

FINDINGS FROM SBAG 12, JANUARY 6–7, 2015

SBAG eagerly anticipates a banner year for small bodies science in 2015. While our science will advance across diverse fronts including telescopic, laboratory, and modeling investigations, the simultaneous spacecraft exploration of Ceres, the Pluto system, and comet Churyumov-Gerasimenko will focus public attention on small bodies science as never before. The anticipated flood of discoveries in 2015 is the fruit of decades of effort. ***The attention it will attract gives the small body science community a spectacular opportunity to communicate the value of our work.*** To build a healthy future, we all must make an extra effort this year to engage with the public over these exciting missions.

1. Need for a Near-Earth Object Survey

NASA's Asteroid Initiative comprises aspects of human exploration, planetary defense, resource utilization, and science related to near-Earth asteroids and comets. SBAG reiterates its previous findings that ***a space-based near-Earth object (NEO) survey telescope would be a foundational asset that would most efficiently achieve the goals of NASA's Asteroid Initiative in the shortest amount of time.*** Construction and implementation of such an asset should be supported by all three of NASA's major space exploration directorates and not just by the limited resources of the Near-Earth Object Observations (NEOO) program within the Science Mission Directorate (SMD). Cross directorate support for a space-based asteroid survey is fully consistent with the Asteroid Initiative already established as an agency-wide goal. It should be noted that a space-based NEO survey telescope would be capable of detecting human-accessible NEOs far enough in advance for their mission opportunities to be implementable.

Response: The capability of a space-based NEO survey telescope to complete the survey is not disputed. However, appropriations for the NEO Program do not support acquisition of such a space-based capability. NASA will continue to seek ways to maximize survey capabilities within the means allowed by congressionally appropriated budgets for the NEO Program.

2. Affirmation of the NAC Statement of Human Missions to NEOs in Their Native Orbits

[The NASA Advisory Council \(NAC\) letter](#) dated August 4, 2014 states that: "It must also be noted that ARM [Asteroid Redirect Mission] is not a substitute for a [human] mission to an asteroid in its native orbit, which appears to be possible at a lower launch energy than previously believed based on recent data (references 2 – 4). Such a long duration deep space mission would be a logical step toward the horizon goal of humans to Mars." ***SBAG strongly supports this NAC statement and finds that a human mission to an asteroid in its native orbit has unique merits and value,*** regardless of whether ARM is flown. SBAG maintains a [summary chart](#) of human-accessible near-Earth asteroid (NEA) data, updated every few months.

Response: The Near-Earth Object Human Space Flight Accessible Targets Study (NHATS) database provides a valuable analysis and resource for a quick assessment of the viability of all discovered NEOs for future robotic and human spaceflight destinations. Previous human

spaceflight studies have shown that human missions to asteroids in native orbits require substantial investments in technology for habitation systems and in-space propellant systems along with high power electrical systems, assuming the target asteroid is shown to be suitable for human systems interaction. Required current funding profiles and the required safety assessments did not allow for these missions today to be initiated in the near term. The ARM mission well supports the strategy for development of capabilities in the cislunar environment and incremental capability development in NASA's plan for preparing for humans to explore further out in to the solar system. NASA will be developing missions that help us gain the knowledge we need to send humans to Mars. These missions may include visiting asteroids in their natural orbits, and the targets discovered by the Near-Earth Object Human Space Flight Accessible Targets Study (NHATS) will likely be utilized in future studies.

While recent analyses indicate the possibility of astronauts visiting an asteroid in its native orbit at delta velocities on the order of 5 km/s from low Earth orbit (LEO), similar to the ARM Crewed Mission, these candidate asteroids still yield transit times from LEO of over 3.5 months. Shorter missions, of the order of 70 days, may be possible at delta-Vs of around 7 km/s. NASA's reference plan for the ARM crewed mission encompasses a 26-28 day mission, including 5 days in a stable lunar distant retrograde orbit, which is within the capabilities of the Block I SLS/Orion vehicles. ARM can be accomplished prior to the availability of additional capabilities such as longer duration life support. In addition, this beyond LEO mission offers drivers for lower mission risk posture such as early crew and Orion auxiliary thruster contingency returns, including within consumables limits. This makes ARM a more logical early step beyond LEO toward the horizon goal of humans to Mars.

Many other aspects of ARM build capabilities and reduce risk for Mars missions, including:

- Moving large objects through interplanetary space using solar electric propulsion (SEP);
- Integrated crewed/robotic vehicle stack operations in deep space orbits (e.g., integrated attitude control, solar alignment during multi-hour EVAs);
- In-space systems for astronaut extra-vehicular activity;
- Sample selection, handling, and containment;
- Lean implementation of an upgradable deep space operational SEP vehicle; and,
- Broad scoped robotic/crewed integration, including crewed system hardware deliveries to and integration and test with robotic spacecraft, and joint robotic spacecraft and crewed mission operations.

