



Human Exploration Workshop on the Global Exploration Roadmap

Workshop Notes

Introduction

NASA conducted the Human Exploration Community Workshop on the International Space Exploration Coordination Group (ISECG) Global Exploration Roadmap (GER) in San Diego, CA from November 14-16, 2011. There were over 100 people in attendance, and 630 unique participants via the webcast. The three main objectives articulated by the chair, Kathy Laurini, were achieved:

1. Share the details of the GER mission scenarios and the international drivers which influenced them.
2. Discuss the scenarios with the broader community, seeking innovative ideas which improve them. The scenarios are considered as technically feasible and programmatically implementable references which can inform decision making of participating agencies.
3. Discuss innovative ideas which build on the ISS and initial exploration capabilities in order to enable the GER mission scenarios.

The workshop discussion was organized in 3 main panels. Each is summarized below. Panel 4 provided the opportunity for panel chairs to review the observations, findings and recommendations of the 3 main panels. These summaries and all presentations are posted at <http://www.nasa.gov/exploration/about/isecg/ger-workshop.html>. At the conclusion of the workshop, Kathy Laurini noted the topics she considered as possible influences on the international discussions leading to the GER 2nd iteration. These insights are provided at the end of these notes.

The workshop followed the September 2011 release of the GER. The workshop format was chosen in order to allow open and informed discussion of each of GER mission scenario, while reviewing relevant exploration mission scenario work of external stakeholders which might inform considerations for improving the scenarios. It is hoped that the presentations and discussions were useful in communicating the challenges associated with international human exploration missions. The IAF/AIAA Global Space Exploration Conference, May 22-24, 2012 provides the opportunity to continue the dialog.

A very brief summary of each presentation is presented below to facilitate identification of topics you may wish to follow up on.

Opening Presentations

The workshop began with presentations describing exploration planning work at NASA and how this informed NASA's participation in the ISECG. John Olson described the exploration context, how NASA's capability driven approach enables future missions to Mars, near Earth asteroids and the Moon. Chris Culbert, chair of NASA's Human spaceflight Architecture Team (HAT), described the role of HAT and gave some insights into architecture analyses performed to date.

Kathy Laurini introduced the GER and the goals, objectives and strategic drivers that influenced the mission scenarios. She explained the importance of identifying technically feasible and



programmatically implementable approaches (in an international context) to meeting agency shared and individual goals and objectives.

Dan Dumbacher gave an overview of the 3 ongoing exploration programs within the Human Exploration and Operations Mission Directorate: the Space Launch System (SLS), the Multipurpose Crew Vehicle (MPCV), and the 21st Century Launch Complex. He explained the status of configuration definition and development status of each program, including the NASA plan for initial flight tests.

Sam Scimemi reviewed the outcome of a recent workshop on human habitability and operations in Cis-lunar space where possible benefits and challenges of human operations at Earth-Moon LaGrange points were discussed.

The opening session of the workshop included perspectives on space exploration from JAXA and CSA. While the workshop was not intended to communicate the status of all ISECG participating agencies, JAXA and CSA indicated they would benefit from using this opportunity to reach their broader stakeholder community and therefore, they played a prominent role in the workshop.

Panel 1: Asteroid Next

Bret Drake (NASA) and Cheryl Reed (APL) chaired Panel 1. Panel members were Hitoshi Kuninaka (JAXA), Randy Sweet (Lockheed Martin), Mike Raftery (Boeing), Steve Wright (Booz-Allen Hamilton), Paul Abell (NASA), and Roland Martinez (NASA). Panel members were asked to review the ISECG Asteroid Next mission scenario and other scenario options presented, in order to identify areas of consensus and areas worthy of further study.

Roland Martinez (NASA) walked through the details of the GER "Asteroid Next" mission scenario. He provided some additional detail supporting the summary contained in the GER. The scenario builds on the ISS in order to demonstrate necessary technologies and capabilities before deploying the deep space habitat to an Earth-Moon Lagrange point. The early deployment is intended to provide the chance to demonstrate the reliability of key systems necessary to travel in deep space and learn to live without a regular supply chain from earth and fast return abort options. The early deployment of the deep space habitat also provides astronaut opportunities for participating nations, while building our collective beyond LEO experience base. After 5 years, the deep space habitat joins other capabilities for the trip to a near Earth asteroid. Two such asteroid missions are proposed.

