

Sustainable Space Exploration

Dr. María-Paz Zorzano

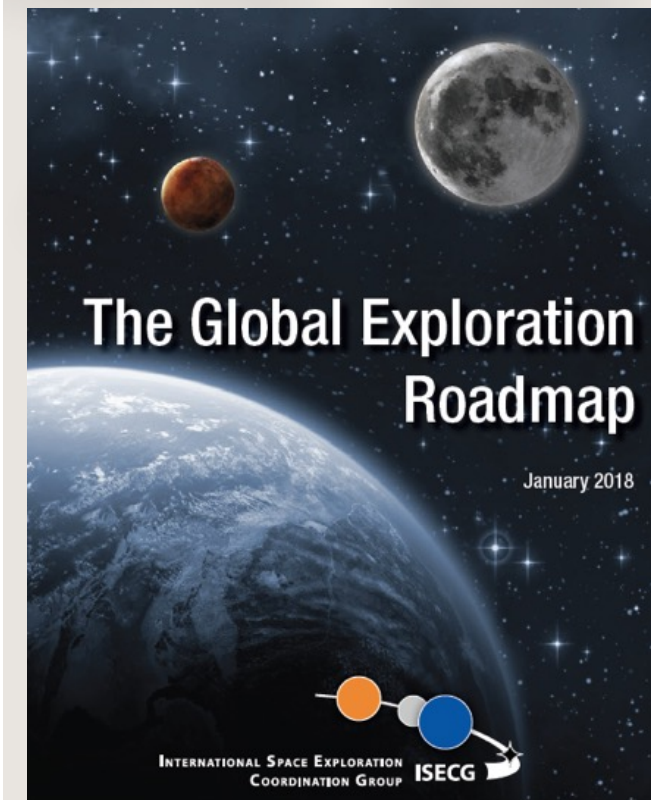
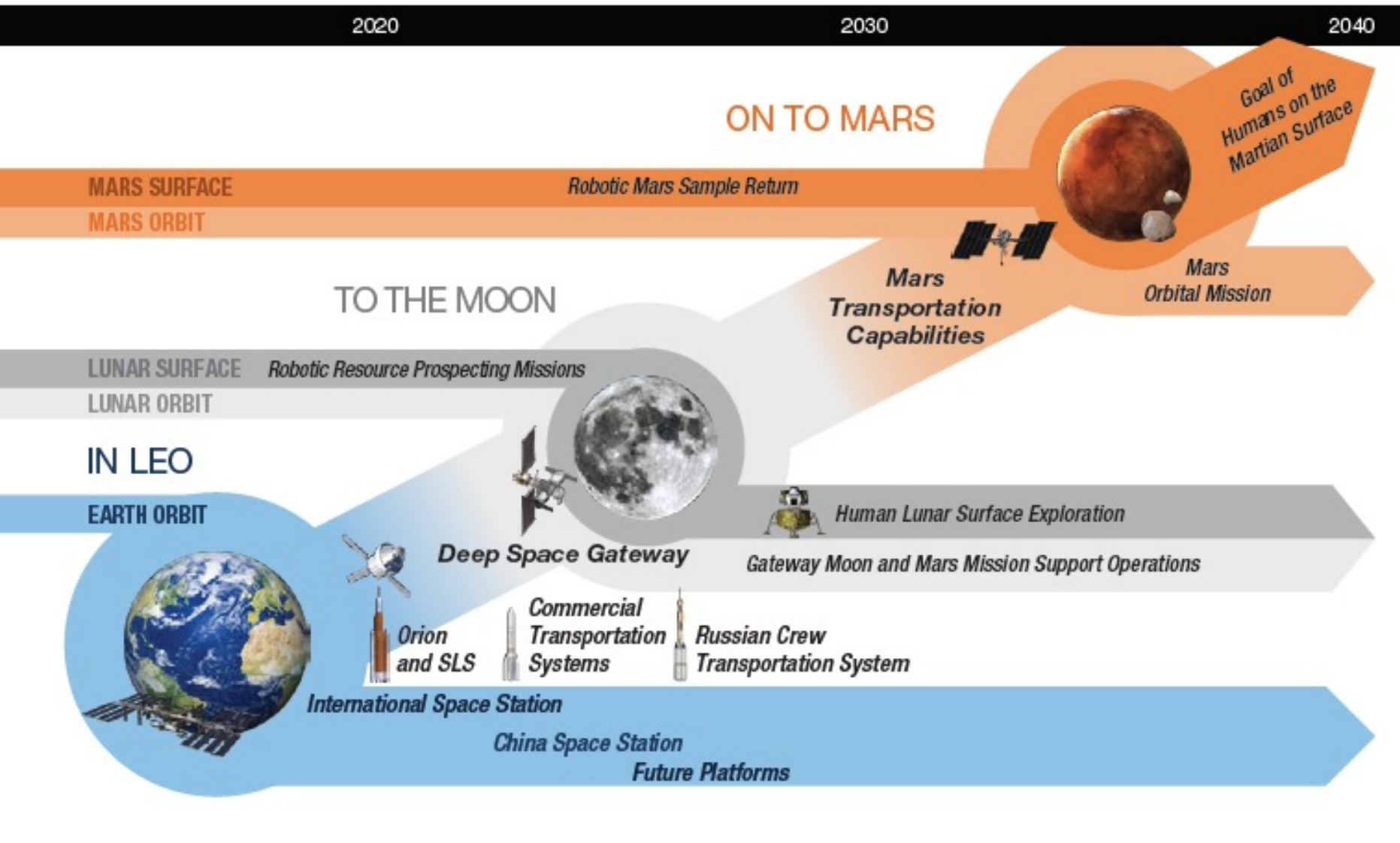
Centro de Astrobiología (CAB)

