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THE VALUE OF THE INTERNATIONAL SPACE EXPLORATION COORDINATION GROUP (ISECG) IN THE FORMULATION OF EXPLORATION CONCEPTS AND PARTNERSHIPS

Douglas Cooke
NASA, Headquarters, Washington D.C., USA, douglas.cooke-1@nasa.gov

Gilles Leclerc
Canadian Space Agency (CSA), Longueuil, QC, Canada, gilles.leclerc@asc-csa.gc.ca

Yoshiyuki Hasegawa
JAXA, Tsukuba, Japan, yoshiyuki.hasegawa@jaxa.jp

Rolf Densing
Deutsches Zentrum fur Luft- und Raumfahrt e.V. (DLR), Bonn, Germany, Rolf.Densing@dlr.de

Richard Bonneville
Centre National d'Etudes Spatiales (CNES), Paris, France, Richard.Bonneville@cnes.fr

Andrea Lorenzoni
ASI, Italian Space Agency, Rome, Italy, andrea.lorenzoni@asi.int

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. The Global Exploration Strategy recognizes that preparing for human space exploration is a stepwise process, starting with basic knowledge and culminating in a sustained human presence in space. The purpose of ISECG is to advance the Global Exploration Strategy by providing a forum where interested agencies can share their objectives and plans, explore concepts that reflect synergies, and develop products which enable agencies to coordinate their investments. As ISECG is not a governance body, its products inform the individual decision making of its participating agencies. In this way, agencies can consider their role in an emerging global scenario and invest in ways which best prepare themselves. ISECG operates in accordance with the key principles set out in the Global Exploration Strategy – Open and Inclusive; Flexible and Evolutionary; Effective; and Mutual Interest. Participating agencies gain insights which are useful to their near term decision making and long term strategy formulation.

Since its inception in 2007, ISECG has focused on developing timely products which serve its members in informing near term decisions. The ISECG Reference Architecture for Human Lunar Exploration was developed to inform the lunar exploration plans of several agencies. Examples of how this product influenced agencies strategic orientation and decision making are listed below:

- NASA Constellation Program requirements development,
- CSA exploration plans and investments in technology development related to space exploration,
- Joint CNES and DLR Report on Exploration
- JAXA and ESA lunar exploration studies
- Programmatic considerations in DLR
- Impact on the space exploration initiative of ESA, EU and their member states

[1] In alphabetical order: ASI (Italy), 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), UKSA (United Kingdom). "Space Agencies" refers to government organizations responsible for space activities.

This paper will review the products of ISECG and discuss how they have enabled participating agencies in refining strategic orientation and to make individual decisions informed by the emerging global scenarios. It will look forward to the role ISECG can play in determining the shape and nature of partnerships to implement the challenging international space exploration missions of the future.

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

INTRODUCTION

With the release of the Global Exploration Strategy in 2007, and the subsequent agreement to form the International Space Exploration Coordination Group (ISECG), participating agencies recognized the importance of working together to enable a sustainable human and robotic space exploration future. Today, many space agencies are active conducting and planning for human and robotic space exploration missions. While resources available to each agency are limited, agencies see the increased benefit of partnering to achieve their objectives. Through their work within ISECG, agencies have been able to identify near-term partnership opportunities.

Space agencies also see the opportunity provided by ISECG to understand the priorities of other agencies in the context of emerging global exploration scenarios. Realizing a robust and sustainable exploration scenario will require appropriately leveraging our individual investments. No one agency can invest robustly in all the needed technology or capabilities needed for executing human or complex robotic missions beyond low-Earth orbit. Agencies are making decisions today regarding technology priorities, use of ISS and other exploration preparatory activities. With an understanding of the priorities of others, agencies can make informed decisions.

Partnering and interdependency of a future global program certainly carry risks. Through the development of collaborative ISECG products, agencies hope to advance the understanding of interdependency. This includes the identification of areas in which interdependency is beneficial or required and for what reasons, and conditions to be met for making interdependency acceptable to all Partners. The work performed by ISECG on this issue may inform the process for aligning agencies policies and the associated required political processes.
This paper will highlight several examples of how participation in ISECG has informed individual agency activities and efforts to prepare the role they will plan in an international exploration effort.