Cheryl Reed (APL) summarized the major results of an important community workshop held in March 2011, the Target NEA Workshop. The proceedings of this workshop are available at <http://targetneo.jhuapl.edu/>. The main takeaway influencing planning of human exploration scenarios to near Earth asteroids is the critical need to find additional targets which requires the early deployment of a space-based telescope survey mission.

Josh Hopkins (LMCO) presented a concept for short, simple missions to asteroids. The intent is to identify enough targets to accomplish a cadence of shorter missions as part of a stepping stone approach to enabling Mars missions. This presentation noted the need for a space-based survey mission and the need better characterize known targets. It also questioned the need for the "Space Exploration Vehicle (SEV)". Is the benefit worth the cost? What are the requirements for human interaction with the asteroid? Do they need to physically interact with it, or can they accomplish objectives from a distance, via tele-presence? Paul Abell described the



benefits of a combined approach of tele-presence and direct exploration of the asteroid by the crew.

Michael Elsperman (Boeing) presented another asteroid mission concept using a platform at Earth-Moon L2 (EML2) to build up the necessary capabilities for the asteroid mission. The platform was considered part of the ISS Program, controlled and managed by the ISS Program. The scenario made use of electric propulsion capabilities where space transit times were not critical drivers to the exploration systems. This presentation triggered considerable discussion on the benefits of early deployment of habitation capability to an Earth-Moon Lagrange point and the recognition that such an intermediate step towards beyond LEO mission scenarios must be done in an affordable manner by interested partner agencies. The presentation also noted the need for identifying additional asteroid targets.

Hitoshi Kuninaka (JAXA) presented an overview of JAXA's Hayabusa I and II missions. Mr. Kuninaka demonstrated how both missions could provide important precursor information to planning an eventual human mission to a near-Earth asteroid.

The panel concluded by panelists summarizing their initial takeaways from the discussion. The panelists liked the GER mission scenario and noted several key points which should be considered in any potential update:

- More data on asteroid targets is needed. The proposed survey efforts are very important if we are to effectively plan human missions. Without such information, demonstrating we can mount a meaningful and affordable human mission is difficult.
- Deployment of a small, man-tended infrastructure at EML1/2 represents a good step to demonstrating the capabilities necessary for asteroid missions. It was also noted that this capability could enable some lunar exploration objectives, as well. The panel felt it is worth evaluating whether such a capability could be provided in a cost effective manner.
- A community understanding of the role of chemical propulsion vs. advanced propulsion such as solar electric or nuclear thermal propulsion would be helpful.
- Does the crew need to touch the asteroid or is tele-presence adequate? What will humans do at the asteroid? And lastly, how does the NEA exploration strategy (tele-presence versus direct crew interaction) impact the type of asteroid characterization required?
- Robotic precursors were considered important, but more work should be done to determine how many missions are considered essential.
- ISS can be used for demonstrating key aspects of safe human interaction with asteroids.
- The role of Phobos and Deimos in an exploration scenario should be discussed within the international community.
- The ISECG work on leveraging technology investments and identifying knowledge gaps associated with each exploration destination is important.
- A system study on the radiation challenges should be conducted. It should include the current state of knowledge on radiation risks, as well as early warning and response capabilities.

Panel 2: Moon Next

Panel 2 was chaired by Cheryl Reed (APL) and Roland Martinez (NASA). Panel members were Naoki Sato (JAXA), Randy Sweet (Lockheed Martin), Mike Raftery (Boeing), Steve Wright



(Booz-Allen Hamilton), Brian Rishikof (Odyssey Space Research), Mike Wargo (NASA) and Jean Claude Piedboeuf (CSA). Panel members were asked to review the ISECG Moon Next mission scenario and other scenario options presented, in order to identify areas of consensus and areas worthy of further study.

