

National Aeronautics and Space Administration



Human Exploration and the Role of NEOS: A NASA Perspective

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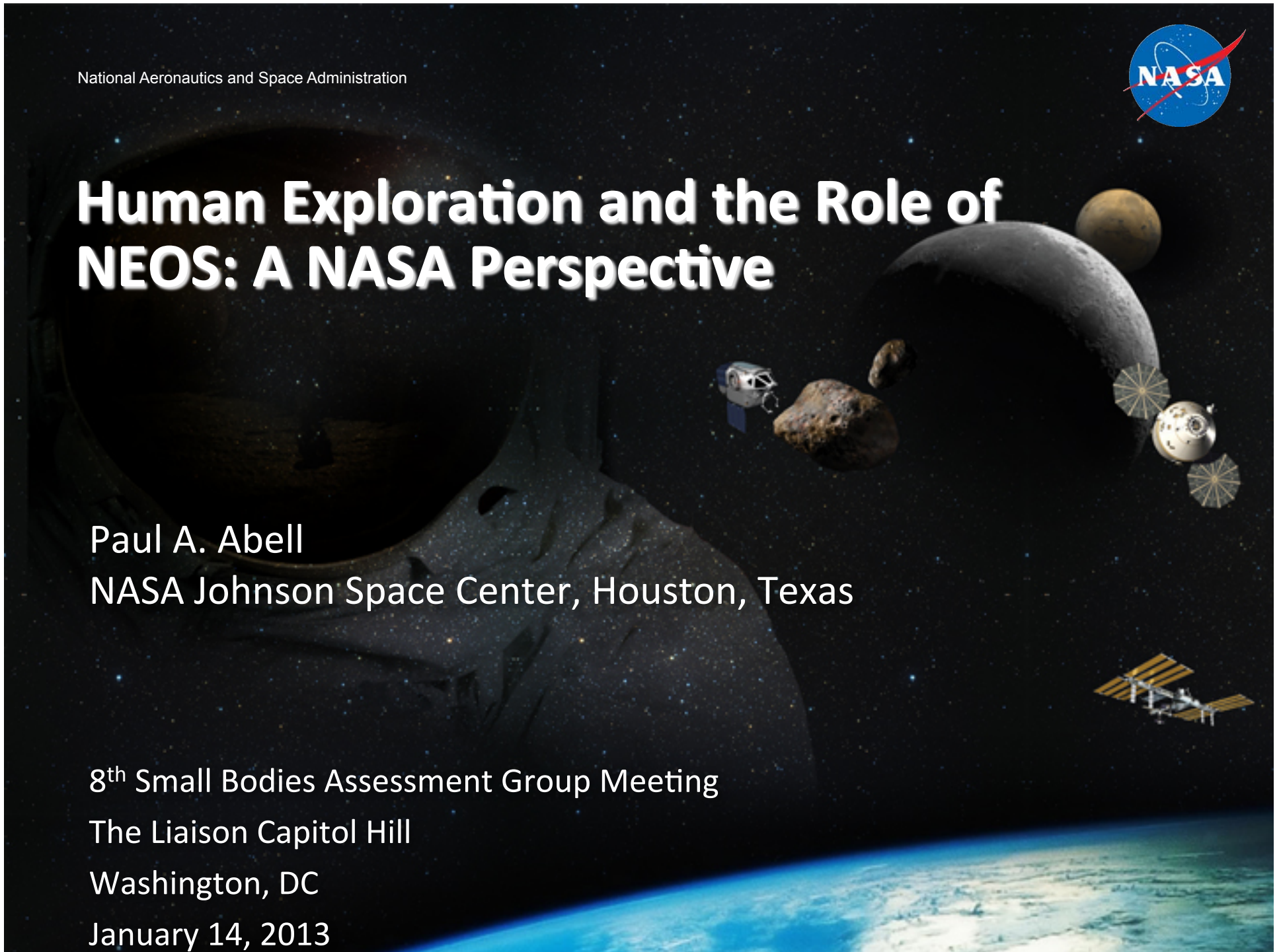
NASA Johnson Space Center, Houston, Texas

8th Small Bodies Assessment Group Meeting

The Liaison Capitol Hill


Washington, DC

January 14, 2013



A horizontal banner at the top of the slide featuring a collage of space-related images: a blue and white Earth, a grey cratered moon, an astronaut in a white suit floating in space, a dark asteroid, and the NASA logo in the top right corner.

