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AN INTERNATIONAL STRATEGY FOR EXPLORATION: DEVELOPMENT STATUS OF THE ISECG GLOBAL EXPLORATION ROADMAP

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The *International Space Exploration Coordination Group* (ISECG) was established in response to *"The Global Exploration Strategy: The Framework for Coordination"* developed by fourteen space agencies[1] and released in May 2007. This GES Framework Document recognizes that preparing for human space exploration is a stepwise process, starting with basic knowledge and culminating in a sustained human presence in space. Robotic exploration is considered an important component of expanding human presence in space in order to increase the knowledge of future destinations, take steps to reduce risks to human explorers, and ensure the human missions can deliver maximum scientific discoveries.

Sharing this common understanding of space exploration, ISECG participating agencies have started an initial dialogue on the purpose and goals of different destinations and associated mission scenarios in the overall exploration sequence recognising that, (a) different destinations and related mission scenarios require different challenges to be mastered and different risks to be addressed and (b) opportunities exist to exploit synergetic capabilities for the exploration of different destinations.

Senior agency managers representing agencies contributing to ISECG have agreed to start the development of the Global Exploration Roadmap (GER), recognizing that such a roadmap will be evolving and responding to new programmatic priorities, scientific discoveries and technological breakthroughs. The Global Exploration Roadmap can serve as a tool or international reference framework for

- Facilitating the alignment of international human space exploration mission plans, programmes and policies and thereby enhancing opportunities for collaboration and coordination;
- Maximising the benefits resulting from each planned mission, considering also opportunities it enables for the development of partnerships and follow-on mission scenarios;
- Encouraging timely investments in enabling technologies and their demonstration, with special emphasis on a near-term commitment to fully use the International Space Station (ISS) for preparing future human exploration missions.

ISECG will reflect exploration missions and activities planned and under consideration, which target the destinations where human can hope to live and work. This will include all missions addressing the themes of the Global Exploration Strategy (new knowledge in science and technology, a sustained presence – extending human frontiers, economic expansion, a global partnership, inspiration and education) executed by robots or humans. It

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

will provide a compilation, characterization and assessment of national and international exploration mission scenarios enabling a multilateral dialog on the importance of realizing the opportunities provided by each human and robotic mission. Through the development of the GER, ISECG participating agencies will further demonstrate their interest in a globally coordinated space exploration effort along the principles of the vision described in the GES and for the benefit of the global society.

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

I. INTRODUCTION

In May 2007 14 space agencies have released the jointly developed *"Global Exploration Strategy: The Framework for Coordination"* (GES) [Ref. 1]. The GES represents a joint vision for globally coordinated space exploration based on shared space exploration themes and goals in service of the global society. It recognizes that space exploration is a process, targeting destinations where human can hope to live and work one day (Moon, Near-Earth Objects and Mars) in a step-wise approach, leading ultimately to sustained human presence in space. It embraces robotic exploration as an important early step for reducing risks to human explorers and ensuring that the subsequent human missions can deliver maximum scientific discoveries. Figure 1 shows the process steps for the exploration destinations and their current status at global level.

As an outcome of the process which led to the development of the GES, the International Space Exploration Coordination Group, ISECG, has been set-up in November 2007 for advancing the GES by providing a forum where interested agencies can share their objectives and plans, explore concepts that reflect synergies, and develop products that enable agencies to take concrete steps towards an internationally coordinated space exploration effort. Significant efforts have been made within ISECG in the time period end 2008 to mid 2010 for developing the first ISECG reference architecture addressing human lunar surface exploration [Ref. 2]. Initial work for the development of a global roadmap and strategy for exploration risk reduction has also been performed and reported at the IAC 2009 [Ref. 3].