Instituto Nacional de Técnica Aeroespacial (INTA), Spain



The Global Exploration Roadmap

GER, Jan. 2018, 50 countries, 14 space agencies



“Sustainability” in Earth Orbit

Space station(s):

1. demonstration of sustainability for life support systems,
2. resupply to Low Earth Orbit within a few hours

Satellites:

1. orbit availability and manoeuvres,
2. negative impact on astronomy observation
3. end-of-life and debris

Earth view, from the International Space Station (NASA/JAXA/ESA/Roscosmos & CSA)
Image credit: NASA

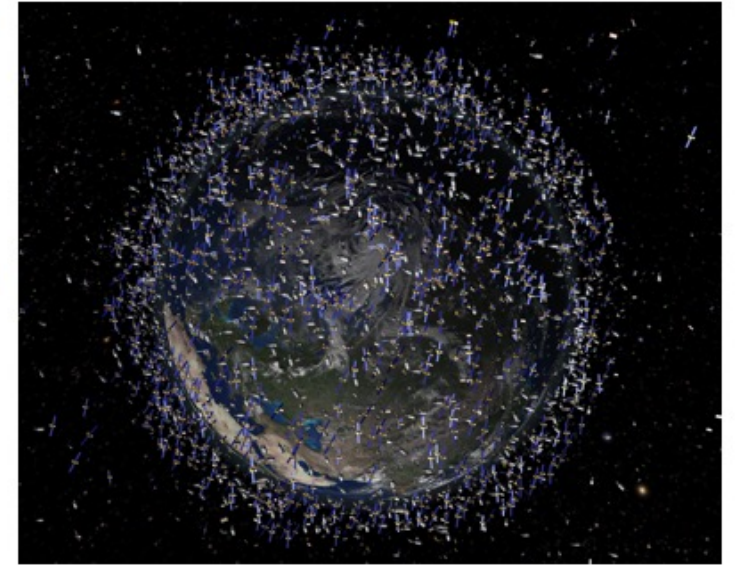
UNOOSA: Registry of objects

Space Treaty Implementation

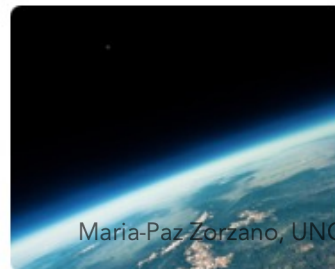
Under the [five international treaties](#), five legal principles and [related General Assembly resolutions](#) that form the body of international space law, the Secretary-General of the United Nations has been requested by States to undertake a number of obligations that facilitate transparency in the conduct of outer space activities.

These obligations include the maintenance of a [central register of objects launched into outer space](#) as well as the dissemination of information relating to the recovery of space objects, launch and re-entry of nuclear powered satellites and other events relating to the use and exploration of outer space. Responsibilities for the implementation of these obligation have been delegated by the Secretary-General to the United Nations Office for Outer Space Affairs.

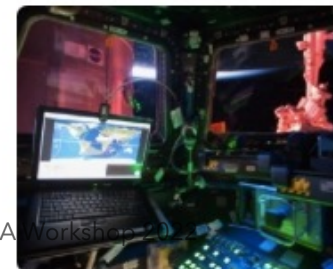
In addition to implementing the Secretary-General's treaty obligations, UNOOSA also provide technical advisory services to States and international intergovernmental organization on issues relating to the implementation of their obligation under international space law. Upon, request, the Office also assists States in the development of their national space laws and regulations.



