FINDINGS FROM STEERING GROUP MEETING (AT LPSC), MARCH 20, 2013

(1) SBAG and PSS Status. The removal of AG Chairs as automatic members of the Planetary Science Subcommittee diminishes independent community input to PSS discussions and the generation of findings. Selected inclusion by PSD management of some — and not all — AG Chairs gives preferential influence to those communities.

HQ Response: The AG structure is currently under review. This finding will be used as input to that review. In the meantime, Don Yeomans is representing the small bodies community on the PSS and he should be utilized to the maximum extent in that position.

Additional Response: The planetary science AG chairs are reinstated as members of the PSS. Formal paperwork to make this official is in progress.

(2) The Need for a Dawn@Ceres Participating Scientist Program. Dawn is currently scheduled to reach Ceres in April 2015. It is important for a Dawn@Ceres Participating Scientist Program to be included by amendment to ROSES 2013 in the near-term. The Dawn@Vesta Participating Scientists have been of significant and continuing value to the Dawn mission, and based on that experience it is clear that Dawn@Ceres Participating Scientists need to be in place well before the Dawn arrival at Ceres. It is expected that the time between Amendment announcement and funding is about 15 months. Consequently, there should be no delay. Time is of the essence.

HQ Response: We believe and have demonstrated in the past (GRAIL) that a PSP can be initiated in a shorter time than 15 months. We seek to continue to provide PSP opportunities taking into account lessons learned from each experience. In the case of Dawn, a review of the implementation and results of the Dawn@Vesta must be undertaken before a Dawn@Ceres can be initiated. We are currently in the process of collecting input from the PSP program for Dawn@Vesta and will take that into account before we release a Dawn@Ceres PSP opportunity.

Additional Response: The goal for any program for additional scientific research on a mission is to increase the scientific return from, and the community participation in, the mission. After interview of participants in the Dawn at Vesta PSP and careful consideration, PSD has decided that the best way to achieve these goals is not through a Participating Scientist Program specific to "Dawn @ Ceres". Instead, a "Dawn Focused Research and Analysis Program" will be created to focus continued attention on the analysis of Vesta now that the data is mostly available in the PDS, and to perform preparatory research for and then during the Ceres campaign. The Dawn Focused Research and Analysis Program is expected to start in FY 2015 (begin solicitation in ROSES 2014) and run for 3-5 years with an annual budget of $1-2M.

CURRENT FINDINGS IN NEED OF HQ RESPONSE

FINDINGS FROM STEERING GROUP, NOVEMBER 22, 2013

(1) Senior Review of the R&A Restructuring Plan. The SBAG Steering Committee finds that a Senior Review, as recommended in the 2011 Planetary Science Subcommittee report, *Assessment of the NASA Planetary Science Division's Mission-Enabling Activities*, prior to implementation would promote a successful restructuring of the Planetary Science Division's Research and Analysis Program. The scope of this review should also be informed by the questions raised by the planetary community with regards to the reorganization.

Response: *This will be addressed in presentations by Jim Green and Jon Rall on Thursday.*

FINDINGS FROM SBAG 9, JULY 10–11, 2013

(1) Decadal Survey Compliance. The planetary decadal survey states the importance of a balanced portfolio of mission classes when the budget is adequate to support this. The decadal survey also makes clear recommendations for how programs should be prioritized if fiscal conditions are worse than anticipated: "It is also possible that the budget picture could turn out to be less favorable than the committee has assumed. This could happen, for example, if the actual budget for solar system exploration is smaller than the projections the committee used. **If cuts to the program are necessary, the committee recommends that the first approach should be descoping or delaying Flagship missions. Changes to the New Frontiers or Discovery programs should be considered only if adjustments to Flagship missions cannot solve the problem. And high priority should be placed on preserving funding for Research and Analysis programs and for technology development**." (Bolded in the report). The focus on flagship missions in the current fiscal environment at the expense of restoring the Discovery cadence, and the continuing funding stress experienced by the Research and Analysis programs, is inconsistent with the decadal survey recommendations.

