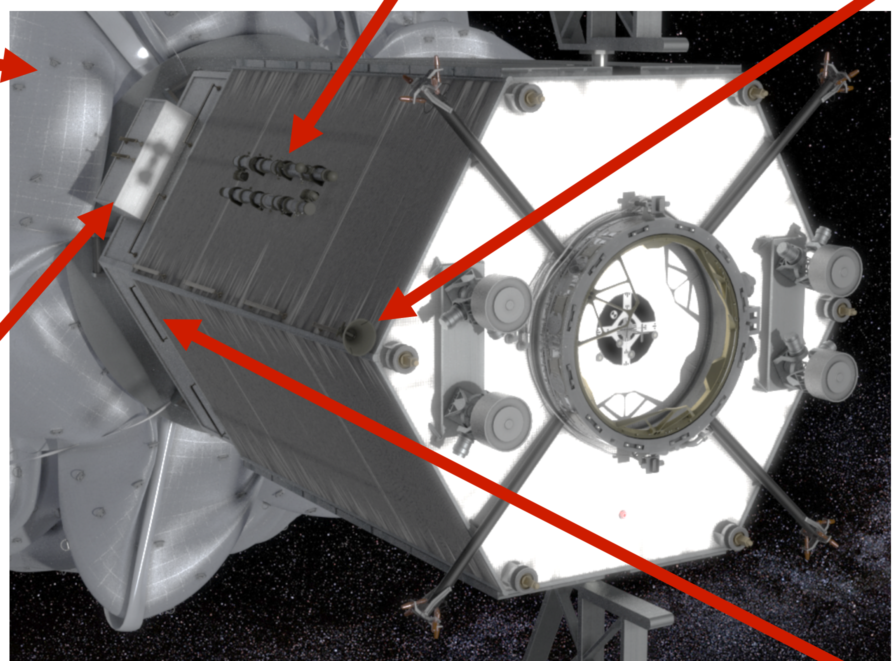


Accommodations for Crewed Mission

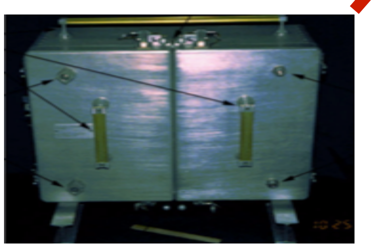
Extra Vehicular Activity (EVA) Translation Booms
- Translation Booms for Asteroid EVA

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

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



Hand Rails
- Translation path to capture bag
- Ring of hand rails near capture bag