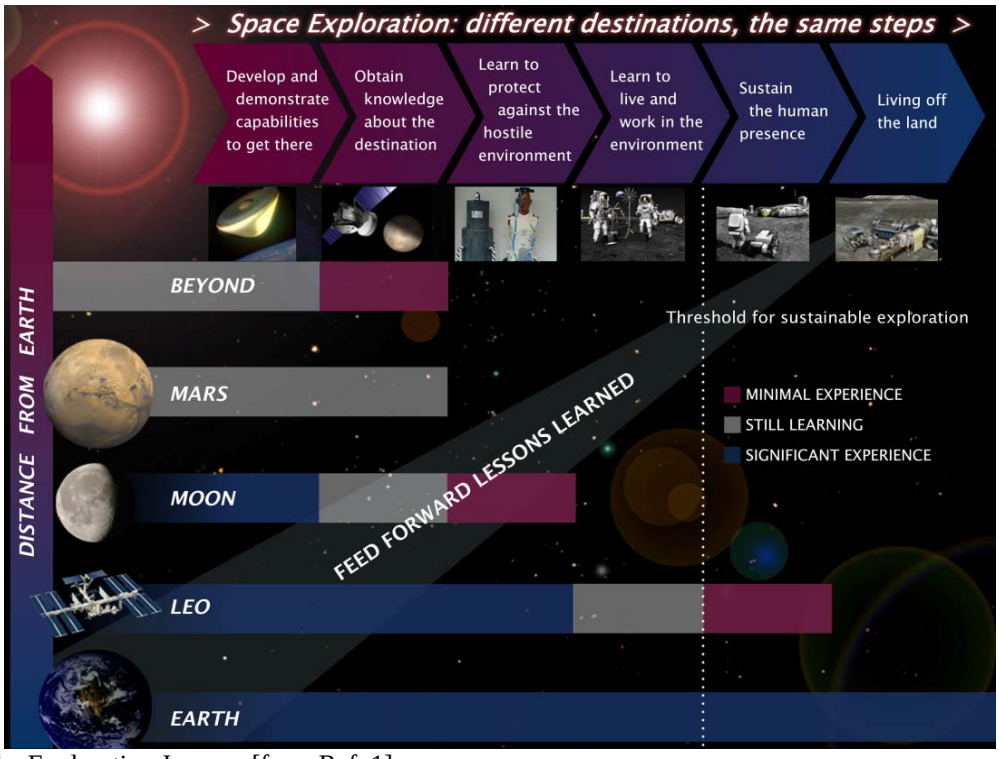

Figure 1: The Exploration Journey [from Ref. 1]

In June 2010, representatives from the senior management of ISECG participating agencies endorsed the plan for ISECG to develop the Global Exploration Roadmap[2] (GER) to further define the common strategic implementation planning of the GES. The GER will represent the illustrative, overarching plan to be taken by ISECG participating agencies towards space exploration destinations. Its first release is planned for mid 2011.

The roadmapping activity will encompass both, an assessment of future robotic and human mission scenarios which are today in the early conceptual analysis phase as well as a summary of concrete plans and ongoing activities performed collaboratively, like the ISS, or autonomously by individual agencies. In this way, the GER will support participating agencies to

- ⇨ Identify opportunities for near term partnerships;
- ⇨ Show how near term plans prepare future collaborative mission scenarios and thereby contribute to the achievement of the common long term vision;
- ⇨ Articulate a rationale for the phased achievement of shared goals and destinations;
- ⇨ Provide a framework for current and future common mission definition and architecture development.

It is envisioned that regular updates of the GER will be made to reflect the plans of contributing nations and future mission scenarios as they evolve.

The purpose of the GER is therefore to serve as a common reference and planning tool for realising near- and long-term benefits towards the implementation of globally coordinated space exploration. Near-term coordination achievements, independent of having multi-lateral cooperation agreements in place, may include

- ⇨ Maximum benefits resulting from each planned mission, considering also opportunities it enables for the development of partnerships and follow-on mission scenarios;
- ⇨ Timely and coordinated investments in development and demonstration of technologies which are critical for enabling future mission scenarios;
- ⇨ Full utilization of ISS in preparing future human mission scenarios.

In the longer-term, availability of the evolving GER may facilitate the alignment of international human space exploration policies, programmes and mission plans. Such alignment is considered essential to enhance and sustain the international partnerships considered necessary for enabling the implementation of the GES vision and implementation of increasingly complex future human mission beyond Low Earth Orbit. It is clearly recognised that individual agencies exploration policies and plans are in general decided at political level. While political engagement and interaction at international level is considered a necessary component for enabling the implementation of the more costly and complex mission scenarios, ISECG considers that the GER can play a key role in developing the foundation for political interactions by preparing the grounds for policy alignment.

