IAC-12.B3.1.9

THE ISECG GLOBAL EXPLORATION ROADMAP: AN INTERNATIONAL EFFORT PREPARING FOR SUSTAINABLE HUMAN SPACE EXPLORATION

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The first iteration of the Global Exploration Roadmap (GER) was released in September, 2011 by the International Space Exploration Coordination Group (ISECG). The GER, developed by twelve space agencies¹, provided insights into agency work in preparing for future human exploration of the solar system. It reflects the work of space agencies to identify common exploration goals and objectives and look for feasible and sustainable approaches to meeting them. It also demonstrates that agencies are looking for opportunities to collaborate and cooperate in ways that enhances their efforts to prepare for the challenging missions of the future. Five areas providing near-term cooperation opportunities were identified by participating agencies: use of the International Space Station, advanced technologies, robotic precursor missions, analogue missions and development of advanced exploration capabilities. Agencies have continued their efforts to prepare for future joint missions through targeted discussions in each of the five areas.

Since its release in September 2011, the GER has served as a useful tool in many ways, both technical and political. Through individual agency and coordinated dialog opportunities, non-agency stakeholders around the world have offered ideas and contributions to improving agency technical work. At the political level, an international dialog on space exploration was held in Lucca, Italy in November 2011. In Lucca, many participating states noted the important contribution of the GER to advancing common exploration goals. They also noted the importance of ensuring that investments in space exploration deliver benefits to their citizens. This paper will discuss the impact of the GER and discuss its role in preparing for future exploration partnerships. It will give a status of the ongoing road mapping efforts of participating agencies, including their work to use the ISS in preparation for exploration. This paper will provide insights into the plans for release of the second iteration of the GER.

For more information on the ISECG please consult the ISECG website at www.globalspaceexploration.org or contact the ISECG Secretariat at: isecg@esa.int.

¹ In alphabetical order: ASI (Italy), CNES (France), CSA (Canada), DLR (Germany), ESA (European Space Agency), ISRO (India), JAXA (Japan), KARI (Republic of Korea), NASA (United States of America), NSAU (Ukraine), UKSA (United Kingdom) and Roscosmos (Russia). "Space Agencies" refers to government organizations responsible for space activities.

INTRODUCTION

The first iteration of the Global Exploration Roadmap (GER) was released in September, 2011 by the International Space Exploration Coordination Group (ISECG). By releasing the GER, participating space agencies provided insights into their joint work in preparing for future human exploration of the solar system. Agency discussion and joint work has continued on topics considered timely and relevant to enabling future partnerships and future missions. The status of these activities will be reflected in the second iteration of the GER, currently planned for spring of 2013. This paper provides insights into the ongoing work and dialog of space agencies which will be reflected in the second iteration of the GER. It will also discuss how this work is an essential contribution to enabling the partnerships that will ultimately implement а sustainable human space exploration effort.



Figure 1: Cover image of the ISECG Global Exploration Roadmap (See Ref 1)

As a non-binding, agency coordination forum, ISECG provides an effective forum for sharing views on topics considered important and timely. Information shared within ISECG and products generated are used by agencies to make individual decisions regarding their own plans and activities. Individual agency decisions regarding on-going programs and activities, as well as plans for future activities are informed by this work. Lastly, the opportunity provided by ISECG to inform consultations with stakeholders is valued by participating agencies. Stakeholders, such as national leaders realize that developing the durable international partnerships necessary will require political support and consensus and look to the GER to play a role in informing future political level consensus.

OVERVIEW OF THE ISECG GLOBAL EXPLORATION ROADMAP

The ISECG Global Exploration Roadmap currently focuses on 3 main areas of technical discussion which are considered important by agencies to prepare for future partnerships: 1) goals and objectives, 2) mission scenarios, and 3) preparatory activities. These discussions have created a joint understanding on kev considerations related to future partnerships as well as joint products which serve as a reference for informing individual agency decision Each of the 3 areas is briefly making. introduced in this chapter, and the reader is encouraged to refer to the document itself (See Ref 1).

