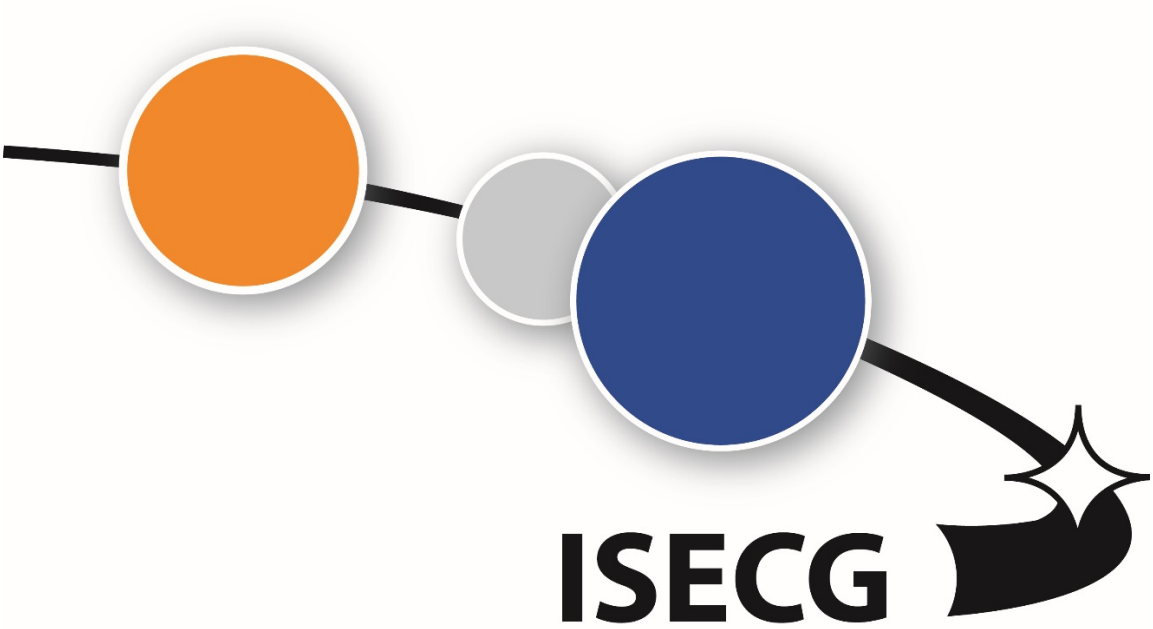

INTERNATIONAL SPACE EXPLORATION
COORDINATION GROUP

Annual Report 2016

International Space Exploration Coordination Group – ISECG

ISECG was established in response to the "The Global Exploration Strategy: The Framework for Coordination" (GES) which was released in May 2007. This GES Framework Document articulated a shared vision of coordinated human and robotic space exploration focused on solar system destinations where humans may one day live and work.

The purpose of ISECG is to provide a forum to discuss interests, objectives and plans in space exploration and to support promotion of interest and engagement in space exploration activities throughout society. The work of ISECG agencies results in documents, papers, findings and recommendations that are critical in informing individual agency decision making. In 2016, ISECG´s membership counted 15 space agencies.

INTERNATIONAL SPACE EXPLORATION COORDINATION GROUP

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All ISECG documents and information can be found on:

http://www.globalspaceexploration.org/

Table of Contents

1 Executive Summary

In 2016, ISECG pursued a range of activities, amongst other things preparing for the next update of the Global Exploration Roadmap (GER), the publication of which is planned for the end of 2017.

A major milestone was achieved in November 2016 with the publication of the document '*Scientific Opportunities Enabled by Human Exploration Beyond Low-Earth Orbit – The Summary*'. It presents key findings of a coordinated interaction of the ISECG agencies with the international science community, in particular with COSPAR, the Committee on Space Research. Key scientific opportunities have been identified for the near term mission themes of the GER (extended crewed missions in the Lunar vicinity, human missions to the Lunar surface and to Near-Earth asteroids) as well as for the horizon goal of Mars. A more detailed White Paper on the same subject is being developed, and will be finalized and published in 2017.