Presentation Outline

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- A large, artistic background image of a spacecraft's heat shield during reentry, showing a bright orange and yellow plasma flow. In the background, a crescent moon and a ringed planet like Saturn are visible against a starry space.
- **Background**
 - **NEA Mission Rationale and Benefits**
 - **Challenges**
 - **Current Activities**
 - **Summary**

President Obama at Kennedy Space Center – April 15, 2010

“Early in the next decade, a set of crewed flights will test and prove the systems required for exploration beyond low Earth orbit. And by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space. So we’ll start -- we’ll start by sending astronauts to an asteroid for the first time in history. By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow. And I expect to be around to see it.”



Source: NASA

- **Current NASA Focus Areas:**

- Extension of the International Space Station until at least 2020
- Support for a commercial space transportation industry
- Development of a Multi-purpose Crew Vehicle (MPCV) and heavy lift launch vehicle (SLS)
- A “flexible path” approach to space exploration opening up vast opportunities including near-Earth asteroids (NEAs), the Moon, and Mars
- New space technology investments to increase the capabilities beyond Low-Earth Orbit (LEO)

Near-Earth Asteroid (NEA) Mission Rationale and Benefits

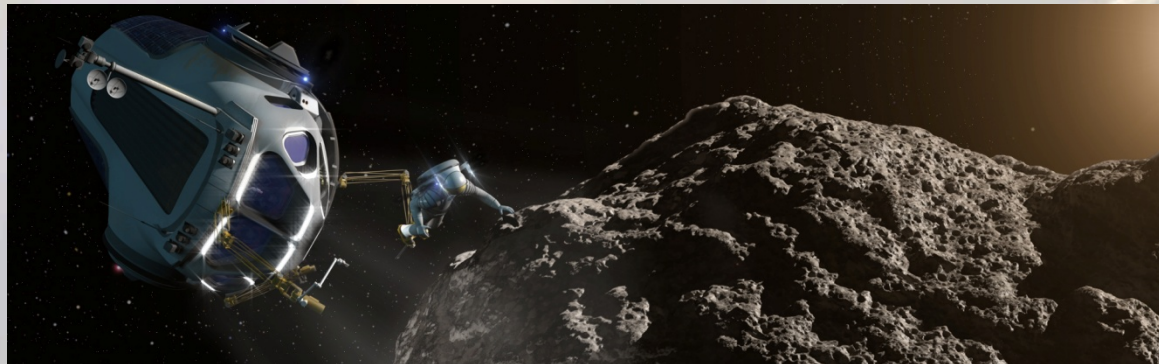


- **Near-Earth Asteroids (NEAs) provide an intermediate destination for human missions between the Moon and Mars that, among other benefits, can reduce the risks for all deep-space exploration**
 - With *sufficient* propulsive capability, missions with durations of one year or less are feasible (e.g., several weeks or a few months)
 - Durations of a year or more are commensurate with the in-space transit segments for sending human missions to the Martian system
 - Provide important scientific discoveries about the Solar System from additional planetary bodies, substantially different in origin, age, and composition from that of the Moon or Mars
 - Open access to resources vital to future exploration and economic activities in space by demonstrating extraction and utilization techniques for water, volatiles, and valuable metals
 - Provide vital operational experience and system development for deep-space missions to Mars and beyond
 - Allow insight into the physical properties of NEAs and provide civil engineering data to assist in the development of planetary defense approaches

Near-Earth Asteroid (NEA) Mission Rationale and Benefits



- **Opportunities exist for commonality/extendability with the systems and elements needed for missions to the Moon, Mars and other destinations**
 - Multi-purpose Crew Vehicle (MPCV)
 - Space Launch System (SLS)
 - Deep Space Habitat (DSH)
 - Multi-Mission Space Exploration Vehicle (MMSEV) (i.e., excursion vehicle)
- **Foster international, commercial, and academic cooperation for both robotic precursor and human missions**
 - JAXA, ESA, Russia, Canada, and other exploration agencies
 - Space X, Planetary Resources, Bigelow Aerospace, etc.
 - Scientific and Engineering academic communities



Source:
NASA/AMA, Inc.



