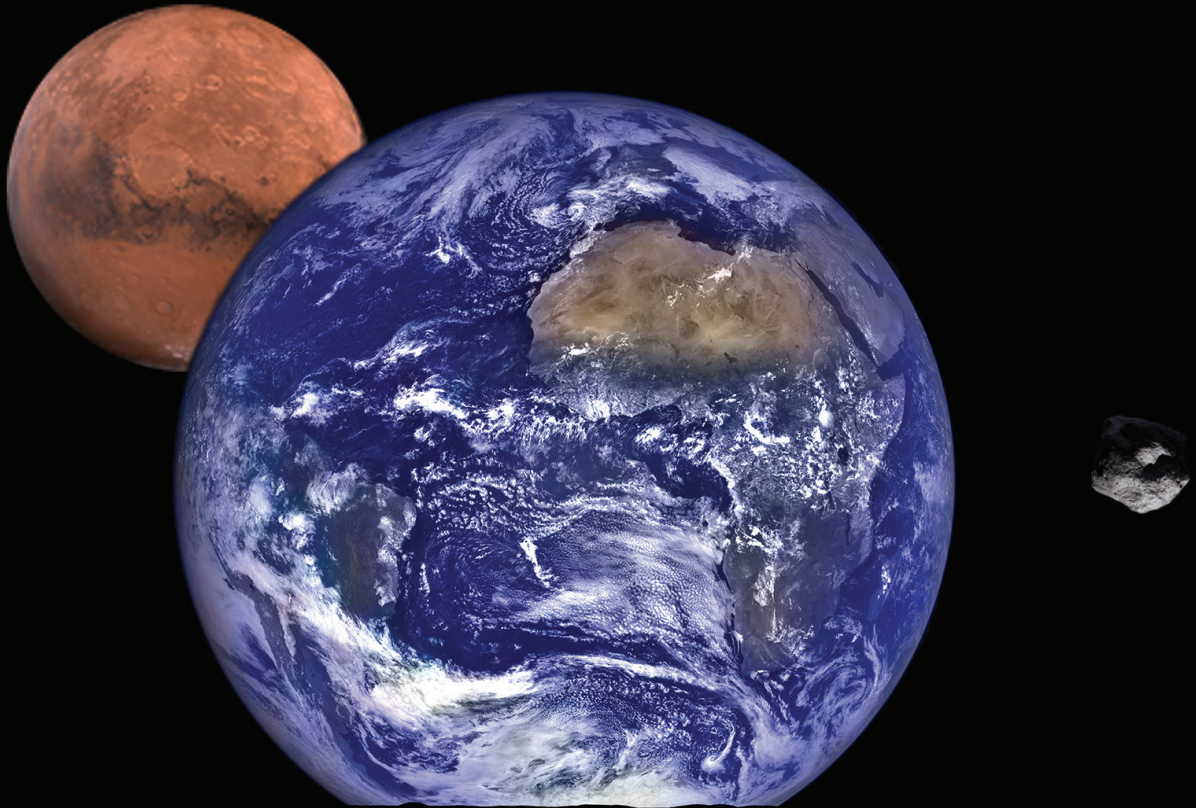


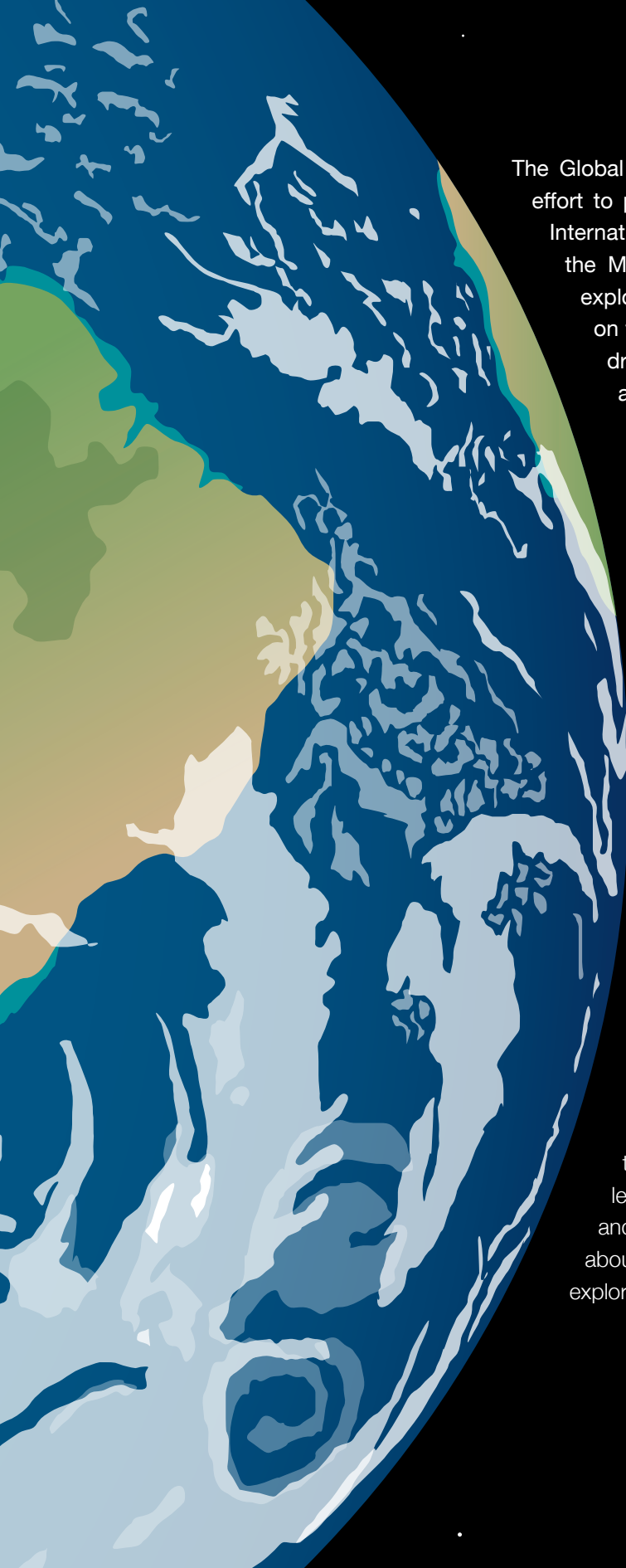
SCIENTIFIC OPPORTUNITIES ENABLED BY HUMAN EXPLORATION BEYOND LOW-EARTH ORBIT

THE SUMMARY



ISECG

INTERNATIONAL SPACE EXPLORATION
COORDINATION GROUP



The Global Exploration Roadmap reflects a coordinated international effort to prepare for space exploration missions beginning with the International Space Station and continuing to the lunar vicinity, the Moon, asteroids and Mars. These missions are part of an exploration endeavour available for pursuit by all space agencies, on their own or in collaboration with others. Human exploration drives innovation and economic expansion, addresses space and terrestrial challenges to improve life on Earth, and inspires people around the world. Integral to these benefits are scientific investigation and discovery.

The Scientific Imperative

Space exploration will result in scientific discoveries that have significance not only to the international science community, but to humanity as a whole. Opportunities for scientific discovery associated with exploration missions are broadly captured in two themes: “Understanding Our Place in the Universe” and “Living and Working in Space”.

Understanding Our Place in the Universe

This theme is about discerning the physical nature of the Universe around us and our place within it. We want to understand the Earth-Moon system, asteroids and Mars and how they formed and developed. We will conduct new observations of the cosmos, including our own Earth. Finally, we will attempt to understand the formation and the evolution of life.

Living and Working in Space

This theme is reflecting the drive for humans to extend our reach into space, which also provides important scientific and technological advances to improve life on Earth. We want to learn more about how humans safely explore the Solar System, and reduce risks that humans face in space. We also want to learn about the local resources in our planetary neighbourhood, and how explorers can maximize the use of what we find around us.