The GER is not intended to reflect the wishes of participating agencies independent of global fiscal realities and political priorities, but rather reflect an agency consensus of next steps in light of fiscal realities and political priorities. Over time, the GER can serve as a key tool facilitating the gradual alignment of exploration policies and plans at international level.

II. DESCRIPTION OF THE ROADMAP

The GER is considered both a product and a process. It will address future missions towards exploration destinations as well as the step-wise development of capabilities required for these missions and the evolution of these capabilities over time. Missions will include international and national missions for both robotic and human mission scenarios.

It is envisaged to develop two major GER products:

1. An overview of firm agency activities and plans for exploration;
2. Recommendations on next steps enabling coordinated space exploration and the implementation of the GES vision.

[2] The following agencies are currently actively engaged in the GER development: CNES, CSA, DLR, ESA, JAXA, NASA, UKSA.

Plans will be considered firm when they meet commonly established criteria.

The overall purpose of the GER development is to maximise opportunities for coordination and cooperation through

(a) Providing transparency on agencies firmly planned near-term activities (represented by product 1);

(b) Developing a global strategic framework for informing agency's decision-making related to future plans (represented by product 2).

Purpose of Product 1

Product 1 will concretely reflect the current policies and plans of participating agencies as well as the intent of these agencies to develop their plans towards achieving the GES vision. It will include information on

- ⇨ Planned robotic missions to exploration destinations. Robotic missions should reflect both science driven robotic missions and robotic precursor missions. The latter serve primarily as pre-cursors to human missions.
- ⇨ Key ongoing and planned exploration technology and capability developments and demonstrations enabling future mission scenarios considered likely. For this point particular emphasis will be placed on
  - o Ongoing and planned ISS activities that contribute to technology and operations capability readiness for exploration;
  - o Ongoing and planned terrestrial analogue missions for validating requirements for future mission scenarios, advancing technology readiness and enabling research for future mission scenarios.

The resulting product will enable ISECG participating agencies to demonstrate their possible role in enabling the GES vision as well as facilitate future dialogues on near-term coordination and cooperation.

Purpose of Product 2

Product 2 will provide recommendations on next steps enabling the implementation of future coordinated exploration activities and the long-term implementation of the GES vision. These recommendations will be developed through a strategic assessment of the information provided by participating agencies on their strategic views, future plans and concepts and other contextual information available. Such strategic assessment may address

- ⇨ ISECG participating agencies key drivers, constraints and strategic considerations for investing in space exploration;
- ⇨ ISECG participating agencies individual objectives for specific exploration destinations, as well as exploration in general;
- ⇨ Identification and analysis of key strategic factors related to international mission architecture, partnership and stakeholder considerations, which are essential for enabling the transition from cooperative human operations in LEO and early robotic missions, to cooperative human missions beyond LEO.
- ⇨ ISECG participating agencies considerations on the priority and sequence of future human mission scenarios. These may involve the characterisation of possible future human mission scenarios and an assessment of optional pathways, for implementing these scenarios in a step-wise and sustainable manner. Figure 2 provides a high-level overview of such possible mission scenarios and optional pathways;
- ⇨ Role firm agency plans play in enabling the implementation of future human mission scenarios, together with the identification of additional preparatory activities required over and above those plans (identification of gaps).

The strategic assessment shall result in the development of recommendations identifying and defining concrete steps towards coordination and cooperation. Near-term recommended collaborative actions may in particular target measures for building confidence towards increased acceptance of international interdependence as a necessary condition for enabling the more complex and

resource demanding future human mission scenarios. Recommended coordinated steps may be based on achieved consensus on the first destinations for human missions beyond LEO or on what should represent the major next collaborative infrastructures to be developed.

Participating agencies hope that this process, leading to an understanding of synergies and competition of their strategic views, will enable each agency to be better informed when their decisions on future plans, concepts and strategies will be made which are dependent on the international context. This may lead ultimately to an increase in opportunities for coordination and collaboration in the near-, medium- and long-term.

For the initial work on product 2, priority will be given to strategic elements which may influence near-term participating agencies' decisions. Such decisions will certainly concern the development of new transportation capabilities, utilisation of ISS for exploration as well as robotic missions.

