

NASA Community Workshop on the Global Exploration Roadmap

April 10-11, 2014

Workshop Notes

Introduction

NASA conducted a Community Workshop on the International Space Exploration Coordination Group (ISECG) Global Exploration Roadmap (GER) at the John's Hopkins Applied Physics Laboratory (APL) in Greenbelt, MD from April 10-11, 2014. The main purpose of the workshop was to provide an opportunity for community engagement on the long-term international human space exploration strategy reflected in the GER and which may inform GER update. There were 120 people in attendance at APL and an additional 170 remote participants.

The workshop was organized around the three near-term mission themes which are conceptually defined in the GER. Each theme was addressed in a particular session, and three follow-on sessions contributed to strengthening specific concepts associated with each of the near-term missions.

Presentation materials and a video archive of the workshop can be found at <http://www.nasa.gov/gerworkshop>. At the conclusion of the workshop, workshop chair Kathy Laurini summarized several key takeaways, which will help influence planning for NASA's continued engagement with international partners advancing the human exploration roadmap.

Opening Presentations

The workshop began with presentations setting the context for the sessions to follow. Kathy Laurini introduced the GER as an international strategy which assumes several space agencies will play critical path roles on future Mars missions. In order to prepare for these roles, the roadmap expands on missions in the lunar vicinity and on the lunar surface—missions which allow agencies to test their evolved capabilities and operations techniques, and learn to manage exploration risks. They also provide the opportunity for astronauts to advance the broader set of exploration objectives, especially science objectives.

NASA's Associate Administrator for Human Exploration and Operations, Bill Gerstenmaier, talked about NASA's long-term strategy and the budget outlook. He stressed the importance of pursuing affordable approaches to exploration and the importance of international cooperation.

NASA's Chief Scientist, Ellen Stofan, briefed the science of exploration with an overview of the rich body of existing solar system knowledge and identified some of the key questions driving planetary science today. These basic scientific questions are also well suited to guide human exploration planning work. Questions related to whether life does or did exist on Mars are complex and the sustained presence of humans, including scientist astronauts, will be important to finding these answers.

To set the stage for the follow-on sessions, Roland Martinez gave an overview of the GER mission scenario. He described each of the mission themes, the capabilities that enable them, and the contributions of key capabilities for future missions to Mars.

Session 1: Asteroid Redirect Mission: Extensibility to Future Missions

Session 1 was chaired by Steve Stich (NASA). In addition to Mr. Stich, speakers were Kurt Hack (NASA), Joe Cassady (Aerojet Rocketdyne), Andy Cheng (APL), Lou Friedman, and Michele Gates (NASA).

Steve Stich described the work he has been leading to define the human segment of the Asteroid Redirect Mission and to ensure that the mission definition maximizes the contribution of the mission (or missions) toward preparing a step-wise path to Mars. One step on this path, the 'proving ground', is an approach that leverages the cis-lunar environment as an analog for the Mars environment and asserts that the Asteroid Redirect Mission will prove several capabilities needed for human missions to the Mars vicinity, including advanced solar electric propulsion, deep-space extravehicular activity, and automated rendezvous and docking. He showed a video describing the current concepts for the human segment of the mission. Mr. Stich highlighted some of the Asteroid Redirect Mission investments include fundamental capabilities needed in execution of future exploration missions.

Kurt Hack described the work NASA is doing to prepare the Solar Electric Propulsion (SEP) system for the ARM mission and the approach for advancing this capability to enable future missions. The reference SEP system for the ARM mission is a 40kw system, using 3 strings with 13kW thruster strings. The NASA Space Technology Mission Directorate is investing in SEP system components (solar arrays, engines, etc) that are evolvable to enable near-term GER and longer term exploration cargo missions. Target performance values are 100-250 Kw systems for Mars mission applications. SEP systems deliver low thrust but very long duration propulsion and can be used in the GER lunar vicinity missions to efficiently shuttle cargo (e.g. habitable infrastructure, propellant, inert cargo, etc.) and deliver or pre-emptively place logistics supplies for subsequent human missions.

Joe Cassady shared a historical perspective on cargo shipping services over the last 400 years as global commerce expanded on Earth. He used this to draw parallels to the future of human expansion into space and the promise of SEP in supporting the shipment of cargo around the solar system in the future. He argued that a networked and interconnected approach to moving cargo would be a huge enabler to pioneering in the solar system – especially when done in an international context. Mr. Cassady emphasized that affordable approaches were needed for exploration and that a modal SEP cargo delivery network will be enabled by international standards and should influence space architectures.