Participating ISECG agencies continued coordination for human missions in the lunar vicinity. Detailed conceptual work focused on potential crew missions to cislunar space to begin assembly of an evolvable deep space habitat, which could be used as a staging post enabling human lunar surface missions and eventually support missions to Mars. On an architecture level, ISECG has further advanced concepts for new elements and surface operations missions to support crewed operations for an international return to the lunar surface. In particular, a robotic demonstrator mission – comprising descender, rover and ascender – was identified as a key first step in the long-term development towards a human lunar lander and pressurized rovers. The mission, at the same time, will meet all robotic and scientific objectives as a precursor mission. Based on the established transportation architecture involving a two-stage lander ISECG has discussed a series of five surface operations conceptual missions. A mobile habitation concept was selected to potentially enable missions to different locations near the lunar South Pole. Mission planning, elements and operation concepts enable opportunities to coordinate technology investments amongst agencies and follow a timeline that incorporates potential synergies and maximizes affordability. Additionally, in the effort to better understand an important element in lunar exploration, lunar volatiles, three virtual workshops were held engaging international experts, also aiming to enable collaboration and cooperation.

In 2016, ISECG agencies also completed two detailed study activities in order to assess technology gaps in discipline areas that traditionally had not been examined on an international level. Teams of subject-matter experts were assembled from participating agencies to examined 'Dust Mitigation' and 'Liquid Oxygen (LOX)/Methane Propulsion'. For 2017, two new study teams have been formed to assess technology gaps in the areas of 'Autonomous Systems' and 'Telerobotic Control of Robotic Systems with Time Delay'. Amongst others, these study teams continue to identify appropriate opportunities to coordinate technology investments amongst agencies.

Another activity that began in 2015 and concluded in 2016 was focused on collecting best practices in communicating and delivering benefits resulting from investments in space exploration. Experts from participating agencies discussed four topics of common interest: technology transfer, health and medicine, sustainable resource management (e.g. life support systems) and robotics. The findings were documented in an internal report in August 2016.

2 ISECG Highlights, Achievements and Special Projects in 2016

Getting Ready for the 3rd Version of the Global Exploration Roadmap

During 2016, ISECG established plans for updating the Global Exploration Roadmap in late 2017. The updated roadmap will share progress made in formulating human missions to cislunar space, highlight robotic exploration missions and share achievements made on the International Space Station to prepare for future exploration missions.

ISECG participating agencies continued planning for human missions in the lunar vicinity. NASA's progress with SLS and Orion towards a first integrated test flight in 2018 and first crewed flight in 2021 will establish a transportation system which will enable humans to explore beyond low Earth orbit for the first time since Apollo. Detailed work by the ISECG Exploration Roadmap Working Group (ERWG) focused on crew missions to cislunar space to begin assembly of an evolvable deep space habitat. The evolvable deep space habitat could support missions to Mars and could also be used as a staging post enabling human lunar surface missions.

Aiming to enable collaboration and cooperation in the effort to understand lunar volatiles, the ERWG held three virtual workshops engaging international experts: 1) Where to explore and how, 2) Lunar surface prospecting instruments, and 3) Lunar volatiles acquisition technologies. Findings from these community workshops can be found at https://lunarvolatiles.nasa.gov. Additional workshops are planned in 2017.

The ERWG's Analogue Team continued to facilitate awareness and foster collaboration opportunities among participating agencies regarding analogue simulation activities designed to prepare for human space exploration as described in the GER. For example, several agencies participated in NASA's Extreme Environment Mission Operations (NEEMO) 21 focused on tasks that could be applied to missions on other planetary surfaces; and the international robotic deployments the "Field Trials Utah", led by the Canadian Space Agency, simulated two elements of a Mars Sample Return (MSR) campaign: (1) sample identification and collection, and; (2) sample fetching.

Concepts for New Elements and Surface Operations Missions

Starting from the human lunar return transportation architecture study completed in 2015, ISECG agencies further advanced a concept for the development and usage of new elements to conduct crewed operations for an international return to the lunar surface. In particular, the ISECG International Architecture Working Group (IAWG) has identified a robotic demonstrator mission as a key first step in the decade long development of a full-scale four-crewed human lunar lander as well as a pair of two-crew-sized pressurized rovers to be used for human lunar return. With human lunar return currently envisioned late in the 2020s, the demonstrator mission would need to occur in the mid 2020's, allowing time to incorporate early test results into the human-scale designs as well as maximize affordability. In contrast to typical robotic programs, the sub-scale lander design, descender, rover and ascender are intended to test and human rate systems for the full-scale lander in addition to meeting any robotic and scientific objectives as a precursor mission.