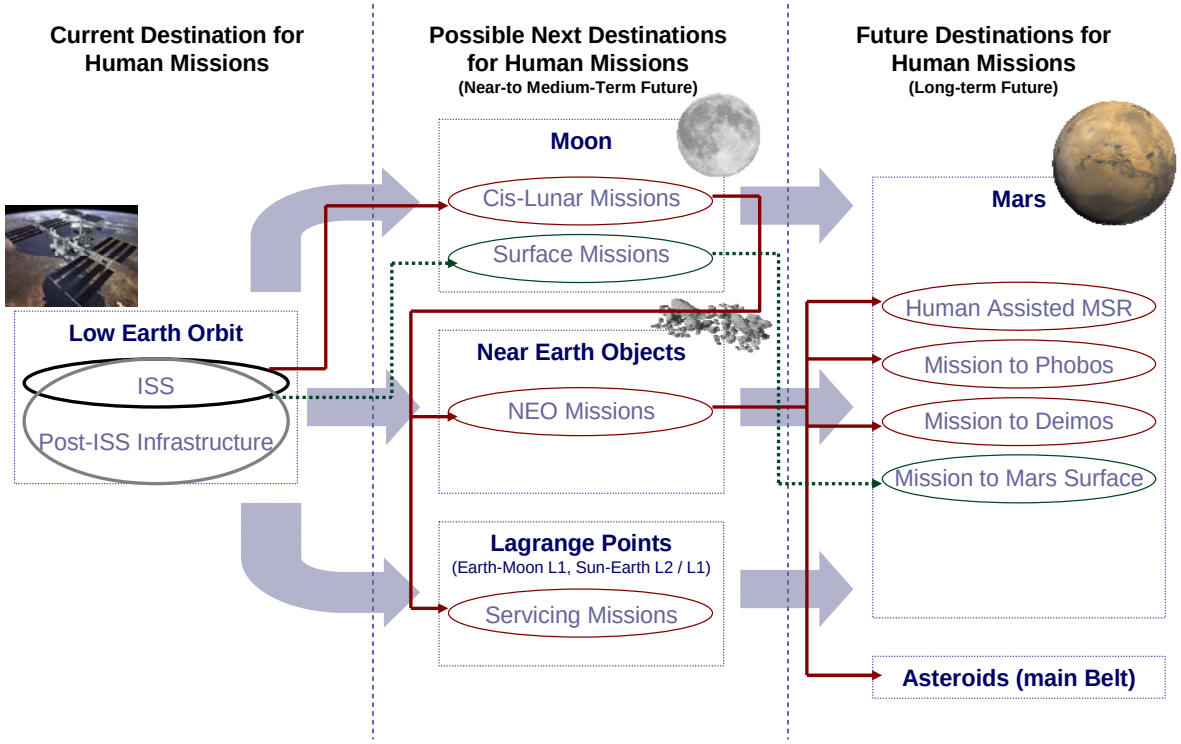

Figure 2: Human Mission Scenarios considered. The red and green, dotted, arrows represent optional pathways for implementing the future human mission scenarios.

III. DEVELOPING THE ROADMAP

ISECG participating agencies are committed to developing the first revision of the GER by mid 2011 with the clear understanding that the GER will evolve. Throughout the development process, engagement and strategic feedback from stakeholders and senior management of ISECG participating agencies will be sought to ensure strategic alignment and value of the evolving GER product.

The process for the development of the GER will generally include the 6 steps shown in Figure 3.

Step 1: Information sharing
Step 2: Overview of firm agency plans
Step 3: Strategic assessment
Step 4: Supporting analysis
Step 5: Development/ updates of GER products
Step 6: GER products review and endorsement

These 6 steps will also be followed each time an update of the GER will be developed. The development of the two products introduced above will be performed in parallel (process steps 2 will be implemented in parallel to process steps 3 and 4). The developed overview on agency plans (step 2) will be taken into account for the strategic assessment (step 3) and supporting analysis (step 4) performed for the development of recommendations on next steps for coordinated space exploration.