Response: This will be addressed in detail in Jim Green's presentation Thursday. However, examination of the FY2014 Planetary Science budget will show that emphasis is being place on the competed programs of Discovery and New Frontiers, and the R&A program, at the expense of Mars and Outer Planets.

(2) Travel Restrictions. The current NASA and government restrictions on travel and attendance at workshops, conferences, science team meetings, etc. is severely impacting the ability of the planetary science and engineering communities to conduct their work. The increased level of oversight forces a disproportionate amount of time and effort by agency personnel to comply with the necessary waivers and forms to attend such functions at the expense of focusing on NASA goals and objectives. In addition, these travel restrictions undermine the effective planning of domestic and international meetings by suppressing attendance in a manner that is difficult to predict, limiting vital interactions of individuals working on projects and missions relevant to NASA interests.

Response: The new budget deal passed by Congress should allow the restrictions placed on travel by the previous "Sequestration budget" to be reassessed and relaxed. As these budgets are passed into appropriations, we expect to see more reasonable implementation of travel policies.

(3) Planetary Defense Office. NASA recently announced a Grand Challenge to protect the Earth's population from extraterrestrial impacts. This involves many aspects of detection, characterization, and mitigation of potentially hazardous objects (asteroids and comets). The SBAG notes that currently there is only one expert at NASA HQ who is conversant with the issues of planetary defense. Given that emphasis will now be placed on the Grand Challenge and that this effort will involve multiple NASA directorates (SMD, HEOMD, and STMD), US agencies (DHS, FEMA, DoD, DoE, State, etc.) and international partners, the SBAG finds that establishing a Planetary Defense Office with enough individuals with required skills and expertise would help NASA to more effectively interface with these diverse entities and provide the expertise required to implement the Grand Challenge.

Response: SMD/PSD is looking at options to pursue the establishment of a "Planetary Defense Office" within the expanded resources planned for the NEO Program. Plans are still in formulation, but expect to hear about them in the near future, certainly by the next SBAG meeting.

(4) NEO Survey Telescope. NASA's Asteroid Initiative combines aspects of human exploration, science, resource utilization, and planetary defense. A NEO survey telescope is a foundational asset that will significantly enhance the ability of NASA to properly evaluate its human exploration objectives, perform valuable science, identify potential candidates for in situ resource utilization, and achieve its Grand Challenge with respect to defending Earth's populations from hazardous asteroids. The SBAG reiterates its previous findings that support the importance of a space-based survey telescope to NASA SMD and HEOMD goals and objectives. The new Asteroid Initiative only serves to highlight the importance of this foundational asset. Any reliance solely upon outside entities to fund, build, and operate such an asset, whose success is beyond NASA control, places NASA's goals and objectives at risk. In addition, SBAG finds that making such an asset a NASA priority would be more consistent with the agency's acceptance and implementation of its Grand Challenge for planetary defense.

Response: We agree with the value a space-based NEO survey telescope would offer, but in the current fiscal environment direct pursuit of such a stand-alone mission would necessarily come at the expense of other already confirmed priorities. We continue to assess the viability of external partnerships to accomplish these objectives and evolve our NEO Program and commitments as those assessments guide us. We are also pursuing enhancement of existing assets and new concepts which have the potential for high return but still lie within the somewhat expanded fiscal boundaries planned for the NEO Program.

(5) Comet ISON Campaign. Comet ISON presents a rare opportunity to study a potentially bright, sun-grazing comet for many months prior to and possibly after perihelion. The SBAG finds that the willing coordination across NASA's Science Mission Directorate to support the unique observational campaign through the use of spacecraft assets, ground-based facilities, and the rapid response of an airborne balloon platform is proceeding and should help to maximize the scientific return from this uncommon event.