Challenge:

NEA Target Identification and Remote Characterization



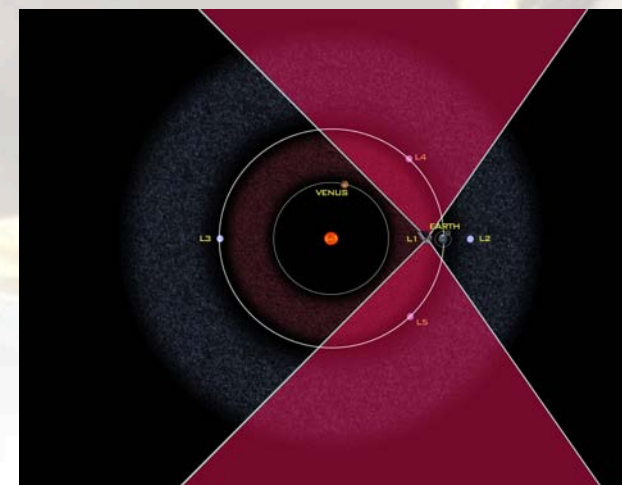
- **In order to be selected as a viable target for near-future Human exploration (2025 - 2030), a NEA should be within reach of attainable and realistic exploration capabilities**
 - Dynamical considerations need to be made with respect to potential exploration system's capabilities
 - Key parameters for this analysis are orbit location, mission duration, number of launches, length of launch windows, number of launch opportunities, and delta V
 - The most accessible NEAs have very Earth-like orbits and can have continuous departure windows that can last many months and repeat for several years
- **Since there are many more smaller NEAs than larger ones, mission opportunities are constrained by the minimal NEA size deemed acceptable for a future human mission**
 - The reasons for this are political and practical (e.g., spin rate)
 - Ideally the astronauts will be asked to rendezvous and interact with the object at some level

Challenge:

NEA Target Identification and Remote Characterization



- **Missions to currently known objects requires crew exposure to long mission durations and development of advanced propulsion and re-entry technologies**
 - Thus, basing a target set on the known NEA population severely constrains program flexibility and lowers its resiliency to budget challenges
 - Increase of mission, programmatic, and budgetary risk
- **Fortunately the deployment of a space-based survey telescope can significantly improve this situation**
 - Only a fraction of the NEA population has been discovered
 - Several of these undiscovered NEAs may be viable as destinations for Human missions
 - The most accessible NEAs have very Earth-like orbits and are difficult to observe from ground-based assets
 - A space-based survey will be able to refine orbit and perform some remote characterization of NEAs (e.g., albedo, size, etc.)
 - NEO WISE results have proven invaluable
 - NASA has engaged in IR sensor development
 - Entered into a space act agreement with the B612 foundation for space-based NEA survey



Challenge:

NEA Target Identification and Remote Characterization



- Identification of a *sufficient* number of *accessible & desirable* NEAs is an important consideration for enabling future human missions – therefore, a robust target list is critical
 - Desirable NEAs characteristics are provided in the table
 - Filtering based on desired values reduces the number of targets

Target Characteristic	Desired Value
Total Mission Duration	< 1 year
ΔV (from LEO)	< ~5 km/s
Size	> 30 m
Departure Window	Weeks+, not days
Rotation Period	> 2 hrs
Orbital Condition Code	0 (desired)
Asteroid Type	Understood

- Prior to conducting either robotic and human missions, securing the NEA's orbit and obtaining remote characterization are critical for cost-effective target selection
 - Hence the need for additional ground-based and space-based observations
 - Identification of targets well in advance of human mission launch possibilities



