IAA Cosmic Study

Dynamics of space exploration activities and outlook

Study Lead: Nicolas Peter/Pascale Ehrenfreund

Henry Hertzfeld, Gerda Horneck, John Logsdon,
Mark Lupisella, Steve Mackwell, Jacques Masson,
Tanja Masson-Zwaan, Patrick Michel, Mazlan Othman,
Serge Plattard, Cheryl Reed, Giorgio Saccoccia,
Kazuto Suzuki, Stephan Ulamec,
Oleg Ventskovsky, Frances Westall

History

Science data from space exploration missions have revolutionized our understanding of the origins and evolution of the solar system

Stunning images have broadened public awareness

1961 Cosmonaut Gagarin

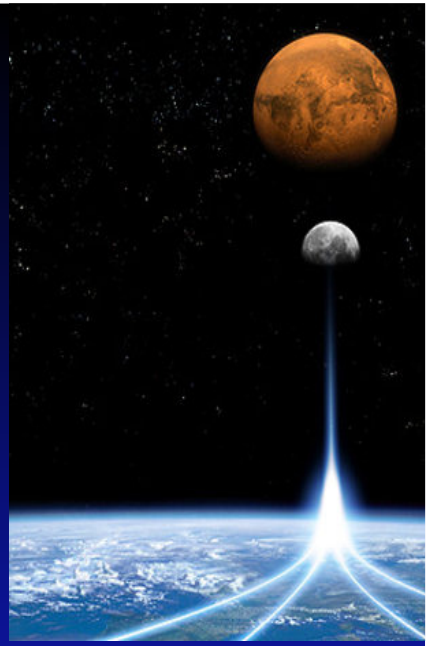
1960/70's 12 U.S. astronauts walked on the surface of the Earth's Moon, others had a close up view of the Moon from orbit

1980's/2000's Space Station era leading to the assembly of the ISS

2010 President Obama proposed a human mission to an asteroid by 2025, followed by trips to Mars and its moons in the 2030s;

The dream of human exploration of the solar system remains alive….

Space Exploration Today



A new vision for space exploration has to be bold, collective, holistic, paved with realistic milestones shared by the stakeholders and thought *ab initio* in a sustainable manner

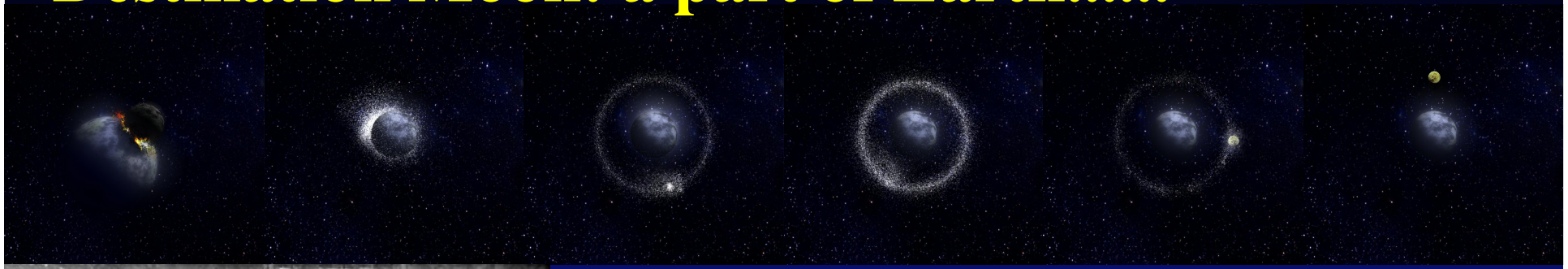
Collective: bringing together the current actors at the proper political level supported by Heads of space agencies to initiate new resilient programs and missions