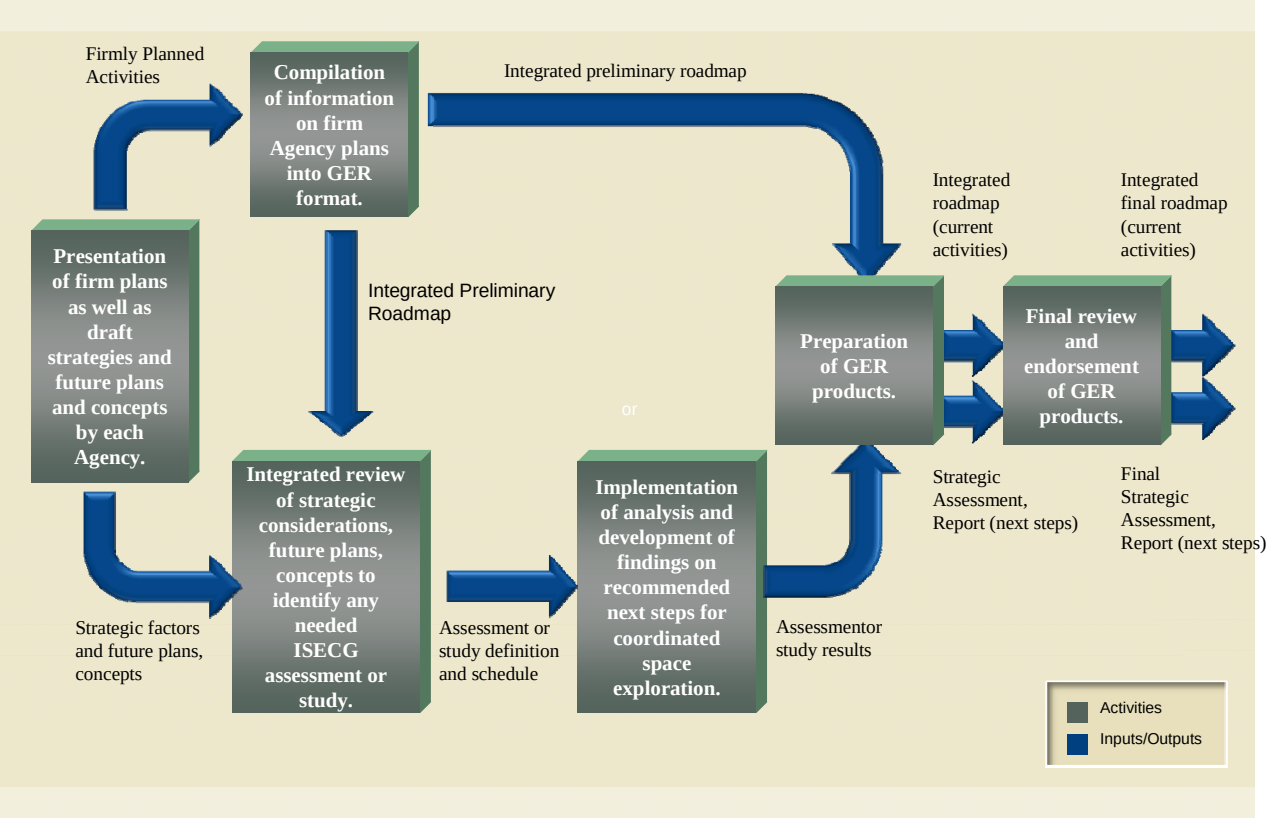

Figure 3: Process Steps for Development of GER

Step 1: Information Sharing

Agencies will share information on firm plans as well as future plans and concepts not yet firm, and draft strategies.

(1) As stated above, firm plans may include planned robotic missions as well as key ongoing and planned exploration technology and capability developments, such as demonstration activities ongoing on the ISS, or investments in a heavy lift launcher.

(2) Future plans may include future robotic mission and capability concepts studied at phase A level for which no firm funding decision has been made, long-term plans for the development of enabling technologies and their demonstration in space, initial studies on future exploration infrastructures and mission scenarios which require international cooperation for their realisation as well as any other concept or idea which could be relevant for the implementation of future coordinated space exploration activities.

In particular information on those future plans will be shared

- ⇨ For which the realisation will depend on the international context and the establishment of partnership;
- ⇨ Which if implemented would significantly affect the global exploration scenario, offer synergies at international level and advance the overall implementation of the GES vision.

It is fully recognised that information on future plans may be subject to evolution. However, sharing draft information will enable the identification of important near-term decision and ensure that the multi-lateral work on the Global Exploration Roadmap will support individual agency decision-making

Commonly developed and agreed criteria will be applied by the agencies to distinguish firm from future plans.