Andy Cheng gave an introduction to the population of near-Earth objects (asteroids, comets) and some insights into their potential for resources, which may be useable by future space explorers and planetary pioneers. He described the physical properties of the range of asteroids as we understand today, and expanded on the challenges of assessing the potential for using any resources.. Mr. Cheng summarized by saying that known accessible objects are very small in size and need to be characterized by precursor robotic missions prior to making a decision to send humans with the intention to harvest potential resources.

Lou Friedman summarized the preliminary findings of the Keck Institute for Space Studies (KISS) workshop on the Application for Asteroid Redirection Technologies. This workshop was conducted at the California Institute of Technology from 7-9 April, 2014, just prior to the NASA Community Workshop on the GER. Attendees at the KISS workshop determined that pursuing the Asteroid Redirect Mission provides important advances in areas such as SEP, deep space guidance and navigation, detection and characterization of asteroids, and planetary defense—as well as scientific study of asteroids and the utilization of material resources found in space.

Michele Gates gave an update on program formulation status and future milestones associated with the Asteroid Redirect Mission. She provided an overview of NEO observation activities to date, a summary

of the two capture concepts under investigation, and objectives of the Asteroid Redirect Mission Broad Agency Announcement released in March 2013.

Session 2: Extended Duration Missions in the Lunar Vicinity

Session 2 was chaired by Kathy Laurini (NASA). Speakers were Josh Hopkins (Lockheed Martin), Carl Walz (Orbital), Mike Gold (Bigelow Aerospace), Greg Schmidt (SSERVI), and Jack Burns (U of Colorado).

Kathy Laurini started the session by stating that the international partners see extended duration missions in the lunar vicinity as an important step to Mars and that these missions are enabled by the deployment of a deep space habitat. She pointed out that the specific location of the habitat (distant retrograde orbit or Lagrange point) would be determined by the timing of habitat readiness and the desirability of the partnership to return to the asteroid placed in the distant retrograde orbit.

Josh Hopkins reported on the work done by an international space industry group that has been meeting over the last 5-6 years on topics related to the next steps in human space exploration. They have looked at how complementary capabilities of the various companies can enable compelling missions through international partnerships. Mr. Hopkins presented the priority drivers identified by the group, such as enabling a regular cadence of astronaut flights from partner nations, to ensuring contributions are consistent with national interests. The group favors an initial deployment of a habitat to Earth-moon Lagrange Point 2 and has advanced lunar far-side exploration objectives which can be enabled by the presence of astronauts and infrastructure, such as a communication relay.

Carl Walz summarized the Cygnus system that is currently providing logistics support to the International Space Station. He shared thoughts on how Cygnus capability can be evolved for use as an exploration habitat module supporting crew beyond LEO.

Mike Gold described work done by the Bigelow Aerospace company on inflatable habitats. He described the particular features of inflatable habitats which made them particularly interesting for use beyond LEO (increase volume, radiation protection, less mass, etc).

Greg Schmidt focused on what the crew could do during its time at an evolvable habitat in the lunar vicinity. He described strong interest in the science community for strengthening the GER by creating alignment with human mission planning and the highest priority science objectives. He discussed several ongoing activities to this end. Of note, Solar System Exploration Research Virtual Institute (SSERVI) is hosting the Exploration Science Forum at Ames Research Center 21-23 July, 2014. An additional day, July 24th, will be added this year as a special session dedicated toward topics focused on science enabled by the GER.

Jack Burns described recent advances in surface telerobotic concepts for lunar far-side exploration. Tests on the ground and on space station are strengthening this concept for using the presence of astronauts in the lunar vicinity to achieve high-priority science objectives related to the moon. Dr. Burns described several tests using different control strategies and planned (such as Orion) or proposed capabilities identified in the GER.

Session 3: Collaborative Human Lunar Surface Missions

Session 3 was chaired by Roland Martinez (NASA). Speakers were Mark Robinson (Arizona State University), Ryan Whitley (NASA), Hiroshi Ueno (JAXA), Bernhard Hufenbach (ESA), and Dana Hurley (APL).

Mark Robinson summarized top discoveries made by the Lunar Reconnaissance Orbiter and how this new information both prepares for human missions and offers opportunities for the presence of humans to address some of the key science and exploration questions. Dr. Robinson showed how key questions can be addressed through study of polar volatiles and lunar geology by deploying both robotic missions with mobility and sample return capability, as well as human-robotic missions.