→ The goal is to develop a common integrated space vision

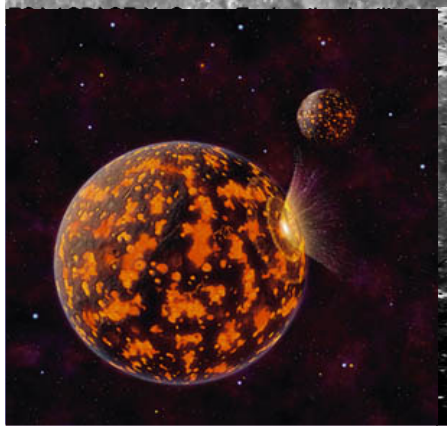
This will require a collective approach with a sense of common commitment, open to every nation able to contribute, and devoted to reaching a new frontier beyond LEO

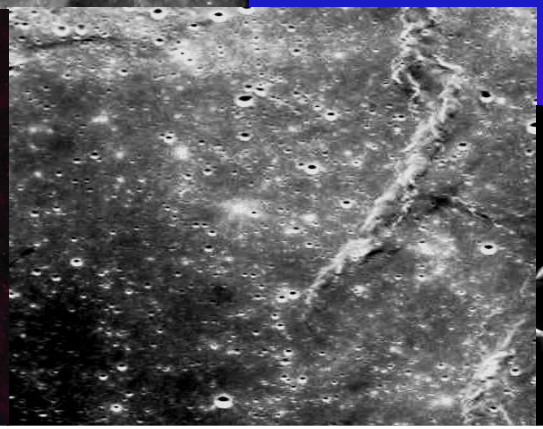

Chang'e-3
GRAIL
LADEE
Luna-Glob 1
Selene-2
Hayabusa-2
Osiris-Rex
Google Lunar X-Prize
Chandrayaan-2
Exploring the Moon, Mars and Near-Earth Asteroids …
Mars Express
MRO
Mars Science Laboratory
MAVEN
Exomars
Exomars Rover
Mars 2020
Mars Sample Return?
Human Exploration?
ISS

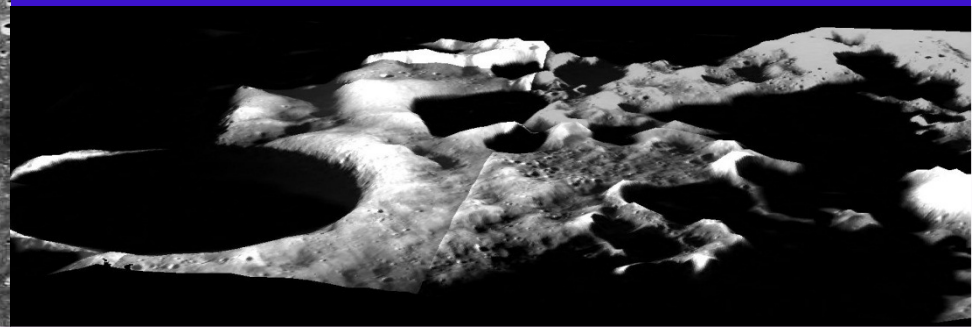
Destination Moon: a part of Earth.....



- Early Earth-Moon System
- Terrestrial Planet Differentiation and Evolution
- Solar System Impact Record
- Lunar Environment







Global Exploration Strategy of the Moon

- Characterize lunar environment
- Use the Moon as stepping stone for Mars exploration
- Study resource potential of the Moon
- Prepare for future human presence
- Construct Habitation modules

Expanding life beyond Earth…

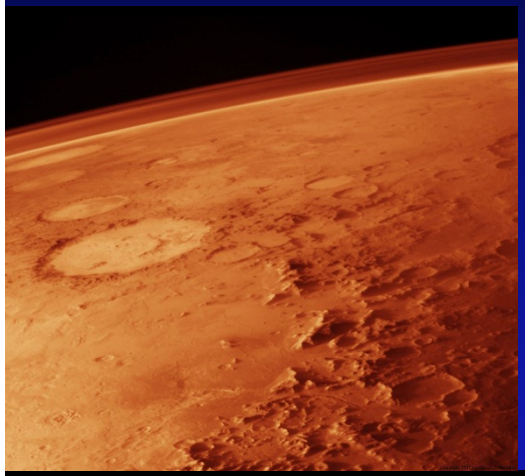
Destination Near-Earth Asteroids: tracing origins...

