National Aeronautics and Space Administration

Roadmap for Human Exploration of Small Bodies

Paul Abell

NASA Johnson Space Center

5th SBAG Meeting

Pasadena, CA

August 25, 2011

Chapter Organization (1 of 2)

- Introduction
- Dynamical Assessment of NEOs Relevant for Human Exploration
- Identification of Human Exploration NEO Targets
- Remote Characterization of NEOs and Human Mission Targets
- Laboratory and Simulation Support for NEO Exploration Studies
- Test Bed and Analogue Mission Operations
- Utilization of the International Space Station for NEOs as a Technology Demonstration Platform

Chapter Organization (2 of 2)

- Robotic Precursor Missions and Operations
- Human Missions and Operations
- Feed Forward to Other Destinations
- International Support and Cooperation
- Recommendations and Forward Path
- Conclusions

Executive Summary

During a visit to Kennedy Space Center on April 15, 2010, U.S. President Obama stated that near-Earth objects (NEOs) should be included as destinations for NASA's future space exploration programs. A few months later, human exploration of NEOs became part of the *National Space Policy of the United States of America* on June 28, 2010. Such missions would reinforce U.S. human spaceflight leadership and foster international collaboration, while significantly increasing humanity's knowledge and experience in such areas as: Solar System evolution and formation; origins of life on Earth; deflection strategies for potentially hazardous NEOs; development of safe, reliable long-duration deep space exploration operations; designs for more capable exploration architectures; and establishment of *in situ* resource utilization (ISRU) efforts.

NEOs provide the U.S. and its international partners with an accessible and exciting set of destinations beyond the Earth-Moon system. More accessible than the Moon in terms of the propulsive requirements for round trip missions, NEOs nevertheless present a different set of challenges that will expand human spaceflight capabilities and demonstrate a firm commitment to ambitious space exploration. Experience gained in low-Earth orbit, in cis-Lunar space, and on the Moon, complemented by true deep-space expeditions to NEOs, will serve the U.S. and its international partners well as humanity plans for the eventual exploration of Mars and beyond.

Small Body Exploration Goals

To conduct international robotic and human expeditions to NEOs that will enable future human exploration of the Moon, Mars, and beyond, enhance scientific understanding of the Solar System, locate and characterize materials for future *in situ* resource utilization, and develop suitable planetary defence initiatives.

Current Status

- **Ground-based facilities continue to discover and characterize NEOs providing context for future exploration considerations.**

- **Increased attention, both from a domestic and international perspective has been focused on robotic and human exploration of NEOs (e.g., trajectory analyses, design reference mission studies, analogue activities, etc.).**

- **Past NEO robotic missions have been successful (NEAR Shoemaker, Hayabusa) in providing a better understanding of NEOs and their environment. Other missions are in development (e.g., Hayabusa 2, OSIRIS REx) or under consideration (e.g., Marco Polo-R) for future launch.**

Priority Needs (1 of 2)

- **An enhanced survey and characterization effort both from ground-based and space-based sensors to expand the knowledge base concerning the size frequency distribution and physical attributes of the NEO population.**
- **A dedicated NEO space-based survey mission to identify future targets for human exploration, but designed to also benefit Solar System science and planetary defence interests.**
- **A robust robotic precursor program with participation from NASA's Science Mission Directorate (SMD) and Human Exploration and Operations Mission Directorate (HEOMD).**
- **Increased cooperation and coordination with international partners regarding NEO activities (e.g., research and development, mission operations, spacecraft design, etc.) to leverage available resources more effectively and reduce mission costs.**

Priority Needs (2 of 2)

- **More laboratory and simulation support is required in order to recognize how materials on small bodies under microgravity regimes will react to proximity and surface interactions prior to developing the systems to be used for robotic and human exploration.**

- **Increased utilization of test beds and analogue missions for future development of robotic and human instruments, operational concepts, and exploration systems.**

- **Development and utilization of the International Space Station (ISS) for future NEO exploration as a technology demonstration platform (e.g., EVA mobility systems, robotics, ISRU, etc.).**

Feedback

- **All feedback and comments are welcome!**
- **Please register for the SBAG Roadmap Listserve:**
  - **http://www.lpi.usra.edu/sbag/roadmap/**
- **E-mail address to provide suggestions/comments/feeback:**
  - sbag.human.exploration@pc93.lpi.usra.edu
  - paul.a.abell@nasa.gov