Ryan Whitley gave a brief overview of the work underway within ISECG to increase the definition of lunar surface access strategies and exploration approaches. The study aimed at trading various options for lunar surface access capability is focused on using the deep space habitat in the lunar vicinity as a staging post for reaching the surface.

Hiroshi Ueno gave an overview of lunar surface access architecture and capability studies underway at JAXA. Lunar surface exploration, while not currently part of the JAXA baseline, is of interest, building on the accomplishments of the Kaguya mission to advance Japanese capabilities and technologies in order to contribute to international lunar exploration scenarios depicted in the GER.

Bernhard Hufenbach discussed the role of the moon in ESA's exploration strategy. He stated that the moon was of interest for its resources, science, and accessibility. It also serves as a stepping stone for future missions. ESA planning focuses on a mission-centric approach, studying possible lunar vicinity/lunar surface missions using GER infrastructure which contribute to ESA's long-term goals and enable ESA to take a significant role a multi-lateral exploration effort.

Dana Hurley provided a detailed overview of the current state of knowledge on lunar volatiles. She also summarized key questions guiding ongoing and future investigations, including those related to the distribution, abundance and composition of the lunar volatiles. This information is essential to understanding their usability as exploration resources.

Session 4: International Standards to Promote Interoperability

Session 4 was chaired by Joel Montalbano (NASA). Speakers were Matt Duggan (Boeing), Lisa Colloredo (NASA), Skip Hatfield (NASA), and Phil Liebrecht (NASA).

Mat Duggan gave a summary of lessons learned from the ISS Program and international standards. He also presented an industry view of effective ways to maximize interoperability in exploration architectures. Mass and cost challenges will be drivers, and several areas were identified for further study, such as atmosphere and water standards, as well as power voltage and quality standards.

Lisa Colloredo discussed the approach and lessons learned by the NASA Commercial Crew Program which might be of use in assessing areas of international standardization to promote interoperability. A key feature of the Commercial Crew Program approach regarding standards was to give as much flexibility to the capability provider as possible, while remaining consistent with the highest priority interests of the government.

Skip Hatfield described the international docking system standard (IDSS) and efforts underway to advance the standard. Currently, the standard addresses all physical mating interface parameters (hard or soft capture) that allow a physical connection between two spacecraft. Work is underway to expand the standard to cover electrical connectors and docking targets.

Phil Liebrecht gave an overview of work within the Interagency Operations Advisory Group to establish standards which permit internationally interoperable data systems for space exploration.

Session 5: Human Assisted Sample Return

Session 5 was chaired by John Baker (JPL). Speakers were Bob Gershman (JPL), Stan Love (NASA), Josh Hopkins (Lockheed Martin), David Kring (USRA), and Hiroshi Ueno (JAXA).

Bob Gershman provided an interim status report on a JPL-led study of crew-assisted Mars sample return. The presentation highlighted the challenges of sample containment to meet planetary protection guidelines, as well as several concepts under study by the team. Study assumptions and figures of merit were also discussed. Stan Love provided insights related to the crew role in such a mission. Josh Hopkins highlighted work done by Lockheed Martin which augmented Orion spacecraft capabilities to support a broader mission. These options will undergo further study by JPL and NASA over the coming months.

Josh Hopkins also shared details of a Lockheed Martin Orion Sample Capture and Return System, nicknamed OSCAR. He shared trajectory and system study work that has been performed. The OSCAR module is essentially an airlock, which would augment Orion to allow proper capture and handling of planetary science samples from Mars, the moon or asteroids.

David Kring provided an overview of science and exploration objectives which could be addressed through human assisted sample return. He described top science questions as captured in the 2007 report of the National Research Council called *The Scientific Context for Exploration of the Moon*. Dr. Kring described how exploring the far-side Schrodinger Basin, something which could be enabled with capabilities described in the GER, contributed to meeting some of the very highest priority lunar and planetary science objectives.

Hiroshi Ueno shared the status of an ongoing JAXA study on human-assisted lunar sample return. Highlighting the importance of the human-robotic partnership, he described JAXA's reference architecture which takes advantage of additional capabilities which could be provided by a lunar vicinity deep space habitat.

Session 6: Evolutionary Path to Mars

Session 6 was chaired by Bret Drake (NASA). In addition to Mr. Drake, speakers were Roland Martinez (NASA), Harley Thronson (NASA), Vincenzo Giorgio (Thales Alenia Space), Craig Kundrot (NASA), Les Johnson (NASA), Steve Hoffman (SAIC) and Sam Scimemi (NASA).