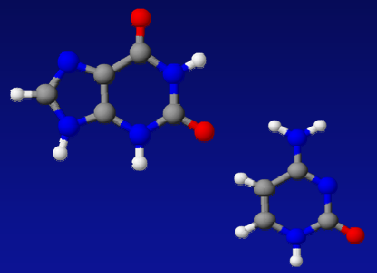
- Knowledge of formation, properties, distribution and evolution of NEOs
- Record: solar system and planet formation

- Human NEO mission expands our spaceflight experience base beyond LEO
- Provides a milestone for exploration and for hazard mitigation

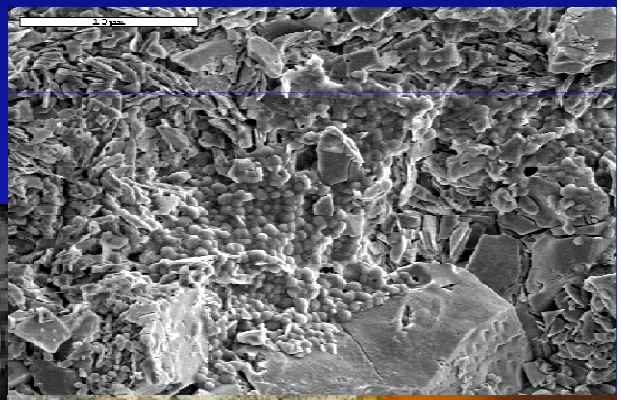
Destinations Mars: Searching for life……

- Determine if life ever arose on Mars
- Understand climate
- Evolution of surface & interior
- Prepare for human exploration