Response: Although a post-perihelion campaign would have been desirable, the Comet ISON Observation Campaign has been incredibly successful for the truly interplanetary comprehensive

study of this comet from discovery to its solar demise. This was an historic campaign by which millions of people saw the comet through NASA's eyes.

(6) Impactor for Surface and Interior Science (ISIS) Mission. JPL is leading a study for a non-competed mission to be co-manifested with the Mars InSight spacecraft. ISIS will impact at hypervelocity speed the OSIRIS-REx target asteroid Bennu, creating a crater and modifying the orbit of that object as a planetary defense demonstration. OSIRIS-REx will be used to gather detailed information about the impact, ejecta, the crater formed, and the effect on asteroid motion. Significant savings are realized in launch vehicle costs (by the co-manifest) and use of OSIRIS-REx (mitigating the need for a second spacecraft component to study the impact results). While total mission cost is estimated at less than $200M, such cost estimates are historically very uncertain for non-competed missions in comparison to the rigorous cost evaluations applied to competed missions. While studying a full-scale hypervelocity impact event for the first time and testing a basic planetary defense scenario are important, the benefit of ISIS has not been determined to exceed those gained from Planetary Science Division funds being used to support the priorities outlined in the Decadal Survey, such as a regular cadence of competed Discovery missions and a robust R&A program.

Response: Although ISIS is an innovative and potentially cost effective concept that leverages the large space-lift margin or observational capabilities of two other confirmed planetary science missions to perform an additional science mission and asteroid deflection demonstration, PSD has determined the current fiscal environment does not allow the Agency to pursue it at this time. The concept study will be wrapped up into a comprehensive information package available to kickstart a future opportunity should it arise.

(7) Deep Impact. The extended Deep Impact mission is providing important and unique observations of comets, including simultaneous, time resolved observations of CO, CO2 and water. A number of important targets are available to Deep Impact for future observations including C/2012 S1 ISON, C/2013 A1 Siding Spring (making an extremely close approach to Mars and will be likely observed by Mars orbit and surface assets), and the highly evolved comet 2P/Encke.

Response: The very regrettable loss of the Deep Impact (DI) spacecraft last August, traced to an overflow of a time-conversion calculation exceeding its limits in the fault protection software which in turn left DI in a configuration that allowed its batteries to drain between planned contacts, unfortunately terminated these extended mission opportunities. However, significant observations of C/Garradd (2009 P1) and limited observations of C/ISON (2012 S1) were obtained.

(8) Asteroid Redirect & Return Mission (ARRM).

(a) ***Planetary science.*** While the SBAG committee finds that there is great scientific value in sample return missions from asteroids such as OSIRIS-Rex, ARRM has been defined as not being a science mission, nor is it a cost effective way to address science goals achievable through sample return. Candidate ARRM targets are limited and not well identified or characterized. Robotic sample return missions can return higher science value samples by selecting from a larger population of asteroids, and can be accomplished at significantly less cost (as evidenced by the OSIRIS-REx mission). Support of ARRM with planetary science resources is not appropriate.

Response: The mission objectives of the overall Asteroid Redirect Mission (ARM) are evolving as concept development matures. NASA has chartered a Robotic Concept Integration Team to assess both the internal NASA study concepts and ideas from the Asteroid Initiative Request for Information released in June 2013. Below are the preliminary ARM mission objectives, which are also being used by this team for alternative robotic mission concept comparison.

Primary Objectives

- Human Exploration to an Asteroid in the mid-2020's that Prepares for Future Exploration
  - Initial use of systems and components, operational experience beyond LEO, crew risk reduction
- Technology Demonstration: Advanced Solar Electric Propulsion
  - High power, long lifetime
  - Enables future deep-space human exploration and enables multiple applications for Nation's aerospace community
- Enhanced Detection and Observation of Near Earth Asteroids for Planetary Defense

Secondary Objectives

- Asteroid Deflection Demonstration/Proof of Concept for Planetary Defense
- [Small-body planetary] Science
- Partnership Opportunities (International and Commercial)

With the exception of support for viable target identification and characterization by the Near Earth Object Observation Program, planetary science resources are not being utilized.