Session 6 included 4 summary presentations and a panel discussion, all expanding on how early human missions in the GER such as ISS, lunar vicinity and lunar surface missions prepare for Mars.

Bret Drake gave an overview of the framework NASA is using to guide new approaches to Mars mission (surface and its moons) studies. Roland Martinez summarized the framework used within ISECG to capture the main challenges and risks and ensure that early missions in the lunar vicinity and on the lunar surface make the strongest possible contributions to preparing for future Mars exploration.

Harley Thronson summarized the findings of the first "Affording Mars" workshop held December 3-5, 2013 at The George Washington University. The gathering of subject matter experts, hosted by the Explore Mars, Inc. and the American Astronautical Society, identified six major recommendations to guide planning for human missions to Mars. A detailed summary presentation is available at http://spirit.as.utexas.edu/~fiso/telecon/Raftery-Cassady_2-19-14/Raftery-Cassady_2-19-14.pdf

Vincenzo Giorgio provided an overview and status of the 2016 and 2018 ExoMars missions in development by ESA in partnership with Roscosmos. Thales Alenia Space – Italy in Torino is the overall prime contractor for the 2016 mission and Mr. Giorgio provided a detailed summary of the hardware status as well as the overall mission objectives.

The session included a panel which made brief remarks on the challenges of preparing for future human missions and fielded audience questions. Human health and performance challenges, transportation system challenges, and mission operations challenges were discussed along with the important role of the space station in meeting many of the future human spaceflight challenges.

Special Topics

Steve Creech gave an overview of the NASA high-capacity rocket, the Space Launch System (SLS). He described the initial and evolvable capabilities of the launcher including increased performance and unrivaled payload volume, showing the range of exploration missions which will and could benefit from this capability. Mr. Creech also gave insight into SLS development status. It should also be noted that the SLS will include capability to accommodate secondary payloads.

Nantel Suzuki gave an well-received presentation on the benefits of space exploration. He described work done by ISECG and within NASA to articulate the most compelling benefits of investing in human space exploration and provided insights into how the benefits could be most effectively articulated to stakeholders.

Workshop Wrap-Up and Summary

Workshop chair Kathy Laurini provided some initial insight into the major takeaways which would likely be interesting discussion topics with international partners participating in ISECG. Upon consideration, the following will be included in NASA's key takeaways and follow-on work, thanks to input from speakers or questions from the audience.

1. Science must be considered an integral component of human exploration mission planning. There are a number of key questions which will benefit from human presence to provide knowledge which contributes to answering the question.
2. Lots of work is going on within the international science community related to strengthening the scientific opportunities provided by lunar vicinity (including the Asteroid Redirect Mission) and lunar surface missions described in the GER. The ISECG should find ways to leverage this work to strengthen the support for implementing the GER and funding the lunar vicinity science.
3. Asteroid Redirect Mission investments, development, and operation of solar electric propulsion will also enable future international exploration missions. Further exploring associated mission concepts, including cargo nodes/hubs, with the international community early in planning, will enable partners to bring innovative solutions and ideas that benefit an overall exploration architecture.
4. Providing a communication relay in the lunar vicinity is a key enabler of the human and robotic lunar exploration missions described in the GER.
5. There are areas where near-term work to establish international standards to promote interoperability is desirable. Space station and Commercial Crew Program lessons learned can highlight essential standards for GER missions (e.g. power, voltage, atmospheric standards, etc)..
6. The LRO mission (and other recent missions) contributed a lot of new knowledge of the moon, facilitating human efforts to answer existing questions while still raising new ones. This recent work should guide the lunar Design Reference Mission definition.

7. Currently, to obtain what we want to understand about polar volatiles, we will probably need long-lasting robotic systems with a mobility capability. Whether astronauts are on the surface or not, these capabilities are going to be important.
8. The community shared the ISECG consensus that a deep space habitat in the lunar vicinity is the next foundational exploration capability. The term 'proving ground' when applied to the lunar vicinity is supported and the lunar surface should also be considered part of the 'proving ground'.

Upcoming Events with opportunities to engage on ISECG GER:

NASA Exploration Science Forum, hosted by the Solar System Exploration Virtual Institute (SSERVI), Ames Research Center, CA, July 21-24, 2014

Japan workshop: Tokyo, Japan, July 31, 2014

European Space Exploration International Conference: Strasbourg, France, October 29-31, 2014