Challenge: NEA Target *In Situ* Characterization

- **Prior to sending a piloted mission to a NEA, additional *in situ* characterization of the target is required**
 - Obtain basic reconnaissance to assess potential hazards that may pose a risk to both vehicle and crew (e.g., *Ranger*, *Lunar Orbiter*, *Surveyor*, *LRO* have done for the Moon)
 - Some NEAs may have physical characteristics that would make them unsuitable as targets for early human exploration
- **Precursor missions would also assess the NEA for future activities to be conducted by the crew and their assets to maximize mission efficiency**
 - Proximity operations (spacecraft, robotic assets, crew on EVA)
 - Surface activities (scientific and engineering investigations)
 - Touchdown site identification and sample collection
- **Build on lessons learned from other small body missions such as NEAR Shoemaker, Hayabusa, Rosetta, Hayabusa 2, OSIRIS Rex, and Marco Polo-R**

Current Activities

- **NASA Near-Earth Objects Human Space Flight Accessible Targets Study (NHATS)**

- Online tool that identifies potential HSF targets and lists future potential observing opportunities that is continually updated

<http://neo.jpl.nasa.gov/nhats/>

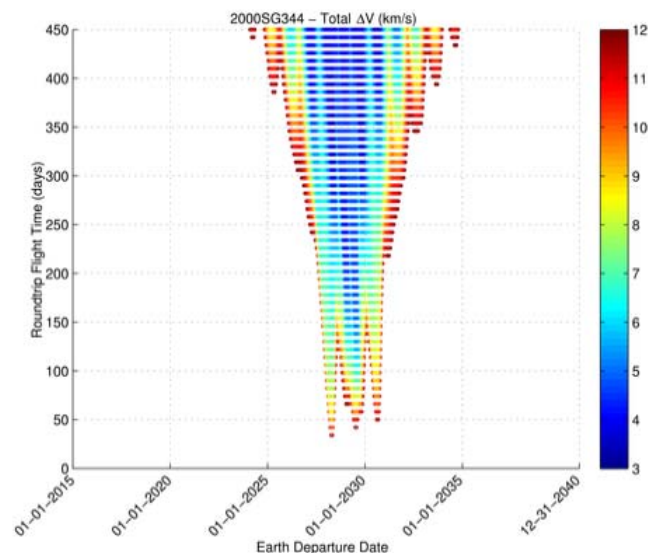
Mission Trajectories Table

Column headings described below

(2000 SG344)	Min. delta-V Parameters	Min. Duration Parameters
Total Mission delta-V (km/s)	3.556	5.973
Total Mission Duration (d)	354	114
Outbound Flight Time (d)	145	49
Stay Time (d)	8	8
Inbound Flight Time (d)	201	57
Launch date (YYYY-MM-DD)	2028-04-22	2029-07-22
C_3 (km ² /s ²)	1.737	3.009
Departure V_{∞} (km/s)	1.318	1.735
Earth Departure dV (km/s)	3.256	3.314
dV to Arrive at NEA (km/s)	0.113	1.067
dV to Depart NEA (km/s)	0.187	1.592
Earth return dV (km/s)	0.000	0.000
Entry Speed (km/s)	11.133	11.214
Departure Declination (deg)	-8.950	-22.493
Return Declination (deg)	-5.933	22.663
NHATS Trajectory Solution ID	890465	2046652

These data were computed on 2012-01-06 using the latest available orbital parameters.

Total Mission delta-V as a Function of Departure Date and Mission Duration



The plot above shows total mission delta-V as a function of Earth departure date and total round-trip flight time (mission duration). It summarizes the many potential mission scenarios by plotting, for each case, the total round-trip delta-V values (color-coded) required for each launch date and round trip flight time considered. Note that these trajectories span a range of possible stay times at the NEA.