The Value of Human Explorers for Science

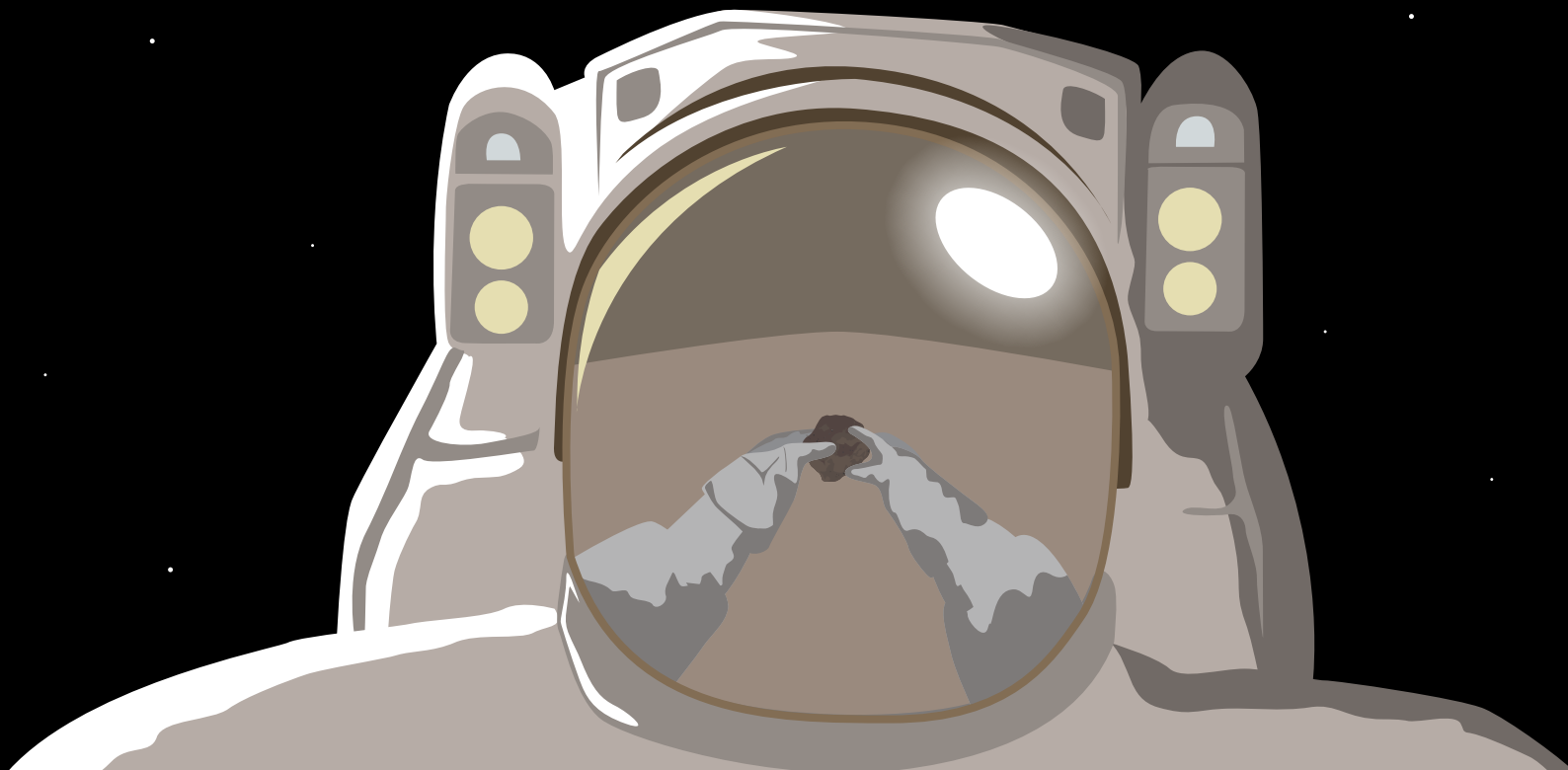
Human exploration brings the human element to the forefront of scientific discovery, bringing flexibility, adaptability, experience, dexterity, creativity, intuition, and the ability to make real time decisions. This was clearly and repeatedly demonstrated by the Apollo missions to the lunar surface. While some science objectives can be achieved by suitably implemented robotic missions, many are greatly facilitated by a human presence, and some may even be wholly impractical otherwise.