Our early 'Proving Ground' missions provide systems and technology testing and operational experience beyond the "Earth Dependent" domain of the International Space Station (ISS). Risk reduction in the Proving Ground, with returns to Earth possible within a few days, complements the important long duration human system risk reduction on the ISS. As presented in the sustainable exploration 'split mission' Mars approach, NASA missions in the Proving Ground will use both chemical propulsion based human transportation systems and high power, long life solar electric propulsion systems as a sustainable path in collaboration with international and commercial partnerships.

3. Asteroid Redirect Mission

SBAG appreciates NASA's efforts to engage and communicate with the planetary science community about the Asteroid Redirect Mission (ARM). SBAG further recognizes that NASA's Asteroid Initiative has raised awareness and emphasized the importance of asteroids within NASA, to other U.S. Federal agencies, to the general public, and to our international partners. Although SBAG has not endorsed either Option A (return an entire small asteroid) or Option B (capture and return a boulder from a large asteroid), the [SBAG ARM Special Action Team Full Report](#), generated at the request of NASA, provides information and rationale for the relative benefits of the two options from science, planetary defense, and resource utilization perspectives. SBAG encourages the use of this document if such factors are considered during the selection of the ARM capture system.

However, SBAG reiterates its concerns from the 11th SBAG meeting about the limited benefits of ARM for advancing asteroid science or furthering planetary defense strategies, and that limits in the current knowledge of near-Earth asteroids contribute to schedule and cost risks. ***SBAG supports continued engagement with the NASA ARM team as the concept is refined.***

Response: NASA greatly appreciates the work done by the SBAG ARM Special Action Team. Their findings were key in assisting the Agency in deliberations about the ARM candidate options. Now that the decision has been made, the Agency solicits greater involvement in mission development by the small bodies science community. Maximizing the science, planetary defense, and resource utilization associated with ARM is a goal of NASA leadership. NASA hopes that SBAG will play an important role in linking ARM with the small bodies community.

4. Cadence of Discovery Missions

SBAG is encouraged by the release of the Discovery AO within 2014, a major step to achieving the strategy outlined in the Decadal Survey. The Discovery program has made important and fundamental contributions to planetary exploration, and is of crucial importance to the future scientific exploration of the Solar System. ***SBAG regards the Decadal Survey recommendation of a ≤ 24 month cadence as an essential guideline and notes that the selection of two missions from the current AO could provide a means to regain the Decadal Survey recommended average cadence of Discovery missions.***

Response: The proposals submitted to the 2014 AO are currently in evaluation so any discussion about mission selections must await the completion of that process.

5. Concern for the Minor Planet Center Status

The Minor Planet Center (MPC) is a unique and crucial facility for the small bodies community both within the United States and internationally. In addition to serving as the clearinghouse for all astrometric observations of asteroids and comets, the MPC also plays a central role in the chain of notification involving potential impactors. ***SBAG is concerned about recent changes at***

the MPC, including the resignation of the director and the center's overall status and future, and urges NASA to review the situation as soon as possible. Such a review should be conducted in conjunction with the International Astronomical Union, the organization under which the MPC is chartered.

Response: Since SBAG 12 convened, the NEO Program established and conducted a review panel staffed by members of the small bodies community, including official IAU representatives, on the MPC's status and future operations. The panel's report is now in final draft and their findings will guide the future course that the Science Directorate Planetary Science Division will take with the MPC.

6. Support for the NEO Program Development Plan

The recent NASA Office of Inspector General (OIG) Audit Report, [*NASA's Efforts to Identify Near-Earth Objects and Mitigate Hazards*](#), includes five recommendations intended to improve NASA's efforts to discover, characterize, and mitigate near-Earth object threats, and NASA SMD's response outlines a general plan to make progress on the OIG report recommendations within the year. (15 September, 2014) SBAG supports NASA's response to the OIG report and considers the recommended development of a strategic plan for the NEO Program a highly valuable activity. In particular, SBAG urges the strategic plan to draw heavily on community reports (*i.e.*, 2010 NASA Advisory Council Planetary Defense Task Force; 2010 NRC Report: *Defending Planet Earth*) that outline planetary defense priorities. ***SBAG strongly supports the creation of a NASA Planetary Defense Coordination Office, a top recommendation of the 2010 NAC Task Force report. Furthermore, SBAG recommends that this new office (1) pursue goals specified in congressional direction, such as NEO population survey completion, (2) work towards development of NEO mitigation technologies through additional funded programs, including flight validation of the most promising mitigation system concepts, and (3) utilize cross-agency and international collaborations as warranted in accomplishing those goals.*** The OIG-recommended full-time equivalent analysis applied to a NEO Program strategic plan guided by planetary defense priorities will be highly informative in creating a program positioned to achieve NASA's planetary defense objectives.

Response: Status of the NEO Program development will be presented at the next SBAG meeting.