Roland Martinez (NASA) walked through the details of the GER “Moon Next” mission scenario. He provided some additional detail supporting the summary contained in the GER. The scenario builds on the ISS in order to demonstrate necessary technologies and capabilities before conducting missions to the lunar surface. The scenario begins with the availability of two classes of cargo landers. One is smaller, capable of landing 1t of payload on the lunar surface. Such a lander can deploy early robots and serve as a logistics supply to eventual human missions. There is a larger lander, which can place 8t on the lunar surface. This lander becomes the descent stage of a human lunar lander which follows 5 years later. The scenario heavily relies on the human robotic partnership to explore the lunar South Pole region, while demonstrating surface exploration capabilities and techniques needed for eventual Mars missions.

Ben Donahue (Boeing) presented a Moon mission concept that uses a platform at EML2. The platform could also support asteroid missions. The concept featured a LOX/Methane reusable lunar lander, triggering a panel discussion on the challenges and benefits of using LOX/Methane in this application. Ben also described the opportunity for controlling lunar surface robots from an EML2 platform. The panel recognized the potential of such a tele-presence capability. The chair of the Lunar Exploration Analysis Group (LEAG), Chip Shearer, described some work that LEAG is currently doing to help inform the dialog on the benefits and challenges of operating robots from EML2. More information on the LEAG and its lunar exploration roadmap can be found at <http://www.lpi.usra.edu/leag/>.

Scott Norris (LMCO) described a concept for step wise access to the lunar surface by establishing small infrastructure at EML2. Scott demonstrated how such an infrastructure could be assembled by international contributions in a low cost manner, based on existing capabilities. Such an outpost would enable far-side lunar science, as well as expanded lunar science via tele-presence.

Naoki Sato (JAXA) presented a lunar design reference mission that included SLS and smaller launchers and in-space stages to provide dissimilar redundancy for delivering cargo to the lunar surface.

Jean Claude Piedboeuf (CSA) emphasized the importance of considering real benefits of space exploration when defining and implementing a lunar exploration campaign. Workshop attendees agreed that this was crucial to obtaining and maintaining stakeholder support for space exploration.

Iain Christie (Neptec) presented work underway with NASA on a proposed payload that will take the initial steps at demonstrating lunar In-situ Resource Utilization (ISRU) technologies. Workshop participants felt that the proposed payload, called RESOLVE, was an important step towards answering questions related to the availability and usability of lunar water and O₂ in the lunar regolith.

David Gump (Astrobotic) presented the status of the Astrobotic robotic lander, currently competing for the Google LunarX prize. The presentation stimulated a dialog on commercial



opportunities regarding lunar exploration. Many workshop participants felt that more opportunities for commercial activities existed in the Moon Next scenario when compared with the Asteroid Next scenario.

The panel concluded by panelists summarizing their initial takeaways from the discussion. The panelists liked the GER mission scenario and noted several key points which should be considered in any potential update:

- The proposed deployment of a small, man-tended EML1/2 infrastructure was also considered an interesting step in preparing for the Moon Next scenario. The value of such an infrastructure compared to the ISS should be understood.
- The GER Moon Next scenario was perceived as expensive, given the amount of elements delivered to the lunar surface.
- Operating robotic assets on the lunar surface from a LaGrange point, i.e. tele-presence was considered interesting and worth further evaluation in order to identify specific activities (i.e. best science) which might be enabled.
- Identification of the specific science priorities was considered important to inform scenario evolution, including knowledge gaps which can be filled by robotic precursor missions.

Panel 3: Near-Term Implementation Plans, Ideas and Strategies

Doug Craig (NASA) chaired panel 3. Panel members were Naoki Sato (JAXA), Jean-Claude Piefboeuf (CSA), Mike Raftery (Boeing), Randy Sweet (Lockheed Martin), Dave Hornyak (NASA), Steve Stich (NASA), and Sam Scimemi (NASA). Panel members were asked to think about near-term capabilities that are available or attainable as enablers for either of the GER mission scenarios.

Dave Hornyak (NASA) summarized the work of the ISS program in identifying technologies and capabilities that would benefit from advancement on the ISS. The ISS Program established a team about a year ago, and the results of this work were summarized.

Pat Troutman (NASA) summarized work ongoing within the Human Exploration and Operations Mission Directorate on small steps that are considered interesting to prepare for exploration. In particular, the concept for an ISS based "Exploration Test Module (ETM)" was briefly discussed.