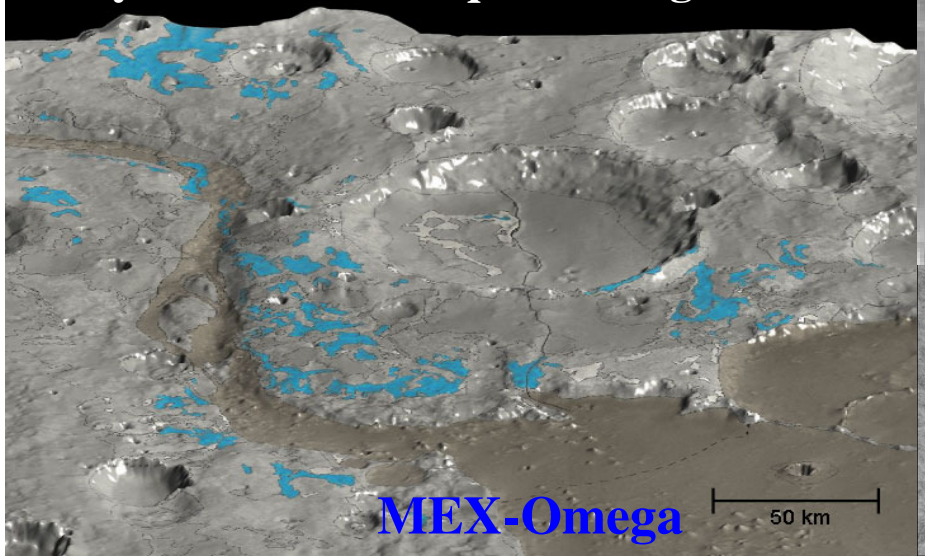


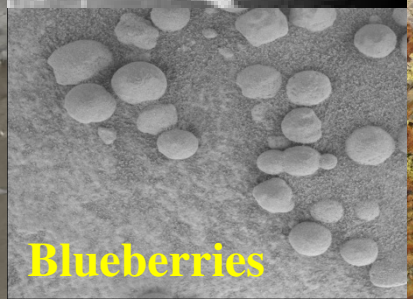


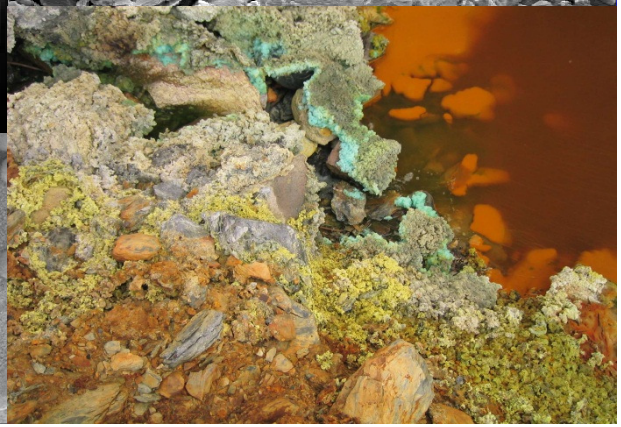
- Biomarkers
- Fossiles
- Microbial catalysis



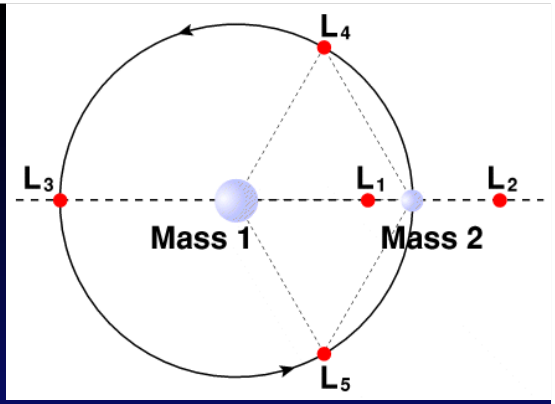
Phyllosilicates → aqueous origin







L2 Destinations

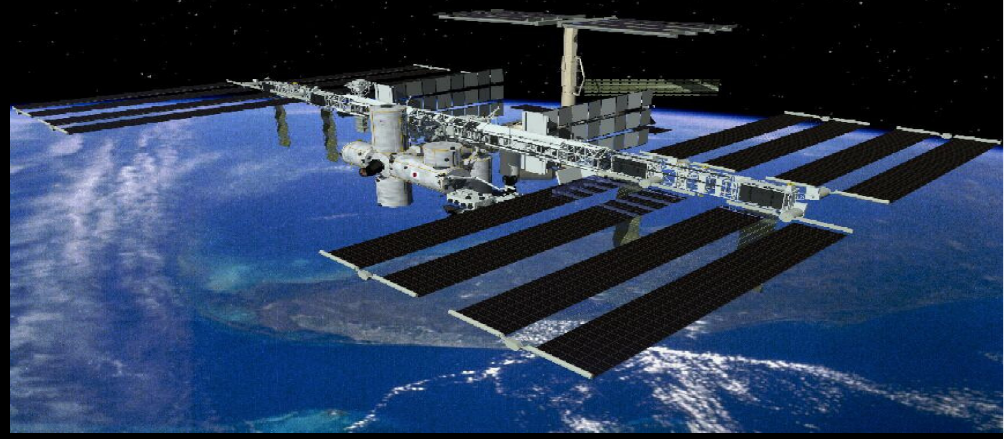


- The Earth-Moon Libration (or "Lagrange") Point 2 (L2), offers notable opportunities to advance space science
- An L2 facility could provide an appropriate environment for evaluating crew physiological and psychological health and performance far from Earth in a way not afforded by missions in LEO
- Coupled effects of radiation and microgravity on microbes and other living organisms (such as plants) could be studied at an L2 facility

The International Space Station

Increasing science return, more facilities, larger crew, over 400 experiments in the last 10 years, strong international cooperation