(3) Each agency will also be invited to share information on key drivers and strategic

considerations for exploration, objectives for the different destinations and broader strategic views on future coordinated space exploration activities. The latter may also include initial views on future collaborative steps towards coordinated exploration.

Step 2: Overview of Information on Firm Plans

The development of a global roadmap of firm agency plans will be the main objective of step 2. The International Space Exploration Coordination Tool (INTERSECT), under development by ISECG since 2007, will be used to capture validated information on agency's firm plans on missions and capability developments. It may also be used to provide overviews of firm plans at different levels (mission and capability level) and for the different destinations and types of missions/ capabilities in support of the following analysis steps. Further information on INTERSECT can be found in Ref. 4.

Step 3: Strategic Assessment

The initial assessment will address firm plans, future plans, and key drivers and strategic considerations.

(1) The assessment of firm plans shall lead to an understanding of near-term opportunities for coordination and cooperation. Firm plans shall also be assessed with regard to the possible role they play in enabling future coordinated space exploration.

Considering the imminent decision of the Partners to the International Space Station (ISS) programme to extend the operations and utilization of ISS until at least 2020, special attention will be devoted to including the ISS utilisation plans in preparation for exploration. Including in the roadmap, a view of the extensive activities already ongoing onboard the ISS will serve to highlight its critical role in enabling exploration beyond LEO.

By assessing the ongoing activities against anticipated exploration technology demonstration requirements, gaps can be identified enabling agencies to consider any additional activities they wish to conduct to close the gaps.

(2) The assessment of shared information on future plans may lead in a first step to an identification of:

(a) Near-term decision points of participating agencies which may significantly affect opportunities for near-, medium,- and long-term coordination and cooperation and

(b) Possible shared near-term steps which would enable coordinated space exploration.

Based on this assessment required joint supporting analysis to either inform important near-term decision-making of participating agencies or the development of consensus on future steps enabling coordinated space exploration will be defined. Such supporting analysis may address the

- ⇨ Context/ rationale for human space exploration beyond LEO that considers the role and importance of each destination.

- ⇨ Definition and assessment of transportation requirements for exploration including the framing of the trade-space for the international transportation architecture.

The latter point is of particular importance, since many agencies plan the development of new transportation capabilities which shall also serve cooperative exploration missions and the investment cost in transportation capabilities will be more than 90 % of the overall costs for sustained exploration.

An important criterion for assessing future plans will be sustainability. Typical sustainability considerations to be addressed may include

- ⇨ **Affordability:** considering in particular different approaches to cost reduction, risk reduction and exploration capabilities development.

- ⇨ **Cooperation Opportunities:** Finding synergies between interests in the near, medium, and long-term will enhance opportunities for cooperation.

- ⇨ **Engagement of and Return to Society:** To maintain broad societal engagement in and support for the programme, a continuous (also in the near-term) and balanced achievement of objectives of different stakeholder groups needs to be secured.

(3) Sharing of agencies views on key drivers and strategic considerations for investments in exploration will enable the identification of key factors which need to be addressed internationally for enabling coordinated space exploration. In particular factors which are important for the transition from human operations in LEO and robotic missions to collaborative human missions beyond LEO shall be identified. Such factors may be of technical or programmatic nature and include for example

- ⇨ **Partnership considerations** such as the role of the ISS partnership, the need and timing for global political engagement and the approach for balancing Partners autonomy and interdependence as well as any relevant legal issues.

- ⇨ **Architectural considerations** such as (1) the requirements and timing for developing key capabilities such as advanced in-space propulsion, energy and resource management, radiation protection and life support, (2) the benefits versus costs of a post-ISS infrastructure for supporting exploration activities and (3) benefits and timing for introducing reusability in the architecture

- ⇨ **Stakeholder engagement considerations** such as the engagement of the global science community and the private sector, also through private sector investments.

It is the objective to achieve growing international consensus on these factors, while recognising that it may not be possible to address all these issues in a satisfactory manner for the 1st iteration of the GER. Future iterations of the GER are therefore important to ensure its alignment with agency policies when they become available.

Step 4: Supporting Analysis

Supporting analysis or trade studies which are defined in step 3 will be performed. Such analysis may be required at the level of mission objectives, architectures or required technologies.

Step 5/ 6: Product Development and Endorsement

The two GER products will be developed/ updated and then be presented, for review by senior management of ISECG participating agencies prior to their publication at the ISECG website (www.globalspaceexploration.org).