THE GLOBAL EXPLORATION STRATEGY

Outlining the reasons for exploration beyond low earth orbit, the *Global Exploration Strategy: The Framework for Coordination*, describes a vision for coordinated human and robotic exploration of our solar system and stresses the importance of international cooperation to meet the challenges. Focusing on destinations that could once be reached by humans, it identifies Mars as the most intriguing destination that is within our grasp. There is much work to be done before a human mission to Mars can be undertaken with acceptable risks.

As outlined in the Global Exploration Strategy the exploration journey already started in low earth orbit considering the Moon, asteroids, and the Mars system as destinations to expand the human presence. A stepwise approach is recommended to master the challenges for missions beyond LEO. As living and working in space on board ISS starts to becoming routine we should initiate the next major steps towards human missions to planetary bodies. It is vital to taking the experiences from the utilisation of ISS into consideration for the design of new infrastructures and vehicles and for their operation.

The Global Exploration Strategy is available at www.globalspaceexploration.org

In addition, lessons to be learned from future technology demonstrations and the operation of new transportation vehicles are mandatory.

Automated robotic missions are necessary to enable landing on celestial bodies, enhance scientific knowledge, and prepare visits of astronaut crews. Lunar orbiter missions can contribute to lunar science, helping to identify future landing opportunities as well as to establish a reliable Earth-Moon communication. A series of lunar lander missions would be highly recommended in order to verify important technologies required like soft precision landing or surface mobility.

Many landing capabilities are generic and not addressing specifically Moon. Mastering the landing technologies including navigation, attitude and orbit control and propulsion are important for any landing scenario. The design and development of infrastructure elements needed for human Moon exploration like astronaut landing systems and pressurized rovers will benefit from the preceding robotic missions.

As Mars Sample Return (MSR) missions are of major scientific and technological interest, the space agencies initiated discussions how to proceed. MSR will certainly benefit from results of Mars lander missions like MSL and ExoMars. Compared to lander missions with in situ research instruments, sample return missions are characterised for being more complex and risky. Once numerous data from several lander missions are gained and evaluated, the search, selection and return of probes shall be envisaged. These missions will be a further step in preparing astronaut flights to Mars.

OVERVIEW OF THE ISECG

As an outcome of the process which led to the development of the GES, the International Space Exploration Coordination Group (ISECG) was conceived. The concept for ISECG was to establish a non-binding forum enabling interested agencies to meet periodically to share their plans and status related to space exploration with idea of looking for opportunities which may contribute to realizing the vision of the GES. The ISECG was set-up in November 2007, and has steadily increased its value to participating agencies.

ISECG operates under a terms of reference which establishes its principles of operation. The terms of reference reflects the key principles set out in the Global Exploration Strategy – Open and Inclusive; Flexible and Evolutionary; Effective; and Mutual Interest. By sharing relevant information and working collaboratively on products, participating agencies hope to inform their individual decision making in ways that effectively leverage investments and identify partnerships which take concrete steps towards partnerships which reflect a globally coordinated exploration effort. Of course, partnerships between agencies are established and conducted outside the scope of the ISECG.

ISECG agencies recognize the importance of striking a proper balance between general information sharing and the development of work products. Care is taken to ensure that collaborative products are serving upcoming decision making needs of participating agencies.

ISECG PRODUCTS

Participating agencies may propose collaborative work on products intended to inform individual decision agency decision making in a timely fashion. The personnel resources committed to ISECG are not inconsequential, so agencies expect a solid return on these investments. The continued agency commitment to ISECG reflects the fact that its products are effective.

Decisions being taken today are generally related to investments in advanced technologies, ISS research, or robotic missions. Some agencies are making investments in the capabilities needed to go beyond LEO. Products are defined and work plans established which serve to enable the availability of the products and related data. These products are usually reflecting merged policy and plans and therefore serve to establish point of reference or sense of the global community.