Based on the established transportation architecture involving a two-stage lander from the Near Rectilinear Halo Orbit (NRHO), the IAWG has designed a series of five surface operations conceptual missions. To enable missions to different locations starting near the South Pole, a mobile habitation concept has been selected in the form of two small pressurized rovers containing two crew each. The goal for each mission is to conduct a 42-day mission (two lunar

days and one lunar night) before returning the crew to the staging orbit and then back to Earth. The pressurized rover concepts are designed to minimize mass and volume by utilizing a minimum-energy régime supported by a radioisotope power system and secondary rechargeable system. After the crew returns from each 42-day mission, the rovers will traverse autonomously, without crew, to the next landing site of interest, requiring one less launch for each subsequent mission.

Development of ISECG Science White Paper, with publication of summary document

A major milestone was achieved in November 2016 with the publication of the document called '*Scientific Opportunities Enabled by Human Exploration Beyond Low-Earth Orbit – The Summary*'. This six-page document summarizes the key findings of a coordinated interaction of the ISECG agencies with the international science community, led by the representatives gathered in a Science Advisory Group. The document provides key scientific opportunities in the near term mission themes of the Global Exploration Roadmap – extended crewed missions in the Lunar vicinity, human missions to the Lunar surface and to Near-Earth asteroids – as well as at the horizon goal of Mars. Opportunities for scientific discovery associated with exploration missions are broadly captured in two scientific themes: 'Understanding Our Place in the Universe' and 'Living and Working in Space'.

In order to prepare for the document above, a workshop of COSPAR (Committee on Space Research) and ISECG took place in Paris in February 2016 in which more than 40 scientists and space agency representatives from around the world gathered to discuss the scientific potential of exploration missions. The workshop was a significant step in enabling the space exploration and science communities work together for the benefit of all.

Topical Gap Assessment: Dust Mitigation, LOX/Methane Propulsion

Based on an analysis of GER critical technology needs, ISECG agencies started to evaluate topic discipline areas that traditionally had not been examined on an international level to-date. The completion and release of the first two gap assessment reports in early 2016 were on 'Dust Mitigation' and 'LOX/Methane Propulsion'. For both topic disciplines the ISECG Technology Working Group (TWG) involved subject-matter experts from participating agencies. Following the release of the two ISECG reports, two AIAA Space 2016 conference papers were published and presented, respectively.

The goal and objectives were to identify technology gaps related to, but not limited by, the current GER mission scenario and to reveal opportunities for international coordination and cooperation for closing identified gaps. Thus, the focus of the analysis was on cislunar and lunar mission themes as well as long-lead items for human Mars exploration.

With respect to dust mitigation viable technology solutions have been identified, but still need further maturation before supporting missions. It was noted that no single technology today provides a complete solution to the challenges, but rather a suite of technologies will be required to address the challenges of dust mitigation. LOX/Methane propulsion still bears open questions related to this propulsion technology and its role as an enabler for future exploration with in-situ (Mars) propellant production, improved performance, and fluid commonality.

It was noted that analysis of additional topics regarding other critical technology needs may be beneficial to agency decision making with respect to the development of exploration technologies and identification of collaboration opportunities. ISECG agencies directed the TWG to form two new teams who will assess technology gaps related to the GER Critical

Technologies of “Autonomous Systems” and “Telerobotic Control of Robotic Systems with Time Delay” in the 2017 timeframe.

Communicating and Delivering Benefits from Space Exploration to Society

Under the organization of the ISECG Strategic Communications Working Group (SCWG) agencies participated in a “Tiger Team” activity focused on collecting best practices in communicating and delivering benefits resulting from investments in space exploration. This activity began in 2015, with the discussions and presentations from agency experts on three topics of common interest to participating agencies: technology transfer, health and medicine, and sustainable resource management (e.g. life support systems). In 2016, agencies added an additional topic of interest, robotics, and undertook an effort to document lessons learned for communicating benefits from investments in space exploration in an informal report to the full membership of ISECG. The report was finalized and distributed in August 2016.

Outlook for 2017/2018

ISECG Working Groups

Exploration Roadmap Working Group (ERWG)

The Exploration Roadmap Working Group will focus on preparing an update of the Global Exploration Roadmap, targeting publication for late 2017.