7. Concern for NASA Educational Efforts

Historically, NASA has taken a leading role in communicating its discoveries to the nation and in inspiring future scientists and engineers. ***SBAG is concerned about the erosion of NASA's educational efforts as evidenced by two recent events: the deletion of a \$4-million education component of the OSIRIS-REx mission, and the marginalization of the small, local programs*** that were at the core of the supplementary Education and Public Outreach (EPO) grants to Principal Investigators.

Missions provide unprecedented educational opportunities, while securing public support for NASA programs and assuring a supply of scientifically literate students and teachers. SMD's goals of enabling STEM (Science, Technology, Engineering, and Mathematics) education; improving U.S. scientific literacy; and advancing national education goals are not served by deleting an educational component of *OSIRIS-REx*'s outreach plan. Programs lost from the mission include Educators' and Students' Workshops, Graduate Student Fellowships, activities kits, internships at partner institutions, and traveling and permanent exhibits. ***SBAG supports a reinstatement of these OSIRIS-REx education programs within NASA's new educational policies and approaches.***

SBAG is also concerned with the erosion of "grass roots" EPO efforts that were served by programs such as the modest EPO supplements to research and analysis grants. Science is most effectively communicated by those producing it, partnering with education specialists. Dozens of local and grassroots EPO activities, which provide unique opportunities to reach underserved communities, have been deleted, placing their future in jeopardy. ***SBAG is concerned that the current SMD Science Education Cooperative Agreement Notice will not engage SMD scientists and will risk losing these valuable EPO activities.***

Response: SMD's restructured approach to science education is informed by recommendations from all four Decadal surveys, and the National Academy of Science's Board of Science Education. Additionally, SMD's goals are consistent with the Administration's Five-Year Strategic Plan (Co-STEM) and NASA's 2014 Strategic Plan. Most importantly, those goals lean toward an overall desired outcome for SMD Science Education of enabling scientists and engineers into the learning environment more effectively and efficiently for learners of all ages. Past efforts, while notable, are not as optimal in today's environment. Also, the small grants to PI's, while providing short-term benefits, had no overarching strategic approach and were often not sustainable beyond three years. There is a fourth goal of SMD's education restructuring: "Leveraging through Partnerships". It is precisely this goal that addresses the "grass roots" nature recognizing that all education is local and our efforts are best served by partnering with community-based organizations. We look forward to presenting results of the restructuring efforts to the future SBAG meeting in the winter time-frame.

8. Concern for Technology Development Efforts

While the funding for technology appears to be relatively flat, ***both exploration and planetary science technology development efforts are in a time of transition and significant changes have occurred that are potential causes for concern by SBAG.*** The Space Technology Mission Directorate (STMD) may have objectives for technology development counter to near-term infusion opportunities commensurate with standard (e.g. TMCO) risk tolerance. While the restart of Pu-238 production has highly valuable and broad applications across planetary science, the effects of devoting approximately one-third of NASA's PSD technology funds towards Department of Energy (DoE) infrastructure and Pu-238 production efforts on other explicit NASA technology development efforts remain to be seen. The Advanced Stirling Radioisotope Generator (ASRG) flight project and the In-Space Propulsion Technology program were both recently cancelled. The coordination and identification of needs for exploration and planetary science missions requires constant and proactive coordination between the "mission customers"

and STMD, in addition to directorate-specific resources to address the gaps. The relationships are maturing and appear to be improving, but it is unclear how technology coordination is occurring and whether appropriate resources are available for both coordination and funding identified technology gaps.

Response: Technology development to close critical capability gaps remains important. Planetary Science is working directly with STMD to identify opportunities to work together to close these capability gaps. For example, SMD and STMD are now in the process of formalizing the methodology for selecting new science-focused solicitation topics for the Game Changing Development (GCD) program and we expect this methodology to be useful for other STMD programs as well. The recent Discovery AO established a new model for infusing relatively new technologies into missions while addressing the risk tolerance concerns. These technologies include the Deep Space Atomic Clock, the Heatshield for Extreme Entry Environment Technology, the Deep Space Optical Communications system, and a number of others. More recently PSD and the GCD program made commitments to partner on 6 different space technologies that are highly relevant to future PSD missions. PSD will continue to work with STMD to address Agency and Planetary technology priorities.

NASA Advisory Council References:

2. [*NHATS: Near-Earth Object Human Space Flight Accessible Targets Study*](#)
3. [*Barbee, B., NASA Small Bodies Assessment Group Science Nuggets.*](#)
4. [*Barbee, B. W., Abell, P. A., Adamo, D. R., Alberding, C. M., Mazanek, D. D., Johnson, L. N., Yeomans, D. K., Chodas, P. W., Chamberlin, A. B., Friedensen, V. P., "The Near-Earth Object Human Space Flight Accessible Targets Study: An Ongoing Effort to Identify Near-Earth Asteroid Destinations for Human Explorers," 2013 IAA Planetary Defense Conference, Flagstaff, AZ, April 15-19, 2013.*](#)