The ISECG Reference Architecture for Human Lunar Exploration

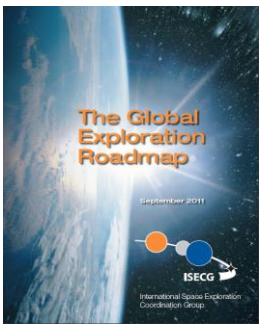
This product was developed as NASA's Constellation Program took shape. NASA hoped to enable an international effort to explore the lunar surface, so ISECG invited interested agencies to participate in a study of lunar exploration objectives and exploration concepts that could meet common agency objectives. Participating agencies succeeded in indentifying a common understanding of how humans could extensively explore the Moon, and laid the ground work for partnerships that would enable such an exciting exploration endeavor.

The result of this study was a significant step forward for advancing the Global Exploration Strategy. The ISECG Reference Architecture for Human Lunar Exploration demonstrated the value of a common international reference scenario. It also demonstrated the usefulness of ISECG in performing pre-program formulation study work. By performing the conceptual lunar study in an open and transparent manner, ISECG was able to inform large and small agencies regarding how their capabilities and long term interests may lead to specific contributions to an international exploration endeavor.

A more detailed description of the ISECG Reference Architecture for Human Lunar Exploration can be found in the paper *IAC-10.A5.2.9, An International Strategy for Human Exploration of the Moon: The ISECG Reference Architecture for Human Lunar Exploration.* (Ref 1).

The Global Exploration Roadmap

The Global Exploration Roadmap further advances the strategy defined in the GES by creating a framework for technical and programmatic discussions among interested agencies. This framework has 3 elements: Common Goals and Objectives, Long Range Human Exploration Scenarios, and coordination of exploration preparatory activities. By understanding the elements common to their exploration goals and objectives and by collaborating to examine potential long range exploration scenarios, agencies seek to inform near term decisions affecting their exploration preparatory activities.



The first iteration of the Global Exploration Roadmap

VALUE DELIVERED BY INFORMING PAST AGENCY STUDIES AND ACTIVITIES

In preparing future space exploration activities and managing the day-to-day activities of ongoing programs and projects, space agencies have benefitted from their participation in ISECG. ISECG products reflect synergies of the programs and plans of participating agencies, so in that respect they are a reflection of emerging global consensus on key matters related to space exploration during this time when agencies do not have many formal human space exploration partnership agreements. ISECG meetings also give agencies the opportunities to learn more about the interests and priorities of their partners. Through both of these activities (meetings and developing products), agencies take away information which informs their decision making. It also enables them to make recommendations to higher level bodies, such as political bodies, which are debating space exploration roles and priorities.

While it is difficult to quantify the importance of benefits enjoyed by participating agencies, this section provides several examples of how individual agency activities of the past have benefited though participation in ISECG.

CSA exploration plans and investments in technology development related to space exploration

The CSA established an Exploration Core program in 2007 to focus its preparatory activities in space exploration in line with the Global Exploration Strategy. In 2009, the Canadian government increased its investment in space exploration technology as part of the Canadian Economic Action Plan. The CSA is investing this stimulus funding to advance the technology in areas of Canadian leadership. Canada participation to space exploration is mainly through contributions to our partner missions. Therefore, ISECG discussions and the various products developed were essential to orient the investments to ensure that the resulting products will represent critical contributions welcomed by our partners.

In 2010, CSA was reorganized and a branch dedicated to space exploration was created. This branch covers ISS (Canadian robotics and ISS utilization), space astronomy, planetary exploration, human space flight and life science related to human health. The Space Exploration Branch is currently producing a space exploration plan. A key element of this plan is to ensure that all space exploration activities bring benefits to Canadian while responding to government priorities.

The discussions taking place with ISECG as for example on the lunar architecture and the Global Exploration Roadmap provide essential information to CSA. This information allows CSA to tailor its investment to ensure a better return. The discussions on the benefits of space exploration are also essential because they allow CSA to improve the demonstration of positive outcomes of space exploration.