Marianne Bobskill (NASA) presented the work of the HAT Cis-Lunar destination team in identifying the tasks that could be performed at a small, man-tended infrastructure deployed at EML1/2.

Larry Price (LMCO) described the MPCV/Orion development status, including early mission concepts.

Mike Raftery (Boeing) presented a concept for building a small exploration platform at ISS in order to demonstrate capabilities and readiness to deliver the infrastructure beyond LEO. The platform, called the ISS-Exploration Platform, would be considered an extension of the ISS Program.

Jay Ingram (Bigelow) presented a status of inflatable structures and habitats in work at Bigelow Aerospace.



Naoki Sato (JAXA) presented the summary of a JAXA study on the GER concept of an Exploration Test Module (ETM). JAXA systematically identified technologies which would benefit from such a platform (vs. other opportunities). A concept for the ETM was also presented.

The panel concluded by panelists summarizing their initial takeaways from the discussion. The panelists noted several key points that should be considered in any potential GER scenario updates:

- The need to make sure any future direction recognizes and accommodates stakeholder needs in order to ensure long-term commitment.
- Early flight opportunities to prepare for exploration are important and should be mindful of the importance of maintaining a cadence of accomplishments and astronaut flights.
- EML1/2 seems a good location for a near-term capability that accommodates multiple future paths.
- Any near-term exploration activities, such as a small, man-tended platform at EML1/2, should be based on evolving current capabilities, using a systematic approach to identify the priorities related to enabling follow-on exploration goals, objectives and missions.
- Further work on the options for moving hardware from LEO to EML1/2 was considered important.
- The ISECG work on leveraging technology investments was considered an important activity.

Workshop Wrap-Up and Summary

Workshop chair, Kathy Laurini, provided some insight into her major takeaways which would likely be interesting discussion topics with international partners participating in ISECG. She felt that the 2 possible pathways presented in the GER (Asteroid Next, Moon Next) were supported by workshop discussion. She shared results from a previous discussion within ISECG regarding designation of EML1/2 as an exploration destination, per se. Notably, that ISECG did not consider LaGrange points as an exploration destination, but saw them as an interesting intermediate location which may enable sustainable exploration of near Earth asteroids, and potentially the Moon.

Regarding the Asteroid Next scenario:

- The GER deployment of a deep space habitat (DSH) in 2025 was seen as far in the future, and perhaps an early deployment of a small, man-tended infrastructure at EML1/2 could be an important step towards a fully functional DSH. Concepts for realizing this capability in an affordable manner were proposed, but further work must be done before these ideas can be considered interesting.
- Efforts to understand the value of an infrastructure at EML1/2 are essential. What, specifically, can we do there to prepare for exploration of future destinations? What, specifically, can we do to achieve lunar exploration goals and objectives?
- An asteroid survey mission is essential. Without it, it is difficult to develop a strategy for human exploration of these important targets.
- The international community should reach a common understanding of the benefits and challenges of missions to Phobos or Deimos, as preparatory steps towards the Martian surface.



- Tele-presence concepts are worth further study, focusing on the specific tasks that can be accomplished from EML1/2 while demonstrating the habitation capabilities necessary to undertake deep space exploration missions.

Regarding the Moon Next scenario:

- There was a perception that the GER scenario involves too many surface assets and therefore would be unaffordable. Is there a way to reduce the elements and meet agency objectives?
- Early deployment of robotics and the establishment of a meaningful human/robotic partnership in exploring the moon were seen as a very strong point in the scenario. However, more work should be done to ensure that the scenario meets established science objectives such as those contained in the recent US Planetary Science Decadal Survey or the LEAG roadmap.
- Commercial opportunities associated with lunar exploration were seen as very promising, and the GER could do more to show that ISECG recognizes this and wishes to enable effective opportunities.
- It is worth taking a look at the benefits and challenges of a re-usable lunar lander. Perhaps an infrastructure at EML1/2 could make this more interesting and globally affordable.
- Using local resources is widely considered an element of a sustainable space exploration program, however there are many challenges that must be assessed before agencies can take concrete steps to use ISRU in development of exploration architectures. The GER should address the challenges and promise of ISRU to some extent. In addition, the proposed RESOLVE payload seems mature enough, has international interest, and is seen as a good step towards answering key questions regarding resource availability and usability.