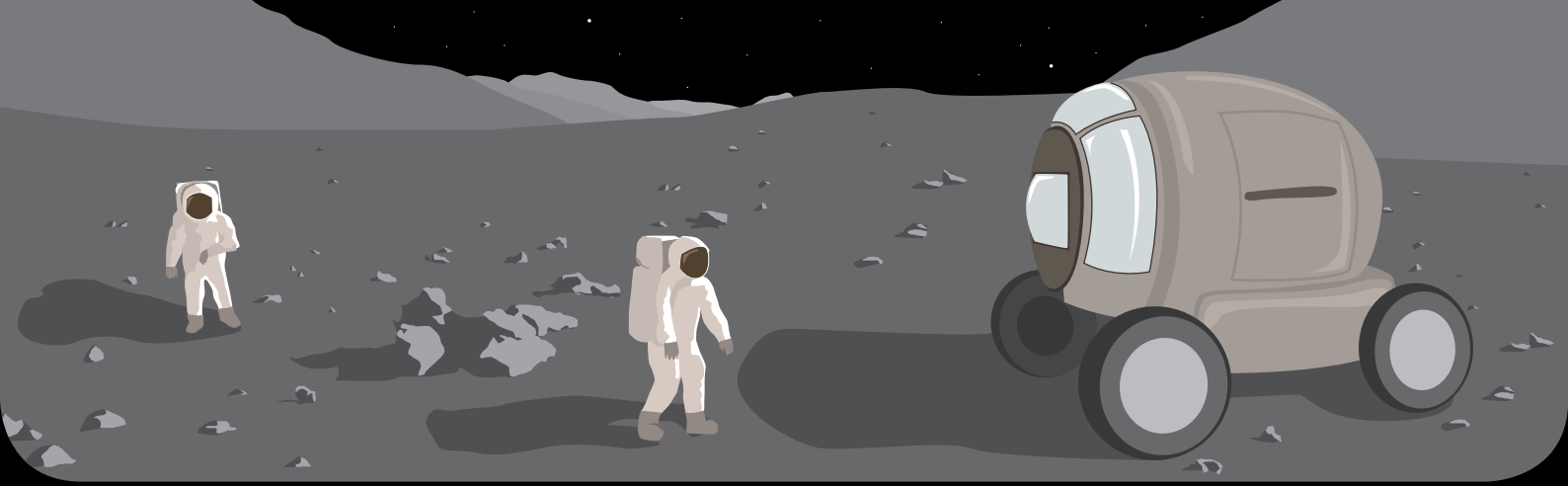
- Humans can efficiently and intelligently select and collect samples from a diverse range of localities. Trained explorers will also provide a broader geological context due to integrated observations, thus returning the best samples to address specific science and exploration questions. In addition, human missions typically return larger amounts of samples per flight.
- Humans are uniquely capable of installing, maintaining, upgrading, and troubleshooting problems with complex scientific equipment, as historically exemplified with the Hubble telescope servicing missions.

- Humans can often achieve tasks faster than robots and act intelligently in exploratory science.
- As demonstrated by Apollo and on the International Space Station, humans are unique in their ability to recognize and to adapt their response to new observations or serendipitous discoveries.

In addition to scientific benefits, gaining operational experience in deep space or on a planetary surface is extremely beneficial for the later exploration of more distant targets, such as Mars.

Humans have long looked to the stars and asked, “What is out there?” Exploration, investigation, and scientific discovery are essential elements in the history of humanity, and the same will be true in our future. Human exploration missions significantly increase the potential for scientific discovery at the lunar vicinity, the Moon, asteroids, and Mars.