Common Goals and Objectives

The GER reflects the initial work to identify common exploration goals and objectives amongst the various national priorities. The following eight high-level common goals, with associated objectives, reflect recognition by agencies that exploration benefits must touch all key stakeholder groups.

- Search for Life
- Extend Human Presence
- Develop Exploration Technologies and Capabilities
- Perform Science to Support Human Exploration
- Stimulate Economic Expansion
- Perform Space, Earth and Applied Science
- Engage the Public in Exploration
- Enhance Earth Safety

Mission Scenarios

Two possible exploration mission scenarios were presented in order to demonstrate feasible and sustainable approaches to meeting common goals and objectives. The selected mission scenarios allow participating agencies to remain consistent with existing national policies and reflect that there are currently differences of opinion regarding the best next destination.

Human Exploration Preparatory Activities

The GER demonstrates that agencies are looking for opportunities to collaborate and cooperate in ways that enhance their efforts to prepare for the challenging missions of the future. Five areas providing near-term cooperation opportunities were identified by participating agencies: use of the International Space Station, advanced technologies, robotic precursor missions, analogue missions and development of advanced exploration capabilities.

Many of the activities performed in each of these areas are designed to prepare for human missions. It is recognised that the existence of a common long-range strategy can facilitate coordination of preparatory activities by establishing a common reference to assess specific parameters or measures. By sharing of information related to preparatory activities, agencies can establish cooperative projects or partnerships.

STAKEHOLDER ENGAGEMENT

As stated in the document itself, agencies participating in ISECG published the GER in order to share the results with the broader community and generate innovative ideas and solutions to meeting the challenges ahead. The GER was posted on the ISECG website and several agency websites. Roughly 50,000 copies have been downloaded. Following GER release, agencies took steps through press releases, web postings, or brochures to further communicate the availability of the GER and its significance.

In order to facilitate discussions related to innovative ideas and solutions, space agencies conducted a variety of national stakeholder engagement activities ranging from meetings to open workshops ISECG also received very useful ideas and feedback from a multidisciplinary international audience at the International Astronautical Federation (IAF) and the American Institute of Aeronautics and Astronautics (AIAA) Global Space Exploration Conference (GLEX) in May, 2012.

1. THESEUS Launch Event

The THESEUS project, funded by the European Commission, aims at developing an integrated European life science research roadmap enabling human space exploration. The launch event of this roadmap took place at CNES headquarter in Paris on 15 March 2012. Following the launch event, the THESEUS project organised a town hall meeting to discuss the ISECG GER. This session held on 16 March 2012 was attended by an interdisciplinary audience of 50 international investigators involved in THESEUS expert groups. As an outcome of this discussion a declaration was issued summarising the consistency between the ISECG and THESEUS roadmaps related to habitat design and management. It further recommended that integrated human adaptation and life sciences (including countermeasures) aspects should be considered in an appropriate and dedicated way to reach a more balanced and complete perspective of mission scenarios. Triggered by this feedback, agencies participating to the development of the ISECG GER have agreed to address human health challenges in more detail in the 2nd iteration of the GER and to recognise on-going international efforts in this domain.

2. ESA Benefits Workshop

In April 2012, the European Space Policy Institute (ESPI) organized a workshop with stakeholder representatives of European communities and some ISECG participating agencies for reviewing initial work on the space exploration benefit assessment informed by the ISECG GER. The key objective of this workshop has been to review alternative methodologies for modeling space exploration benefits. The stakeholder communities "Public", "Industry", "Politics". "Science". and "Education" have been represented at the workshop. Different methodologies for modeling space exploration benefits qualitatively and quantitatively have been presented. Based on an intense discussion on the merits of different approaches, the feedback received will guide the further consolidation of the benefit assessment model and related stakeholder engagement activities. (See Ref 2).

3. NASA Community Workshop on the GER

In November 2011, NASA conducted an open workshop on the GER, seeking to communicate the status of international collaborative mission scenario work and seek ideas from several key stakeholder groups, namely industry and CSA and JAXA also used the academia. workshop as an opportunity to reach industry stakeholders. Over 100 representatives from industry, academia, and other organizations were in attendance at the workshop, in addition to over 630 unique participants via the webcast. Participants in the workshop provided several suggestions for enhancing the international dialog such as 1) improving the science community input, 2) clarifying commercial opportunities. and 3) examining the opportunities created in cis-lunar space. At the workshop, NASA committed to providing future similar opportunities for feedback and input from industry and academia.