Joint CNES and DLR Report on Exploration

The Ministers of France and Germany agreed in February 2010 that CNES und DLR should working together on a proposal for future exploration activities. Consequently, the agencies engaged in a series of dialogs to develop a joint report. It concludes that the timeframe 2010 – 2020 (step 1) will focus on ISS utilization, the ExoMars Project, and the Lunar Lander Mission. The decade thereafter (step 2) should reflect on options for European contributions to international robotic and human exploration missions to the Moon, the near Earth asteroids and Mars, including MSR (2020 – 2030). The period after 2030 should then be used for the preparation of a human mission to Mars as well as advanced robotic missions into the deep solar system.

The outlined CNES/DLR strategy considered both robotic and human missions equally. Scientific, technological and societal outcomes and their mid- and long-term financial consequences were analysed carefully. The CNES/DLR effort found that Europe has to concentrate on its own strengths to prepare for cooperation. The European planning should keep a certain flexibility in order to react if international partners change their plans. In a context of international cooperation in which any partner, including the USA, cannot afford everything, Europe must develop significant and critical contributions of scientific and technological expertise consistent with its domains of excellence. The ISECG work on a lunar exploration scenario enables Europe to identify interesting areas of contribution, building on its strengths.

It is also important that European contributions remain feasible even in the case of retreating partners, while they should aim at providing complementary capabilities where possible, and critical redundancies where necessary. Large exploration achievements can be expected and many lessons can be learned from ISS. Those are comprehensive scientific results of ISS research and validation of various technologies with high relevance for exploration:

- Routine cargo transportation to LEO, eventually including cargo return to Earth,
- Demonstration of European capabilities for landing and surface mobility on planets,
- Technology demonstrations and validations for future robotic and human space exploration,
- Scientific results about the Martian atmosphere, surface composition and possible identification of traces of extinct or extant life,
- Scientific results of the surface properties of the Moon.

The automated Lunar Lander is a valuable option to develop precision landing capabilities early in order to move into step 2. It also enables mastery of critical technologies needed to implement the ISECG lunar architecture.

In the DLR/CNES vision, step 2 shall allow an increased European participation in international exploration activities. Based on the success of step 1, Europe will be well-prepared to contribute essential elements for robotic missions and human space flights to ISS and beyond. Several options have to be evaluated, e.g. to participate in sample return missions with a high interest from the science community, and/or to focus more on advanced in-situ research through landing missions to Moon, Mars and NEOs.

Depending on the European choices in step 2 elements, step 3 would be shaped. It would require highly sophisticated and reliable technologies in many areas. The continuous efforts on global scale will bring humans to Mars and possibly beyond, connected with numerous sophisticated robotic missions in the solar system.

NASA Constellation Program Requirements Development

As NASA moved further in formulating the Constellation Program, specific requirements for capabilities to reach and explore the lunar surface were needed. Transportation systems such as the Altair Lunar Lander and the heavy lift launcher, Ares V were approaching their systems requirements reviews. NASA wanted to inform the requirements for these transportation

systems by considering the role they would play in an international lunar surface exploration program.

The ISECG Reference Architecture for Human Lunar Exploration provided an excellent opportunity to understand what an international exploration campaign might look like. The work on common goals and objectives identified a strong interest in balancing scientific exploration of the moon with testing exploration technologies needed for Mars exploration. Some of the Mars exploration technologies, such as extended mobility systems, could only be robustly tested via extended stays of astronauts on the lunar surface. Until this time, NASA had considered only two design reference missions for lunar exploration: Sortie mission and Outpost mission. The addition of the Extended-Stay design reference mission drove Altair requirements as the crew would stay on the lunar surface for increasingly longer durations exploring locations without a permanent outpost. These missions, up to 28 days, were clearly important drivers to the Constellation transportation elements and would have been costly to add after conducting a systems requirements review.