International Architecture Working Group (IAWG)

The IAWG continues to refine a reference lunar surface architecture for the primary GER mission scenario in response to strategic guidance from the ERWG. In 2017, the IAWG is planning to review the concepts of new elements and missions described in Chapter 2 within the larger ISECG community with the intent of including the new reference architecture in the Global Exploration Roadmap to be published later in 2017.

Science Working Group (SWG)

The Science Working group continues its coordinated interaction with the scientific community, in particular through

- Publication of the full Science White Paper in early 2017
- Consolidation of links with the global science community
- Feed of key science aspects in the upcoming version of the Global Exploration Roadmap

Strategic Communications Working Group (SCWG)

The SCWG will continue to implement and coordinate communication of the ISECG mandate, its products and activities. Major activities will comprise the following:

- Issuing ISECG webnews as appropriate;
- Preparation of the ISECG Annual Reports 2017 and 2018;
- Providing support of ISECG publications (e.g. the Global Exploration Roadmap 3 and the Science White Paper), ISECG outreach activities (e.g. Global Cooperation video, mentioning ISECG´s 10 year anniversary; co-hosted workshops) and ISECG contributions to international conferences;
- Preparation of key messages and success stories to communicate benefits from space exploration

Technology Working Group (TWG)

In 2017, the TWG will continue to advocate coordination and collaboration in technology development efforts of individual ISECG space agencies in support of the GER. In particular, the TWG will interact from a technological point of view with the GER3 elaboration and will continue to perform a technology gap identification and closure analysis with focus on critical technologies and investment gap analysis in relation to the implementation of the latest GER and identify opportunities to collaborative technology development. Two new gap assessment teams will carry out the assessment of the discipline topic areas of “Autonomous Systems” and “Telerobotic Control of Robotic Systems with Time Delay”, with estimated report completion early fall of 2017.

Major Events (status February 2017)

- Humans to Mars Summit 2017 — Washington D.C./USA, 9-11 May 2017
- Global Space Exploration Conference (GLEX 2017) — Beijing/China, 6-8 June 2017
- 68th International Astronautical Congress (IAC) — Adelaide/Australia, 25-29 September 2017
- International Space Exploration Forum (ISEF2) — Japan, 3 March 2018

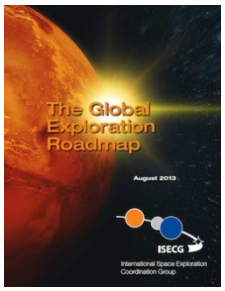
Annex I

Publications

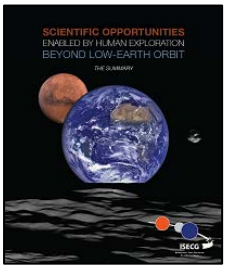
ISECG Webnews 2016

Towards a Scientific Perspective on the Global Exploration Roadmap	January
ISECG Space Agencies and International Scientists discuss Scientific Perspectives for the Global Exploration Roadmap	March
ISECG Annual Report 2015 published	April
Outcome of the International Moon 2020-2030 Symposium on a New Era of Human and Robotic Exploration	July
NASA's OSIRIS-REx Speeds Toward Asteroid Rendezvous	September
Space for Inspiration	November
Scientific Opportunities of Exploration Beyond LEO	November
ExoMars – Ready for Science and for the Future	December

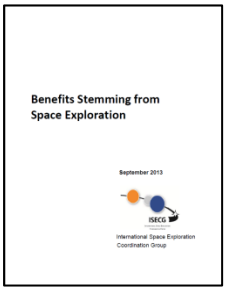
Major ISECG Documents



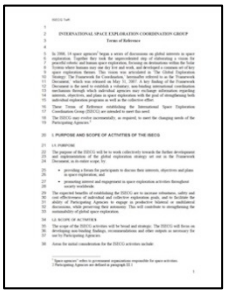
The Global Exploration Roadmap (GER), August 2013



Scientific Opportunities enabled by Human Exploration beyond Low Earth Orbit – The Summary



[Benefits Stemming from Space Exploration]



[ISECG Terms of Reference]

More ISECG documents and published papers can be found at [ISECG Publications].