(b) ***Searching for Potentially Hazardous Objects.*** There is great value in enhancing NASA's capabilities in small body discovery and characterization. The enhancement to NEO discovery and characterization efforts proposed as part of the Asteroid Initiative would be greater still if it were to be continued for more than one year. The discovery of smaller asteroids (i.e. potential ARRM targets) is an expected byproduct of this campaign expansion. There is concern that a focus on acquiring ARRM targets, and ARRM itself, can come at the expense of the detection rate and follow-up observations of 140m and larger asteroids.

Response: The detection strategy for NASA's Near Earth Object Observation (NEOO) Program continues to be to search for potentially hazardous objects. The discovery of asteroids smaller than considered "hazardous" has been and is expected to continue to be a byproduct of the Program, but the campaign is to be expanded as part of NASA's Asteroid Initiative. This expanded program is planned to continue for the foreseeable budget horizon. The estimated increase in detection rate of smaller asteroids is based on the NEOO Program observation strategy for PHA's, including speed and depth of sky coverage and coordination for follow-up observations. In fact, the challenge of rapid follow-up and characterization of smaller asteroids provides for excellent testing of our techniques and response timelines should a true impact hazard be detected.

(c) ***Relevance of ARRM to Planetary Defense.*** Given the size of the ARRM target (< 10m), ARRM has limited relevance to planetary defense. Retrieving a NEO this small only tangentially benefits planetary defense, as the stated target body may not be representative of the larger, hazardous bodies.

Response: The Robotic Concept Integration Team is assessing alternative mission concepts using figures of merit derived from the overall ARM mission objectives listed in response to finding 8(a), as well as programmatic feasibility. We expect completion of this analysis in April 2014. The ARM mission objectives include the primary mission objective "Enhanced Detection and Observation of Near Earth Asteroids for Planetary Defense". This has direct relevance to planetary defense. The secondary objective "Asteroid Deflection Demonstration/Proof of Concept for Planetary Defense" could be one of the distinguishing factors in this comparative assessment of mission concept options.

(d) ***Mission Objectives.*** ARRM does not have clearly defined objectives, which makes it premature to commit significant resources to its development. The mission description/objectives fidelity appears to be lower than a "selectable" Discovery mission. NASA statements that deployment of a solar power array is sufficient for mission success, but capture and return of an asteroid to lunar orbit is not, brings into serious question the importance of investment in the asteroid capture and return portion of the mission plan. Firm baseline and minimum requirements must be set in order to assess the cost-effectiveness of achieving those requirements and to assess the value of the mission with respect to exploration goals. The Mars 2020 Science Definition Team released a 150+ page document outlining the mission objectives and merits. There is little comparable justification provided with respect to ARRM, yet ARRM is expected (by some estimates) to be a higher cost mission. The SBAG finds that formation of an independent Mission Definition Team (MDT) prior to commitment of significant resources and mission confirmation would allow for community participation in the relevant fields for the mission (including small body science) and provide a non-advocate peer review of the expected benefit if mission success criteria are met. In place of science objectives and traceability, the strategic knowledge gaps (for HEOMD) and technology roadmap (for STMD) can be used to provide traceability necessary for successful mission implementation.

Response: ARM mission objectives are being clarified as part of pre-formulation. NASA leaders shared with the community their early thinking on potential descope options for the robotic mission in an emphasis of the importance of NASA's need to balance technical and cost

objectives in this initiative. As part of pre-formulation, NASA has chartered a Robotic Concept Integration Team (RCIT) to assess mission concept options, including ideas provided in response to the Asteroid Initiative Request for Information released in June. Figures of merit for the RCIT assessment are derived from the preliminary overall ARM mission objectives listed in response to finding 8(a) and ground rules for programmatic feasibility. The RCIT assessment will inform the determination of robotic mission requirements and descope options. NASA is also requesting the SBAG to provide assessment in key small body science areas to inform the RCIT assessment. We look forward to the SBAG's participation in this important activity. Meanwhile, leveraging on-going activities allows NASA to progress critical areas immediately, such as asteroid identification and solar electric propulsion technology development. Risk reduction can be pursued which will have independent merit, but will also be relevant to the selected concept.