Artist image of Altair Lunar Lander

Lunar Exploration Strategy Study in Japan

In 2008, the space basic plan was authorized and called for a comprehensive study for Japan's lunar exploration. According to the demand, a study group was organized under the Minister of state for Space Policy and intensively studied the exploration objectives and roadmap for technology development considering international context including ISECG. The study group published a report in July 2010, which is referred from the policy authorized by Strategic Headquarters for Space Policy.

In the report, the following were proposed for the robotic lunar exploration program of Japan:

- First lunar landing and short term investigation around the landing site, by 2015. Demonstration of Japanese capabilities for landing and surface mobility on planets,
- Assembly of the base, long-term investigation and sample return, by 2020.
- Demonstrate leadership in international collaboration scenarios

The following were proposed for human space exploration activities of Japan:

- Research and development of the basic technologies for a human transportation system by around 2020, including
    - Safety enhancements to the rocket engine
    - Emergent escape technology
    - Human-rated re-entry technology
    - Environment control and life support system technologies
- International cooperation is mandatory for human space exploration

Space Strategy of the German Federal Government

The federal government's new strategy underlines the great significance of space technology as a key technology for the future of Germany. Furthermore, it emphasizes the continued and intensified dialogue with our international partners for large scale space mission. This includes the exploration of other planetary bodies "in situ", exerting a particular fascination towards the hope to answer the question of the origin of life. It applies equally to manned missions to the International Space Station as well as for advanced robotic missions to the depths of the universe.

From the government's point of view, space exploration missions need to be judged by their contribution to the solution of societal challenges. Therefore it is important to serve a clear scientific purpose, to maintain a high technical quality and to face a transparent monitoring of results.

Guided by a focus on benefits and needs, the principle of sustainability and close European and international co-operation, the strategy

features autonomous and intelligent robotic systems as key technologies for future space exploration.

ONGOING AGENCY ACTIVITIES INFORMED BY ISECG

This section describes activities underway within various agencies and how ISECG participation influences these studies and technical activities.

ASI Study on ISS

Within the human exploration initiatives, ASI considers ISS an important test-bed for experimentation of some enabling technologies. To reinforce this point and inform future areas of investment within ASI, several studies have been initiated. Understanding the specific requirements and priorities of the international community, through participation in ISECG, has provided a very useful context to these studies. The main areas of study are:

- Autonomous/self regenerative environmental control and life support systems to be tested on ground and in orbit
- The behaviour of the human body in the long duration mission including the relevant medical countermeasures
- The use of the planetary local resources to be tested in reduced gravity environment

It is expected that the results of these studies will be available within the next year.

ESA Studies on Future Human Spaceflight and Exploration Scenarios

In 2009, ESA initiated a study process on future human spaceflight and exploration scenarios for informing the development of a strategic plan and roadmap for Europe. The work on the scenarios has been closely aligned with the ISECG work on the Global Exploration Roadmap. In this way,

- The identification, definition and assessment of potential European contributions to future international human spaceflight and exploration missions is based on an international reference scenario commonly developed by all major space agencies worldwide;
- The identified European objectives and interest inform and influence the development of the international reference scenario.

As part of the study process, ESA has engaged its internal advisory structure and broader stakeholder community for collecting feedback on the ISECG work on the Global Exploration Roadmap as well as on potential European contributions to future mission scenarios and the overall European roadmap considered. The feedback obtained proofed to be highly valuable for both, the consolidation of the European roadmap as well as the development of the 1st version of the Global Exploration Roadmap. Furthermore, sharing early work performed by ISECG has helped to demonstrate to the broader community the commitment of agencies investing today in preparatory activities for future exploration to coordinate and seek partnerships.

NASA Exploration Architecture Studies

NASA continues to pursue an ambitious vision for human spaceflight that will take astronauts beyond low Earth orbit and ultimately Mars. To enable this vision, NASA is investing significantly to speed the development of technologies needed to take us deeper into space, including travel to a series of destinations including asteroids, the Moon, the moons of Mars and eventually Mars itself. NASA is focusing its resources on innovation, and developing two fundamental exploration building blocks, the Space Launch System and the Multipurpose Crew Vehicle. NASA also continues its dedication to the successful International Space Station and hopes to leverage private sector resources to enable continued crew and cargo support.