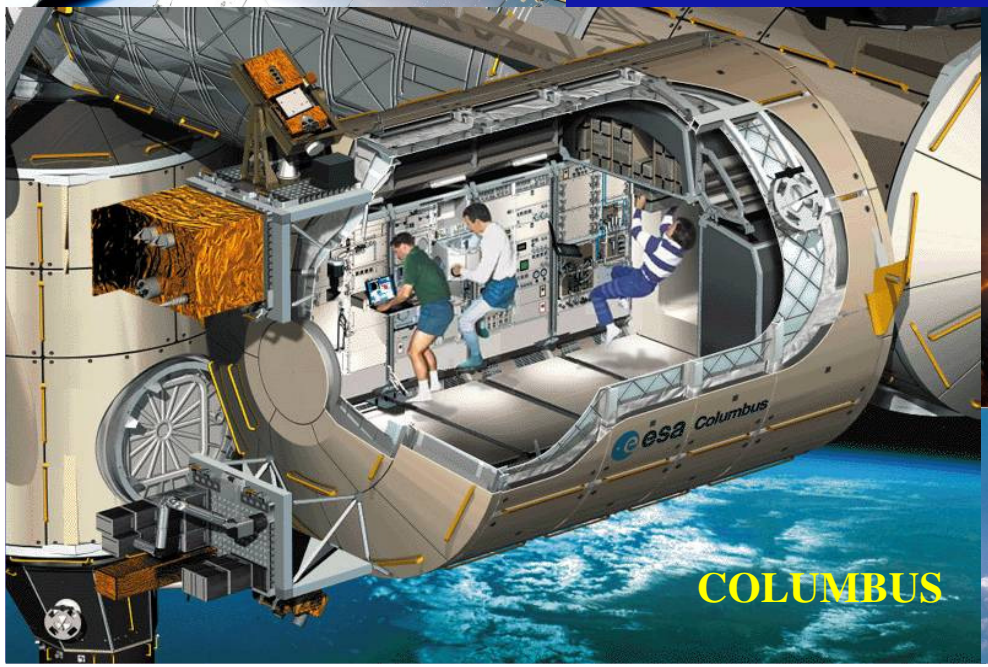
- Human life science
- Biological science
- Human physiology
- Physical science
- Material science
- Earth and space science



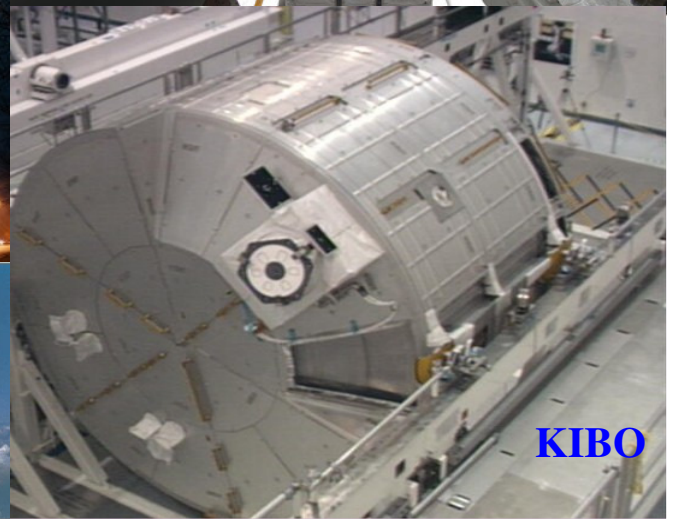
MISSE

LADA

International exploitation of the ISS in preparation for exploration



COLUMBUS

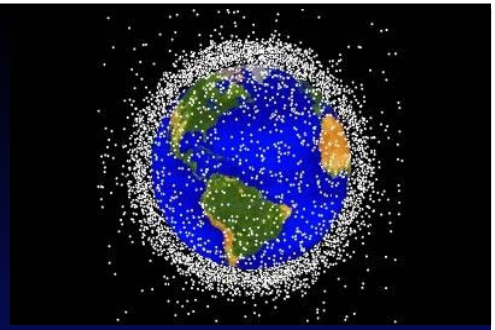


KIBO

Access to Space

- **The list of countries with available or capabilities to provide space access for the purpose of exploration is *limited***
- **In the US, leverage non-NASA capabilities for the LEO access**
- **Russia continues to routinely supply both cargo and astronauts to ISS with different modifications of Soyuz and remains, for the time being, the only country (among the ISS participants) capable of providing the manned missions**
- **China is making progress in creating a new line of launchers - Long March 5/6/7, and advancing Space Module Tiangong 1**
- **New launcher developments in Europe, Japan and India**

Multilateral non-binding initiatives on space sustainability



- At the moment, several initiatives are being developed simultaneously to help protect the safety, security and sustainability of space activities.