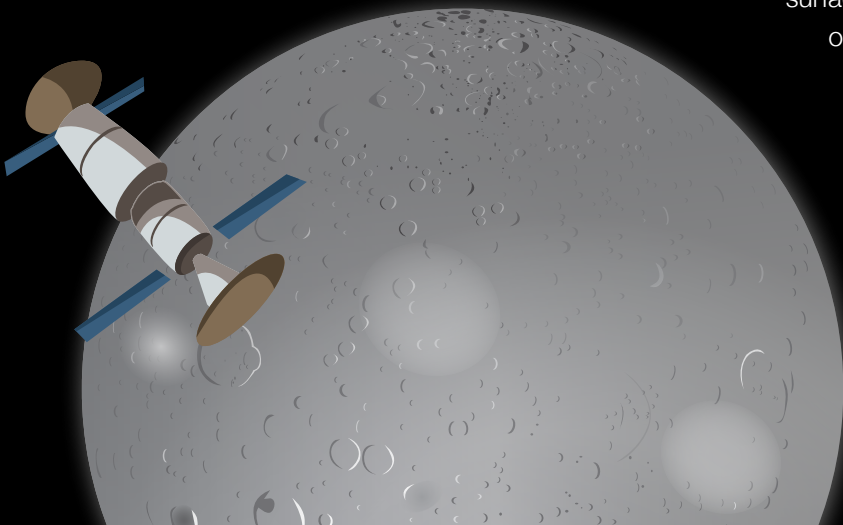
The Next Step Beyond Low-Earth Orbit

The vicinity of the Moon is the ideal location as the next step in the expansion of human space activity from the International Space Station leading to investigations of the Moon, asteroids, and Mars. This deep space environment enables testing and validation of habitation systems and related operations techniques, while remaining close enough to Earth as we learn to manage exploration mission risks. Increasingly longer duration missions to a habitat in the deep space environment enable study of the interplay of radiation, microgravity and isolation on human health, valuable for future spaceflight to more distant destinations, notably Mars, as well as health research on Earth. The infrastructure can support cubesats and small satellites by providing services such as deployment and communication relay. It can facilitate remote controlled robotic exploration on the lunar surface. It can also be used for investigations in areas such as astronomy, fundamental physics, collecting interplanetary materials, and heliophysics.

The Lunar Surface

Scientific investigations, including collecting the right samples, on the Moon will improve our understanding of the origin and evolution of the Earth-Moon system, and of terrestrial planets in general. The Moon has experienced many of the geologic processes that have shaped the terrestrial planets in our Solar System (e.g., impact cratering, volcanism, tectonics, etc.). We can date impact events and decipher the impact flux for the Earth-Moon system over geologic time to better understand its role for the evolution or extinction of life on Earth. The lunar soil and subsurface also provide a historical repository of the Solar System's evolution.

Human presence could permit the emplacement of delicate surface instrumentation on the lunar surface. Indeed, the far side of the Moon is unique in that it is “radio quiet”, offering the opportunity for sensitive measurements that look back in time to the earliest moments of the Universe. Investigating the physiological response to working in reduced gravity on the lunar surface could help prepare for keeping humans healthy on the surface of Mars, whilst providing new insights into a range of human health issues for Earth.