4. CSA Exploration Plan

In parallel with the development of the first iteration of the GER, the CSA initiated a consultation with the Canadian space exploration community to establish the goals and priorities for space exploration in Canada. This plan discusses robotic and human exploration on ISS, the Moon and Mars in addition to space astronomy. This plan is closely link to international space missions and to the GER. A draft of the plan was produced early in 2012 and an additional consultation round took place with the various Canadian stakeholders during the winter and spring 2012.

A concrete example of collaboration on analogue activities is the NASA-CSA joint deployment in Hawaii in July 2012 to demonstrate the potential of in-situ resource utilization on the Moon.

5. GLEX

In May 2012, the IAF and the AIAA jointly organized the Global Space Exploration Conference (GLEX) in Washington, DC. ISECG was asked to co-chair the conference program committee, making the GER a significant focus of discussion in many technical sessions. The conference brought together over 600 people, from a range of stakeholder communities, enabling an extensive dialog on the shared challenges and opportunities of human and robotic space exploration.

Through presentations, panel discussions and ad-hoc dialog, the GER generated very constructive exchange regarding the technical and political challenges ahead in preparing for space exploration and enabled a diverse set of stakeholders to share their views on priorities and solutions. Feedback and comments received at the GLEX were discussed within ISECG and updates to the work plans agreed where agency consensus resulted in further analysis or examination of a particular idea.

OUTLOOK FOR THE 2ND ITERATION OF <u>THE GER</u>

Since release of the GER in September 2011, agencies participating in ISECG have put a major focus on creating opportunities to maximize the impact of their investments in preparatory activities. Insight into this work was shared at the IAF/AIAA Global Space Exploration Conference held in May 2012 (see Ref 3 and Ref 4). A short summary of highlights is presented below.

Use of ISS to Prepare for Exploration

The ISS partners have put a dedicated effort on ensuring that this remarkable platform is used to the maximum extent to prepare for exploration. Four categories of work have been identified and a significant focus has been placed on understanding the priorities and opportunities within each of these categories. The categories are 1) demonstrating exploration technologies, 2) human health and performance risk mitigation research, 3) maturing critical systems, such as life support and habitation systems, and 4) operations simulations and techniques. In each of these 4 areas, the ISS partnership is working to ensure that the highest priority activities are flown and given adequate time and resources to deliver the answers needed to support exploration preparation.

Robotic Missions

Agencies are identifying a list of strategic knowledge gaps associated with potential destinations for human exploration, what measurements or data are needed to fill those gaps, how the knowledge is best obtained, and when the knowledge is needed. Filling these strategic knowledge gaps informs the selection of future destinations, supports the development of exploration systems, and reduces the risk associated with human exploration. The effort also includes articulating how currently planned robotic missions will contribute to filling the gaps.

Advanced Technologies

Agencies continue their dialog on understanding the opportunities provided by advanced technologies to enable or enhance exploration mission scenarios. The overall intent is to leverage investments in technology development across individual ISECG agencies. This work also provides a basis for enabling agencies who ultimately engage in program formulation activities to understand the technological advancements necessary to achieve their defined requirements.

<u>A New Generation of Space Systems and Infrastructure</u>

NASA's work on the Orion Multipurpose Crew Vehicle (MPCV) and the Space Launch System (SLS) heavy lift launcher are good examples of projects underway which evolve existing capabilities towards the advanced capabilities needed for space exploration. Each program is conceived such that upgrades and enhancements can be made which enable accomplishment of increasingly challenging missions. Other space agencies, such as Roscosmos, are actively studying exploration capabilities with an eye towards making decisions in the near term. These capabilities present opportunities for international partnership. For example, NASA and ESA are in the final stages of examining a potential partnership on Orion, where ESA provides the service module for the initial flight(s) of Orion. A European service module would build heavily on the work done to develop and operate the Automated Transfer Vehicle (ATV), a critical resupply vehicle for

the ISS. Other opportunities for partnership are expected as nations advance projects and programs which will lead to new in-space capabilities.