IV. THE ROADMAP AS A TOOL FOR ALIGNING POLICY AND PLANS

The implementation of the GES will require an increasing alignment of ISECG participating agencies exploration policies, plans and individual roadmaps with increasing complexity of and resource requirements for missions as humans venture beyond Low Earth Orbit. Over time, the GER shall serve as the key tool facilitating the gradual alignment of exploration policies and plans at international level.

Individual agencies exploration policies and plans are in general decided at political level. Political engagement and interaction at international level is considered an essential component for enabling the implementation of the more costly and complex mission scenarios. However, the GER can play a key role in developing the technical foundation for political interactions by preparing the grounds for policy alignment through

- ⇨ Defining a common view on the global exploration scenario as shared by the ISECG participating agencies;

- ⇨ Identifying opportunities for complementary long-term role of the individual partners;

- ⇨ Highlighting the key areas requiring large investment and advanced technologies, and perhaps political engagement and decision-making at international level;

- ⇨ Developing a shared framework for identifying priorities for near-term investments.

Figure 4 depicts the concept of GER evolution as a tool for increasing alignment of individual agency policies and plans.

The exploration policies and plans of ISECG participating agencies are currently reviewed and certainly not all will mature in time for the 1st release of the GER. Therefore, the GER will be developed in an iterative manner, enabling the integration of exploration policies and plans as they become available. It is the ambition that with each iteration of the GER,

- ⇨ The number of strategic elements on which consensus can be achieved is increased;
- ⇨ More areas and opportunities for cooperation are identified;
- ⇨ More agencies participate and endorse the GER;
- ⇨ Global stakeholder support and engagement is enhanced.

With increasing maturity of the GER, the GER may become itself a tool and reference for individual ISECG participating agencies policy formulation. Future iterations of the GER will also duly take into account and respond to new scientific discoveries, technological breakthroughs, and evolving programmatic priorities of the ISECG participating agencies.

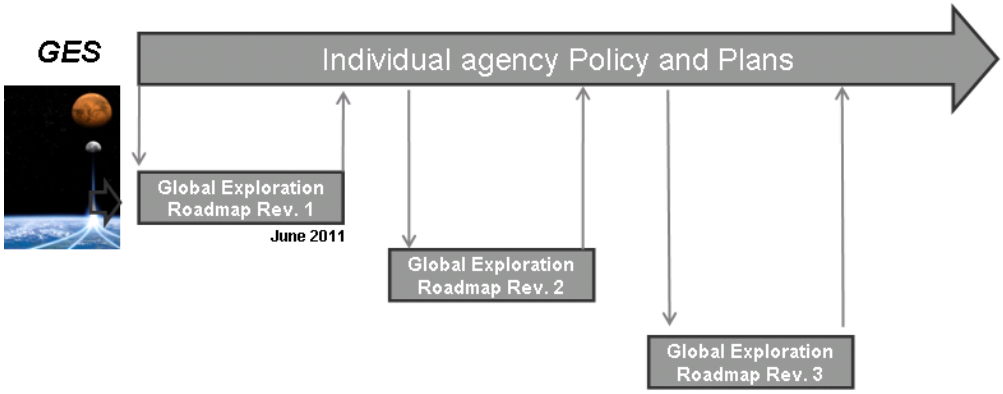

Figure 4: Step-wise Process for aligning GER and ISECG participating agencies exploration policies and plans

V CONCLUSIONS

The ISECG, which has been set-up as an outcome of the process leading the publication of the GES, has been a useful forum for sharing information on exploration policies and plans of its members. It has also recently developed its first reference architecture addressing lunar surface exploration as a common tool for strategic planning. Mid 2010 senior managers of participating agencies have tasked ISECG to develop the GER and provide a first iteration of it by mid 2011.

The GER represents a further elaboration of the GES and will be an instrumental tool towards the implementation of the GES vision. The value of the GER will increase with the number of agencies engaging in its development. The process leading to the GER will be transparent and initial results will be communicated also to the broader stakeholder community. The development of GER is meant to contribute to the complex transition from human operations in LEO and robotic missions to exploration destination, to humans venturing beyond LEO, with common interest and with support of a broad international partnership.

VI REFERENCES

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