Current Activities

- **Advanced Exploration Systems (AES) Goldstone Radar Project**
 - Enhanced Goldstone capability to observe NEAs at higher spatial resolutions (~ 4 m)
 - Obtain information on NEA surface properties relevant for Human exploration considerations (Human Exploration and Operations Mission Directorate funded)

Goldstone Radar Image of Asteroid 2005 YU55

3.75 m x 0.03 Hz

Nov. 07, 2011

Current Activities

- **NASA Desert Research and Technology Studies (DRATS)**
 - Mission analogue for NEA simulations in 2011 and 2012 at NASA JSC
 - Combination of vehicle mock ups, virtual reality, and simulated low-g EVA via the Active Reduced Gravity Offload System (ARGOS)
 - Simulate science and engineering operations at a NEA



Test subject on simulated EVA via the ARGOS system



Mock up of the Space Exploration Vehicle (SEV)

Current Activities

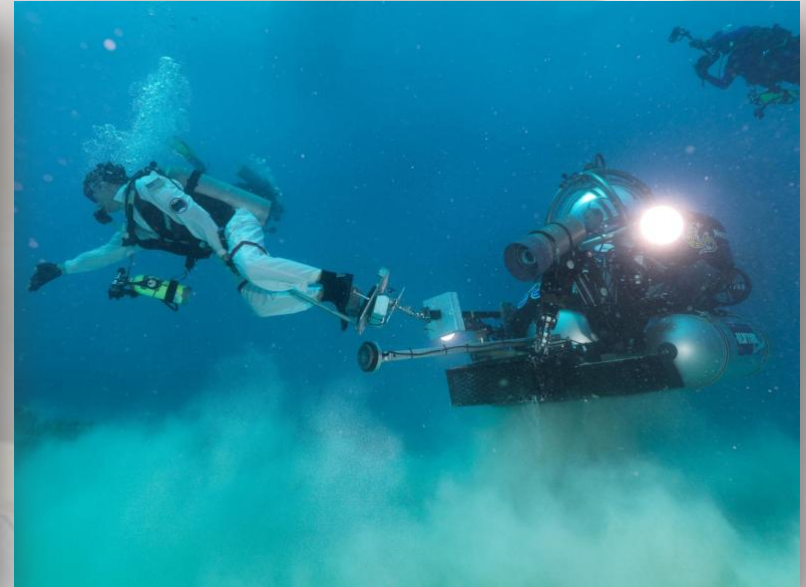


- **NASA Extreme Environment Mission Operations (NEEMO)**

- Mission analogue for NEA operations at the National Undersea Research Center Aquarius Base located 3.5 miles off of Key Largo, Florida 62 feet (18.9 m) under the sea
- NEEMO 15 conducted in October 2011, NEEMO 16 conducted in June 2012
- Simulate science and EVA operations in neutrally buoyant environment with communication delay times of 50 seconds (0.1 AU)



Aquanauts testing EVA equipment during simulated NEA exercise

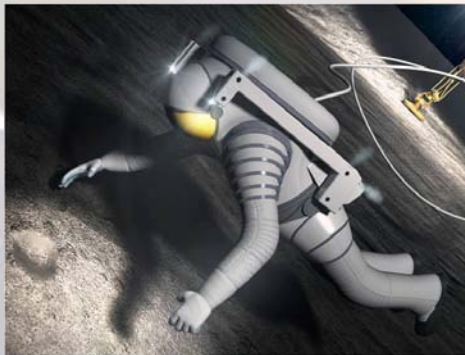


Simulated EVA with crew and SEV using aquanaut and submersible

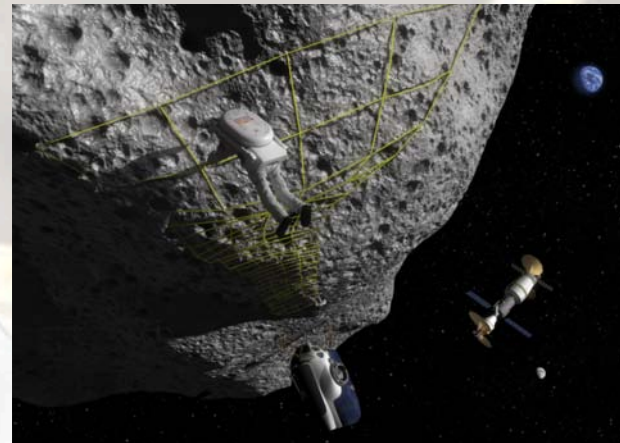
Current Activities

- **Solar System Exploration Research Virtual Institute (SSERVI)**

- Cooperative Agreement Notice released January 10, 2013
- Opportunities for multi-institutional team based proposals (including international partners)
- “Broadly based research program addressing basic and applied scientific questions fundamental to understanding the nature of the Moon, Near-Earth Asteroids (NEAs), the Martian moons Phobos and Deimos, and the near space environments of these target bodies, to enable human exploration of these destinations.”
- Funded by NASA Science Mission Directorate (SMD) and NASA Human Exploration and Operations Mission Directorate (HEOMD)



Source: NASA/AMA, Inc.