(e) ***Target issues*****.** The population and physical characteristics of low delta-velocity targets having diameters less than 10m are poorly constrained by observations. Because of their intrinsic faintness and long synodic periods, characterization must be undertaken over a short time period primarily during the discovery apparition. Such small objects may be rapidly rotating rubble piles, which could be hazardous to spacecraft during interactions with the target object. The mission must be designed to account for these large uncertainties in the properties of potential targets, which could greatly increase the complexity and cost of the mission. It is impractical to begin the planning and design of any mission to capture such an asteroid in the absence of a pre-existing study on the population and the physical characteristics of its members. Such a study would necessarily take a number of years if commenced now, assuming it is adequately resourced. A robust characterization campaign is imperative. Target characterization will be challenging and is expected to be of the utmost importance to mission success.

Response: The HQ ARM Steering Committee is well aware of the current deficiencies in our understanding of the very small body population, and the challenges for identification and characterization of viable targets. That is one reason why alternative concepts for accomplishing the mission are still in study. However, we disagree that we must have a scientific understanding of the entire population before such a mission can commence. Rather, we need only identification and adequate characterization of a sufficient number of viable candidate targets for the selected mission concept. Several candidates have already been identified for concept alternatives as proof of existence for such objects, although we know adequate characterization is still a challenge. We understand that we may not know everything one might like about a candidate target before launching the mission – rarely do we ever, especially for planetary missions - but these factors will be a recognized element of the mission risk strategy. And what we learn in this endeavor can only increase our understanding of this population of small objects very near the Earth.

(f) ***Schedule risks*****.** Because of long-synodic periods, a missed launch window will not be recoverable for the same ARRM target. Therefore, multiple targets meeting orbital and physical characteristic requirements and having appropriately phased launch windows will need to be discovered. Given the poor knowledge of the population of these objects, this is a significant mission risk. The stated schedule for the ARRM, which posits funding of a ~$100M study in FY14 and launch in 2017, is unrealistic.

Response: We agree it would be desirable to have multiple potential targets identified for this mission. The observation segment has already set out to do that. The potential schedule of the asteroid identification, redirection, and crewed exploration activities presented by NASA in the June timeframe showed a potential robotic redirect mission launch in 2017, with the caveat that the timeline was notional. The schedule alignment strategy has evolved to a notional timeline which shows a potential robotic mission launch in 2018. NASA has not committed to a launch date for this mission.

(g) ***Cost risks.*** As a mission that serves as a technology and operations demonstrator, the management approach and acceptance of risk needs to be better defined to determine the feasibility of the aggressive schedule and its impact on cost and mission success criteria. The full-cost target, funding profile, and funding sources are not provided and limit any credible assessment of the schedule and mission cost to the various directorates. Lack of clarity of both resources available and resources required limits any determination of mission value, merit, and/or whether the mission is the most efficient use of available resources to achieve NASA's objectives.

Response: ARM mission objectives and cost and schedule goals are being clarified as part of the current pre-formulation phase. Management approach and acceptance of risk will also be clarified. We are only at the stage now where we are looking at the specifics of concept options and how these compare to stated objectives. We are also assessing the "deltas" that would be needed in our budgets to implement this mission as compared to our on-going work elements, such as for a SEP tech demo only and early SLS and Orion flights. Meanwhile, leveraging on-going activities allows NASA to progress critical risk reduction areas immediately, such as the asteroid identification and solar electric propulsion technology development.