- "Draft Code of Conduct on Outer Space Activities" , initiated by the European Union in 2008

- "Working Group on the Long-term Sustainability of Outer Space Activities" (LTSSA) of the Scientific and Technical Subcommittee of UN COPUOS

- Group of Governmental Experts on Transparence and Confidence Building Measures in the context of the UN Treaties on the Peaceful Uses of Outer Space

United Nations support for space exploration

- The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), established in 1959, that deals with international cooperation in peaceful uses of outer space has launched the

- Human Space Technology Initiative (HSTI), aimed at engaging more countries in activities related to human space flight and space exploration,

- The work of COPUOS and activities of HSTI in the coming years are geared to supporting the ⟶ global human space exploration agenda for the benefit of humankind

Cosmic Study Perspectives

- The objective of the IAA Cosmic Study is to compile a comprehensive space policy report on the current state and potential evolution of the domain of space exploration
- The study will identify the drivers and trends of various individual space stakeholders
- Scientific, technological, political and legal motives to support decision-makers and the community will be assembled
- Emerging challenges and opportunities will be analyzed in order to align space stakeholders nationally and internationally

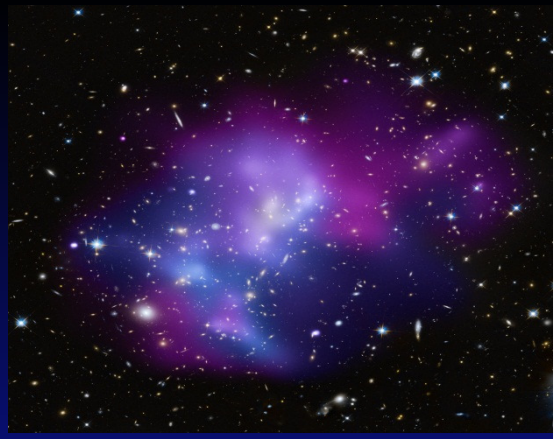
Recommendations:

Assess the feasibility of an **International Space Exploration Council** that acts as an efficient planning and decision-making body and unites a number of stakeholders from governments, space agencies, space entrepreneurial entities, the aerospace industry, the scientific community, and civilian society from all spacefaring countries.

An **International Space Exploration Council** could be effective in designing and implementing an innovative long-term roadmap that will allow new countries and stakeholders to join and engage in an overall effort and exploit tangible and intangible resources for a sustainable global space exploration program.

Back-up

Cosmic Study Outline



Changing space exploration context
History and Geopolitics

Sciences drivers for exploration (per destination)
Moon, Mars, NEOs, Mars Moons, ISS, L2

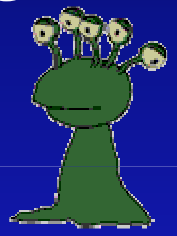
Dynamics in pillars of exploration
Robotic and Human exploration, Technology, Access to Space

Legal issues (legal regime for exploration)
Sustainability and environmental stewardship

Emerging challenges and opportunities

The Human Element

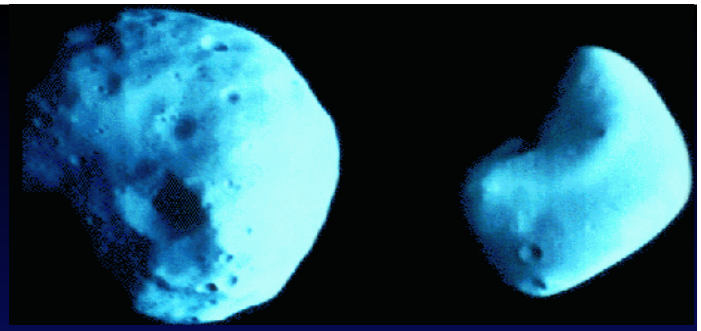
- Intelligent and efficient collection of samples – large quantities, different location, wider geographical areas
- Facilitation of large-scale exploratory activities (e.g. drilling)