Engagement within ISECG is an important element of NASA's efforts to lead these exciting future missions. By sharing the status of ongoing architecture studies with international partners, NASA gains insights which are used to improve study products and take steps towards building consensus on capabilities and future missions.

Joint Agency Studies Related to Exploration Contributions

A major goal of agencies participating in ISECG is to enable exploration partnerships which will enable them to realize their objectives in a more

robust manner. Being a multilateral forum, where dialog is open and transparent, specific partnership arrangements are out of scope. However, through their participation in ISECG, several agencies have identified areas of interest which have led to dedicated bilateral studies. Near-term partnerships in the areas of ISS utilization, robotic interface commonality and terrestrial analog activities have materialized. Partnerships in the development of exploration capabilities are expected to follow.

ONGOING WORK WITHIN ISECG

This section highlights several ongoing ISECG activities which are intended to influence future decision making. Agencies participating in ISECG see the value of collaboratively developing products related to exploration. As stated above, ISECG remains relevant because care is taken to identify products which are useful for informing individual agencies decision making in the near term. Examples of how ISECG products have informed recent, current and future decision making are shared in this chapter.

Robotic Precursor Mission Knowledge Gaps

Robotic missions will continue to provide information which informs the planning and implementation of human exploration missions. Whether originated as science missions or human precursor missions, robotic missions will characterize solar system environments, identify risks and potential resources. ISECG is working to collect a list of strategic knowledge gaps associated with the human exploration of the Moon, asteroids and Mars. This information will be prioritized and tied to the needs of each of the mission scenarios in inform current and future decision making. Decisions in these areas are expected to take concrete steps in preparing for space exploration initiatives:

- Use of ISS for Exploration
- Robotic Precursor Missions
- Advanced Technologies
- Next Generation Capabilities and Infrastructure
- Terrestrial Analogue Activities

This paper has demonstrated how the work of ISECG has and will continue to inform agency decision making. Going forward, the GER will provide an effective framework for having discussions related to individual agency areas of interest. Agencies participating in ISECG feel strongly that work on the GER will continue to productively inform their decision making and planning.

the Global Exploration Roadmap. It will be published in the next iteration of the Global Exploration Roadmap. By developing this list of knowledge gaps, participating agencies will be able to assess the extent to which planned robotic missions contribute to filling these gaps and identify interesting investigations for future precursor missions.

Exploration Technology Assessment

No one agency can invest in all the needed technologies which make human space exploration sustainable and affordable. Agencies participating in ISECG are interested in advancing key technologies as soon as feasible to enable future exploration missions. They are looking for opportunities to appropriately coordinate investments being made today. In some cases, partnership opportunities may also make sense. To begin this process, agencies are sharing their ongoing technology priorities. They are also mapping needed technologies to ISECG mission scenarios in order to establish a common understanding of exploration needs. Agencies are confident that this work will enable them to make informed decisions regarding individual technology investments, understanding the efforts underway in partner agencies.

SUMMARY

Agencies are investing in many activities today which will prepare for exploration missions of the future. Activities preparing for human exploration missions are ongoing in several areas and agencies are benefitting from their participation in ISECG in order to

From today's perspective, the human presence on Mars remains a vision. It is envisioned that missions to asteroids and back to the Moon will contribute to reducing Mars mission risks. Many of the infrastructure elements needed for missions to Mars could be tested, demonstrated, and prototyped on Moon as a test bed. Deep space missions, such as those to near Earth asteroids will demonstrate advanced propulsion and habitability systems. To master all the challenges of manned trips to Mars and to bring a crew safely back to Earth, a tremendous effort

in research, advanced technology development and building next generation capabilities has to be done collectively. ISECG enables agencies to gather the insights they seek in preparing their part of these exciting future missions.

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