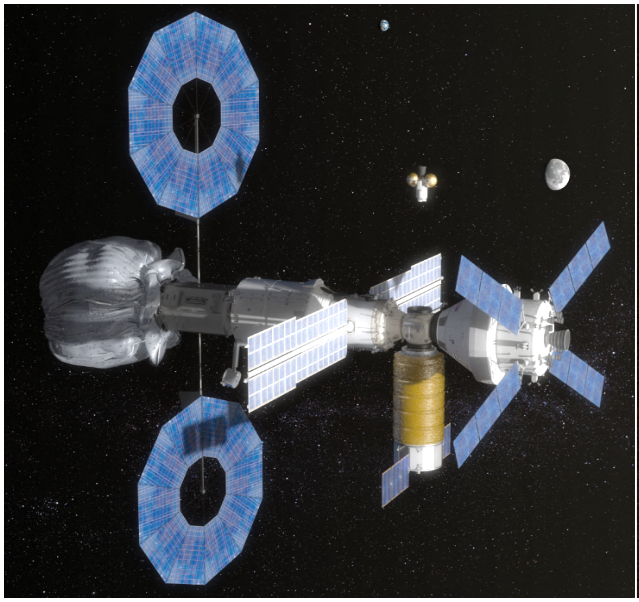


Pre-positioned EVA Tool Box
- Tool box stores 85 kg tools

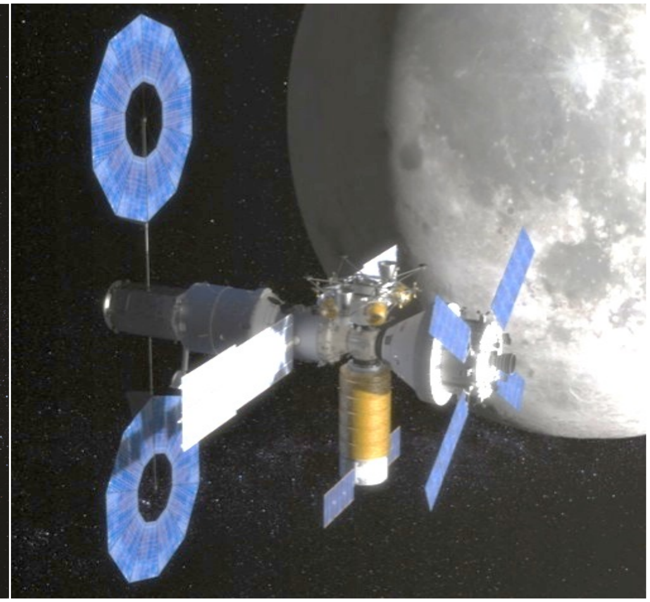
First Steps to Mars and Other Destinations

Sequence \ Mission	Current ISS Mission	Asteroid Redirect Mission	Long Stay In Deep Space	Humans to Mars Orbit	Humans to Surface, Short Stay	Humans to Surface, Long Stay
In Situ Resource Utilization & Surface Power						X
Surface Habitat						X
Entry Descent Landing, Human Lander					X	X
Aero-capture				X	X	X
Advanced Cryogenic Upper Stage				X	X	X
Solar Electric Propulsion for Cargo		X	X	X	X	X
Deep Space Guidance Navigation and Control		X	X	X	X	X
Crew Operations beyond LEO (Orion)		X	X	X	X	X
Crew Return from Beyond LEO – High Speed Entry (Orion)		X	X	X	X	X
Heavy Lift Beyond LEO (SLS)		X	X	X	X	X
Deep Space Habitat	*	→	X	X	X	X
High Reliability Life Support	*	→	X	X	X	X
Autonomous Assembly	*	→	X	X	X	X

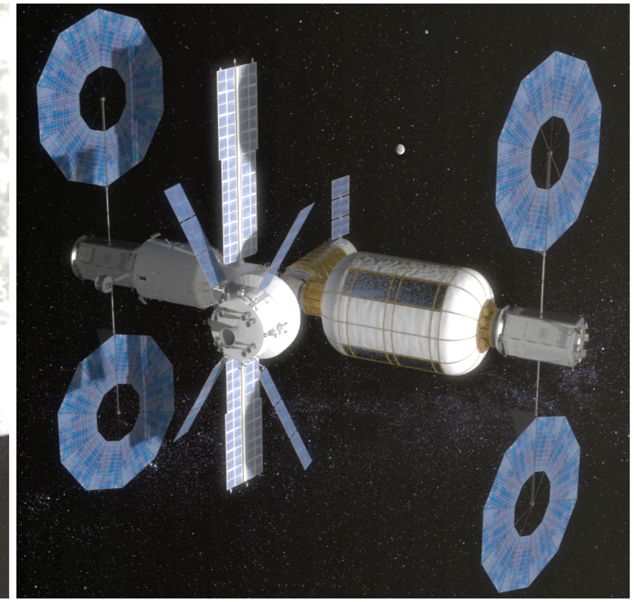
Asteroid Redirect Mission builds upon Orion/SLS to enable Global Exploration Roadmap



Asteroid Exploitation Missions



Lunar Surface Missions



Deep Space Missions

Asteroid Initiative Ideas Synthesis Workshop
September 30 – October 2, Houston, TX

- 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