Analogs to Simulate the Extreme Environment of Space

Several agencies conduct terrestrial simulations to test equipment designs, operational concepts, procedures, or just to validate approaches to space exploration mission design. Within ISECG, agencies are sharing their lessons learned and future plans, with the objective of maximizing the return from each analog operation.

The 2^{nd} iteration of the GER is planned for release in the spring of 2013 and is expected to show the progress made by agencies since the GER was initially released. In addition to the activities described above, the 2^{nd} iteration will expand on the early design reference missions in each mission scenario.

PAVING THE WAY FOR FUTURE PARTNERSHIPS

Agencies are making decisions regarding preparatory activities which are informed by knowledge of the international context and emerging consensus areas. By and large, today's decisions are specific to technology projects, robotic missions, and ISS utilization activities. In some cases, agencies are choosing to conduct studies which inform future decisions on contributions to an international exploration mission or mission scenario. In the coming years, nations and agencies will be faced with the decision to create the international partnerships necessary to explore. Α generalization of the process is shown in figure 2.

In what form these future partnerships are constructed will depend on a number of factors. Certainly, the model of the ISS partnership should be relevant to consider. The legal framework established in the ISS agreements as well as the overall approach for managing this international program could serve as a starting point for any new human space exploration partnership. Specific ISS clauses, such as those



Figure 2: How the work of ISECG informs future partnerships

that create ISS utilization rights and compensation obligations, will necessarily have to correspond to the unique needs of exploration partnerships which still need to be better defined and understood. Some of the factors to be considered in this regard are listed below:

- 1) What are the boundaries and scope of the partnership?
 - a. the development of a capability or system
 - b. the implementation of a single mission
 - c. the implementation of a series of missions
 - d. to single or different destinations
 - e. involving human or robotic missions, or both
 - f. the construction of a commonly operated in-space infrastructures such as the ISS today
 - g. the integration required in planning missions in order to realize common long-term goals

- 2) Is there a need for an intergovernmental agreement such as that guiding for the ISS program?
- 3) Is there a single nation/ agency who will lead the effort?
- 4) How can non-governmental entities contribute to the effort?
- 5) Are the arrangements bilateral, multilateral, or a combination thereof?

Whether one large partnership, like the ISS program, is appropriate, remains to be seen.

Nations and agencies that decide to partner will need to establish a common set of goals and objectives, and agree on how to meet themtechnically, programmatically and politically. By exchanging views in a non-binding, conceptcentric forum like ISECG, agencies are able to explore alternatives and considerations. They are able to develop a common understanding of considerations affecting a successful effort. They are able to understand what is important to prospective partners and consider how partner priorities correspond to their own. In addition, agencies are able to discuss longerterm strategic considerations which will impact the success of future partnerships. Within ISECG, agencies are gaining the understanding of how goals, objectives and long-term strategic considerations will affect the engineering approaches and exploration architecture as well as the form and function of future partnerships. This chapter expands on a couple of examples.

Defining the Features of a Sustainable Human Space Exploration Effort

Sustainable human space exploration is a term often used to describe the desired state where we (humankind) develop and maintain the capabilities and the motivation to send humans into space in order to do meaningful work. For example, agencies participating in ISECG agree that dedicating most of our resources today to putting human footprints on the surface of Mars in the near-term would not constitute a sustainable human spaceflight effort.

While the recent success of NASA's Mars Science Laboratory Curiosity has raised awareness around the world about the wonder and promise of human exploration of our sister planet, there is much work to be done before the risks of such a mission can be reduced to an acceptable level and the costs can be considered affordable. It is easy to describe what is not sustainable, but in order to facilitate partnership discussions when the time is right, it is important to have agreement on what <u>is</u> sustainable.

Beginning partnership negotiations with a commonly established understanding on strategic principles will facilitate the effort to agree on the parameters of an exploration partnership. Through discussion within ISECG, agencies have agreed on several characteristics of a sustainable program. Examples under discussion are listed here.