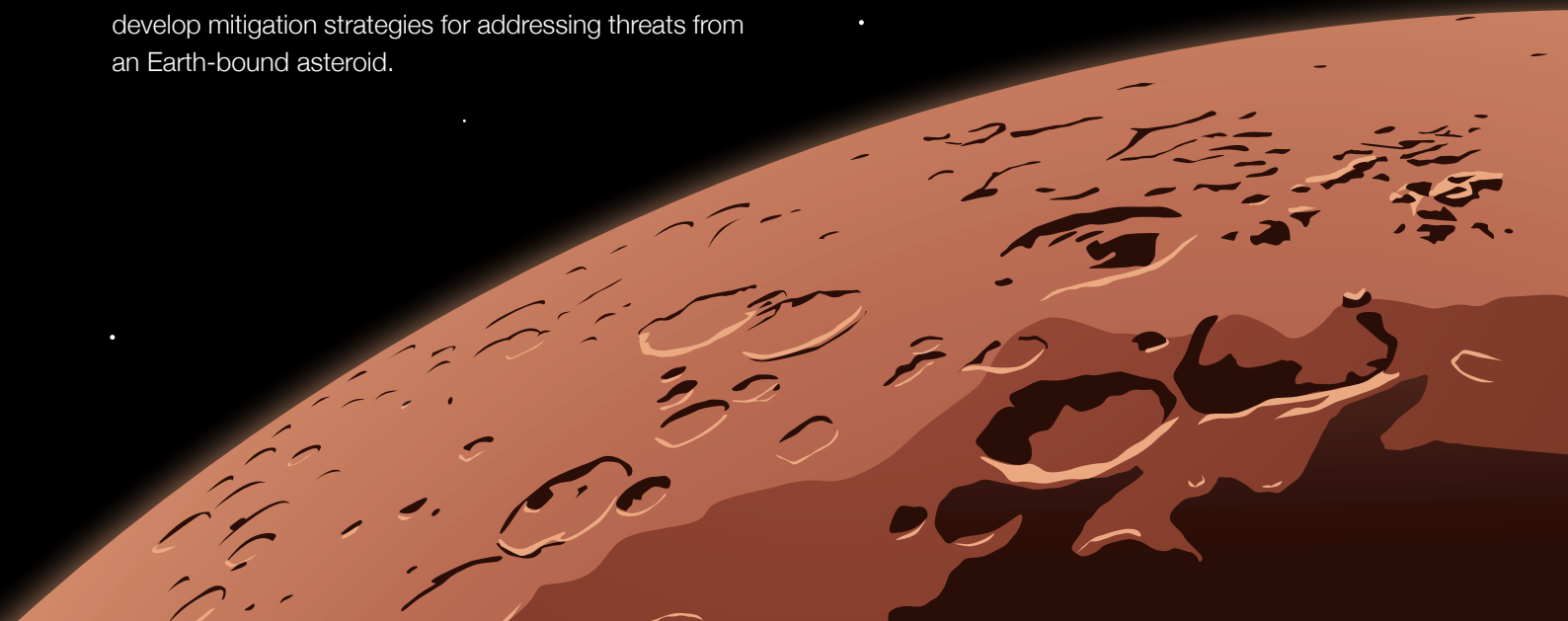


Near-Earth Asteroids

Near-Earth asteroids exhibit considerable diversity within their population and they have witnessed events and conditions throughout the history of the Solar System. The presence of humans, whether on a returned asteroid boulder in the lunar vicinity or on an asteroid in its native orbit, will permit placement of complex instruments on the asteroid surface, as well as the ability to sample surface and subsurface sites to obtain information on the ancient history of the Solar System which larger, evolved planetary bodies have lost. Carefully chosen samples by a trained explorer can also help us to better understand the thousands of meteorites we already have available for study by scientists, providing geologic context to meteorites that have formed much of the paradigm for the origin of the Solar System. We will also work to better understand the internal structures of Near-Earth Asteroids, a vital part of the puzzle needed in order to develop mitigation strategies for addressing threats from an Earth-bound asteroid.

Mars

Mars is the shared horizon goal driving sustainable human exploration. Mars has the greatest similarity to Earth in past and current planetary processes, and may have the best record of when life started in our Solar System and of catastrophic change in planetary evolution. Our robotic missions have shown that Mars has significant amounts of water that is promising for the possible existence of life (past and/or present) and supporting humans. Exploration of Mars will result in answers to profound scientific and philosophical questions such as: How did life start in our Solar System? Did life exist on Mars and does it exist today? What can we learn about Earth's past and future by studying Mars? Building on over 50 years of robotic-enabled science and eventually, sample return, human explorers on the surface of Mars will be critical to reveal the subtleties needed to answer these complex and fundamental questions. Humans will make possible intelligent sampling in geologic context, iterative environmental field investigations and sample preparation/analyses in a habitat-based laboratory. Humans will advance a multi-disciplinary set of scientific objectives, such as investigations into astrobiology, atmospheric science, medicine, and geoscience.



Scientific Opportunities Enabled by Human Exploration Beyond Low-Earth Orbit The Summary

Space agencies participating in the International Space Exploration Coordination Group (ISECG) are discussing an international approach for human and robotic space exploration to achieve broad social, intellectual and economic benefits. This document is a summary of a forthcoming white paper of scientific opportunities enabled by the presence of humans, and their infrastructure, as they explore the Solar System, as documented in ISECG's Global Exploration Roadmap. The science white paper will inform the next edition of the Global Exploration Roadmap, expected in late 2017. It was developed by ISECG agencies together with a Science Advisory Group, including representatives from the international scientific community and reflecting the views and inputs from an open interaction with this community.

ISECG was established to advance the Global Exploration Strategy by providing a non-binding forum where 15 space agencies share their objectives and plans, and explore synergistic concepts. ISECG agencies are committed to the development of products that enable participating agencies to take concrete steps toward partnerships that reflect a globally coordinated exploration effort.

ISECG members:



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