Annex II

ISECG Members and Working Groups

Members

Agenzia Spaziale Italiana (ASI), Italy

Canadian Space Agency (CSA), Canada

Centre National d'Etudes Spatiales (CNES), France

China National Space Administration (CNSA), China

Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany

European Space Agency (ESA)

Indian Space Research Organisation (ISRO), India

Japan Aerospace Exploration Agency (JAXA), Japan

Korea Aerospace Research Institute (KARI), Republic of Korea

National Aeronautics and Space Administration (NASA), United States of America

Russian Federal Space Agency (Roscosmos), Russia

State Space Agency of Ukraine (SSAU), Ukraine

United Arab Emirates Space Agency (UAE Space Agency), United Arab Emirates

United Kingdom Space Agency (UKSA), United Kingdom

Working Groups

Exploration Roadmap Working Group (ERWG)

The Exploration Roadmap Working Group leads the human spaceflight roadmapping effort which is intended to establish a common roadmap and a common framework to promote partnerships in realizing exploration missions. A summary of their work is communicated in regular updates of the Global Exploration Roadmap (GER).

International Architecture Working Group (IAWG)

The International Architecture Working Group leads multilateral reference architecture work, develops shared requirements, identifies critical functions and technologies and shares innovative architectural concepts. The IAWG is currently building concepts to augment the GER mission scenario, focusing specifically on characterizing human missions to the lunar surface based on robust international partner contributions.

Strategic Communications Working Group (SCWG)

The objectives of the SCWG are to provide a clear, consistent and coordinated communication of the ISECG mandate, its products and activities, to support the development of ISECG products, as well as to support the exchange amongst agencies on stakeholder engagement activities. Major activities of the SCWG include the development of ISECG webnews, the preparation of the ISECG Annual Report and the facilitation of topical exchanges amongst agencies.

The SCWG is fostering an exchange on lessons learned and best practices among ISECG agencies in communicating and delivering benefits resulting from investments in space exploration.

Science Working Group (SWG)

The Science Working Group coordinates with science communities on exploration planning and activities as required for the generation of ISECG products. It currently focusses on advancing the development of a Science White Paper for the articulation of science opportunities in the GER in conjunction with the science communities.

Technology Working Group (TWG)

The goal of the Technology Working Group is to identify and raise awareness on critical technology gaps related to the GER, and to advocate coordination and collaboration in technology development efforts of individual ISECG space agencies in support of the GER. The strategic nature of technology investments and the desire of space agencies to focus investments to maximize their contribution potential while enabling meaningful and achievable opportunities for all participating agencies must hereby be recognized.

Annex III

ISECG at a Glance: Scope and Background

ISECG, the International Space Exploration Coordination Group serves as the forum where space agencies work together on means of strengthening individual exploration programs, facilitating collaborations and advancing the Global Exploration Strategy (GES) through the coordination of participating agencies' mutual efforts in space exploration. ISECG also supports promoting interest and engagement in space exploration activities throughout society. In 2016, ISECG membership counted 15 space agencies[1].

The **scope of ISECG** is broad and strategic. Its activities are based on the following **principles**:

- Open and inclusive
  - ISECG receives inputs from all interested agencies that invest in and perform space exploration activities.
  - ISECG provides for consultations among all agencies with a vested interest in space exploration.
- Flexible and evolutionary
  - Existing consultation and coordination mechanisms are taken into account.
- Effective
  - ISECG workshops and products provide value to individual participating agencies.
- Of mutual interest
  - ISECG activities benefit all participants and respect national prerogatives.
  - ISECG activities allow for optional participation based on the level of interest.
  - ISECG participants focus on developing non-binding products - findings, recommendations and other outputs as necessary – based on consensus.

Background

In May 2007, an initial group of 14 space agencies jointly released "The Global Exploration Strategy: The Framework for Coordination". It describes a shared vision of coordinated human and robotic space exploration focused on solar system destinations where humans may one day live and work.

The GES identifies a common set of **exploration themes and benefits**:

- New knowledge in science and technology
- A sustained presence – extending human frontiers
- Economic expansion
- A global partnership
- Inspiration and education

One of the many Framework document findings was the need to facilitate information exchange among individual agencies regarding their interests, plans and activities in space exploration. Therefore, the GES called for a voluntary, non-binding coordination mechanism among interested space agencies. This call led to the establishment of **ISECG** by the participating agencies including the formulation of Terms of Reference (ToR).

[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), SSAU (Ukraine), Roscosmos (Russia), UAE Space Agency (United Arab Emirates), UK Space Agency (United Kingdom). "Space Agencies" refers to government organizations responsible for space activities.