- 1. Affordability Do exploration efforts have to be affordable within current and expected budgets?
- 2. Value to all stakeholders, including society at large What is important to

each stakeholder group? How to you balance the needs of each group? What is the role of agencies in the value delivery system and how can we be sure we deliver?

- 3. International partnerships How do you build on the ISS partnership? How can opportunities for new partners be included? How do you construct an architecture and partnership which is robust to changes in partner commitment or readiness?
- 4. Human-robotic partnership How can we maximize the synergies between human missions and robotic missions typically done with a strong science focus?

The Role of ISECG in Preparing Future Exploration Programs

In order to implement human exploration missions beyond Low Earth orbit, to either the Moon or an asteroid, specific plans and agreements are needed. These plans and agreements must be supported at agency level and approved politically. They will include programs goals and objectives, specific missions, roles and responsibilities, governance models and international agreements.

As an open forum, ISECG is not the place to define these agreements which are necessary to form a partnership. However, by sharing plans and concepts and discussing possible synergies opportunities, agencies can identify and potential partnership opportunities. They are also able to share views on a range of topics, as sustainability, influence such which partnerships.

Common Communication to Stakeholders

As effective and lasting partnerships will require political support, preparing for the eventual political dialog will benefit if agencies understand and address the elements which are of common interest to their political stakeholders. During the first political level dialog on space exploration, held in Lucca, Italy in November 2010, government representatives committed to begin the open structured highlevel policy dialog on space exploration for the benefit of humankind. They recognized that a sustainable space exploration endeavour is beyond the capabilities of a single nation. Often cited during agency remarks, ISECG and the GER were seen as a positive reflection of the work necessary to be done by space agencies to inform the political dialog.

While space exploration as an engine of economic growth was a critical element of their support, it was clear that government representatives from all nations, both experienced and emerging actors, clearly stated that investments in space exploration must continue to benefit people on earth. Thev recognized that humanity's need to explore new frontiers and make new discoveries is never ending and brings benefit to people on earth. examples were cited including Several addressing global challenges in space and on Earth through the use of innovative technology; global partnerships creating by sharing challenging and peaceful goals; inspiring society and especially the younger generations through collective and individual efforts; and enabling economic expansion and new business opportunities.

Understanding how agencies deliver value to their stakeholders through their exploration activities is a big area of focus of ISECG. Developing this understanding will help in establishing a common method to measure and communicate the extent to which space exploration generates benefits to all stakeholder groups, including society at large.

Describing a Common Long-Term Vision

One of the reasons that agencies intend to update the GER on a regular basis is to establish a common and stable long-term vision which will serve to inform decision making in many ways. Keeping the international community focused on a common long-term vision – such as the goal of sustained human exploration of the surface of Mars will enable incremental progress over time ensuring that agencies can maximize the impact of their efforts. A stable long term vision enables new partners to prepare, over time, for their entry into the effort. It also articulates to the broader stakeholder community long-term opportunities and challenges to be tackled.

Furthermore, it allows agencies which implement national programs or participate in an international program to articulate their role and the importance of a particular program in the larger context of the space exploration process. It demonstrates the common intent of space agencies to expand the boundaries of human reach and experience and therefore provides an overall framework for the programmes different partnership implemented within frameworks, with different means and possibly targeting different destinations.

CONCLUSION

Interagency discussions in the context of the GER represent an opportunity to exchange views and determine whether the emerging global consensus is consistent with national interests. In other words, would participation in future exploration partnership provide the opportunity to achieve their individual goals and objectives? In the near term, agencies are spending a significant amount of effort on the maintenance and utilization of the ISS, robotic exploration missions and to prepare for future roles in a human space exploration effort. and priorities Sharing work regarding preparatory activities enables agencies to look for opportunities to partner in ways that increases the return from their individual investments.

The publication of the GER reflected the commitment of agencies to collaboratively prepare for a future international human exploration effort. Discussions have continued and the 2nd iteration of the GER should demonstrate that this commitment has not faltered, even in light of extreme economic challenges for all nations. Most importantly, this effort continues to prepare interested agencies for future program formulation and partnership discussions.

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