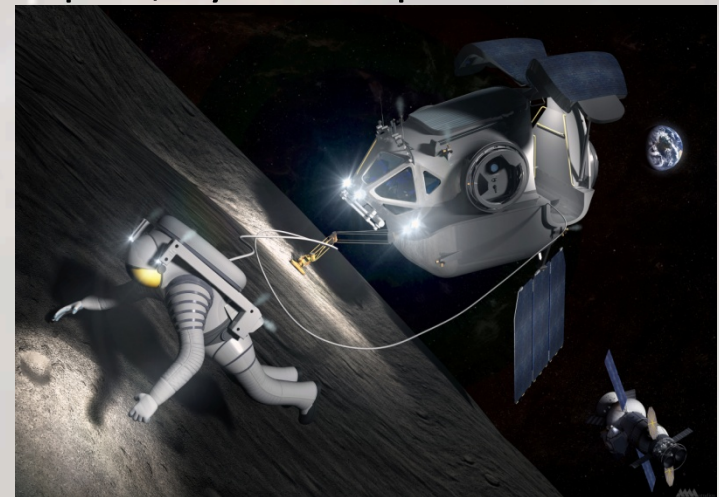


Source: NASA/AMA, Inc.

Summary



- Human deep-space exploration presents new challenges, many of which can be addressed by exploring NEAs
- Critical areas where additional knowledge is needed for future human exploration to Mars (surface and moons) and other destinations beyond the Earth-Moon system can be addressed, at least in part, by NEA exploration
 - Reliability and reparability of systems
 - Impact of radiation and micro-gravity on crew members in deep-space
 - Deep-space communications and navigation
 - Regolith properties and equipment interaction
 - Proximity operations
 - *In situ* resource utilization (ISRU)
- NEA exploration also offers opportunities for international cooperation in the areas of science, engineering, and planetary defense.



Source: NASA/AMA, Inc.

A Few 'Take Away' Thoughts...

- NEAs for Exploration

- NEAs for Science

- NEAs for Resources

- NEAs for Planetary Defence





WM K HARTMANN
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Backup

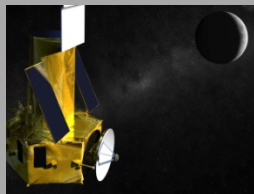


Possible Program Sequence



- With current propulsive limitations, the current NEA catalog provides few opportunities for short duration missions – identifying additional NEAs is extremely valuable (i.e., space-based survey)
- Possible sequence for Human mission given the goal of sending astronauts to NEAs
 - Assumes a robust and stable budget profile
 - Assumes long term commitment

NEO Space Survey



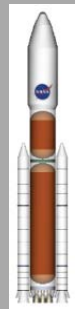
NEA Target Selection



Robotic Precursors



Human mission planning



Notional Program Sequence

NEA Long Duration Mission Challenge and Risk Reduction



- **Challenge: Long-duration human interplanetary space missions, including NEA missions, present unique challenges for the crew, spacecraft systems, and the mission control/support team**
 - The cumulative experience and knowledgebase for human space missions beyond six months and an understanding of the risks to humans and human-rated vehicle systems outside of the Earth's protective magnetosphere is limited at this time
 - New challenges include:
 - Radiation exposure (cumulative dosage and episodic risks)
 - Physiological effects
 - Psychological and social-psychological concerns
 - Habitability issues
 - Supportability & sustainability
 - System redundancy and life support systems reliability
 - Limited mission contingencies and abort scenarios
 - Consumables and trash management with no supply chain
 - Communications light-time delays (crew autonomy, mission control operations, etc.)