- Increased opportunities for serendipitous discoveries
- Humans are 1-2 orders of magnitude more productive per unit time in exploration than controlled robots
- Access to remote locations (e.g. caves)
- Return of large quantities of samples to Earth……

(Crawford 2010)

Phobos and Deimos



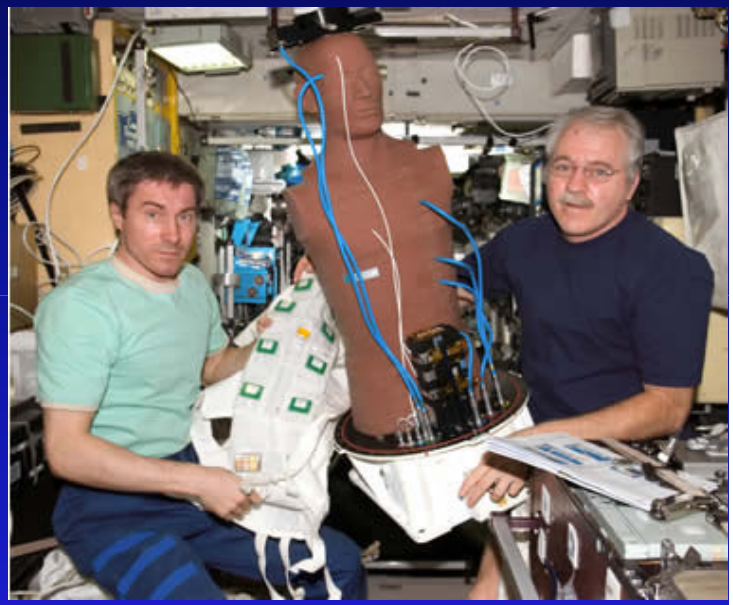
- The compositions, origins, and geologic histories of Mars' moons Phobos and Deimos provide important constraints on terrestrial planets formation and the origin of their volatiles

- Origin ? Dynamical models require the capture of Phobos and Deimos through specific conditions invoking aerodynamic drag by an early Mars proto-atmosphere

- Resolving the origins of Mars' moons' requires additional information on their elemental and mineralogic composition that can only be obtained in situ or by sample return

Research related to space radiation effects

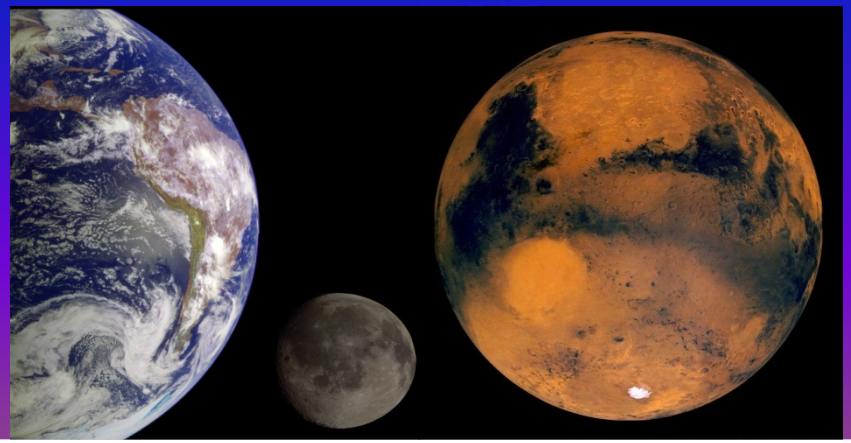
Studies on the biological effects of galactic cosmic radiation provide information:



- **For assessing the radiation risks for human exploratory missions**
- **For assessing the habitability of other bodies in the solar system**
- **For assessing the chances of microorganisms to survive a natural transport between planets of our solar system**

Protecting solar system environments

- We risk losing the ability to measure and understand the subtle pristine conditions of these bodies before they are irrevocably altered by human-induced activity
- Greater need for environmental protection as commercial pressures relegate
- It will be increasingly necessary to clarify and complement these current guidelines and develop a stronger legal regime



COSPAR PPP, PEX
IAA studies