NOTIFICATIONS UNDER ARTICLE V OF THE OUTER SPACE TREATY



NOTIFICATIONS UNDER ARTICLE XI OF THE OUTER SPACE TREATY



NOTIFICATIONS UNDER ARTICLE V OF THE RESCUE AGREEMENT

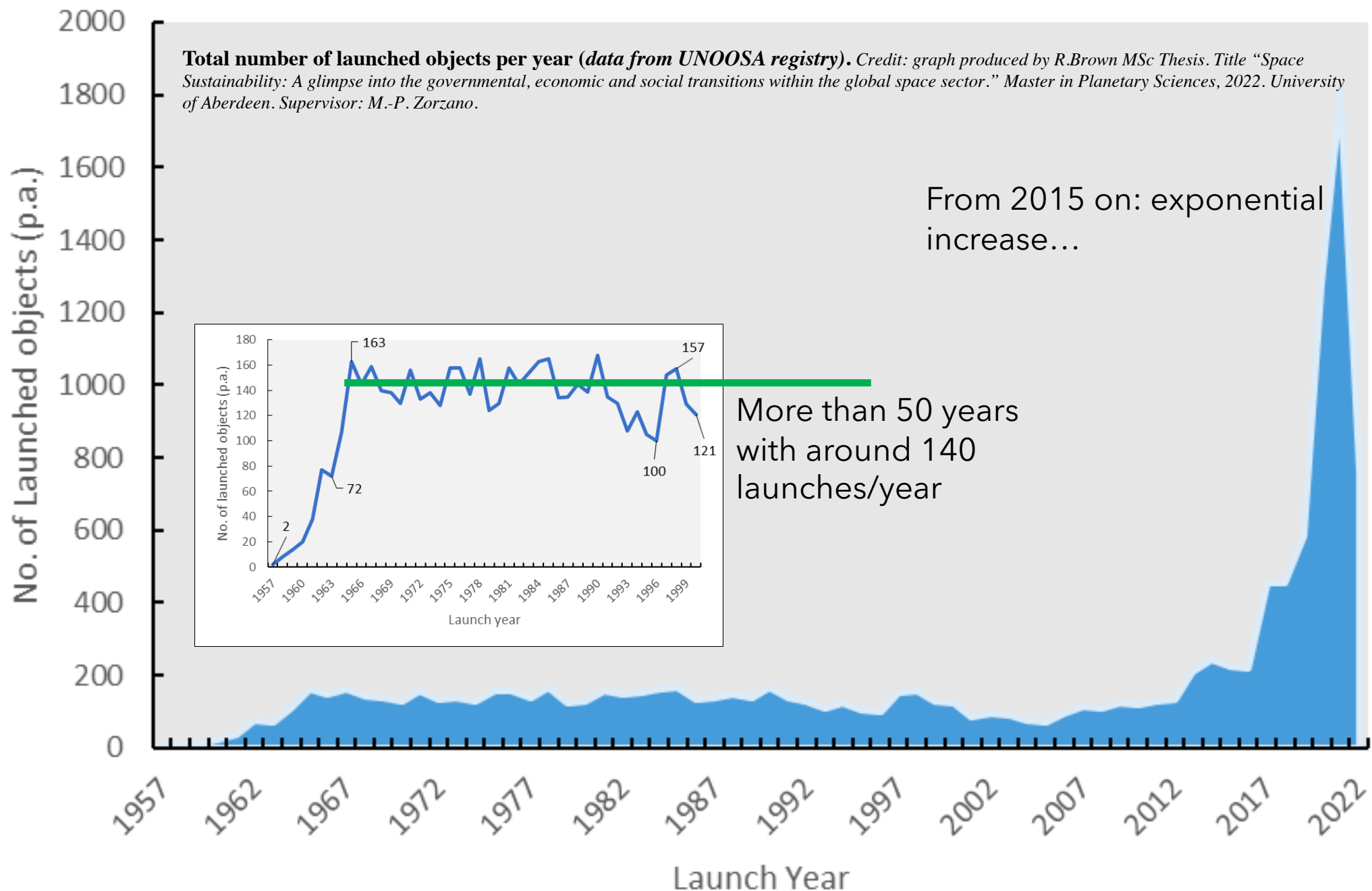


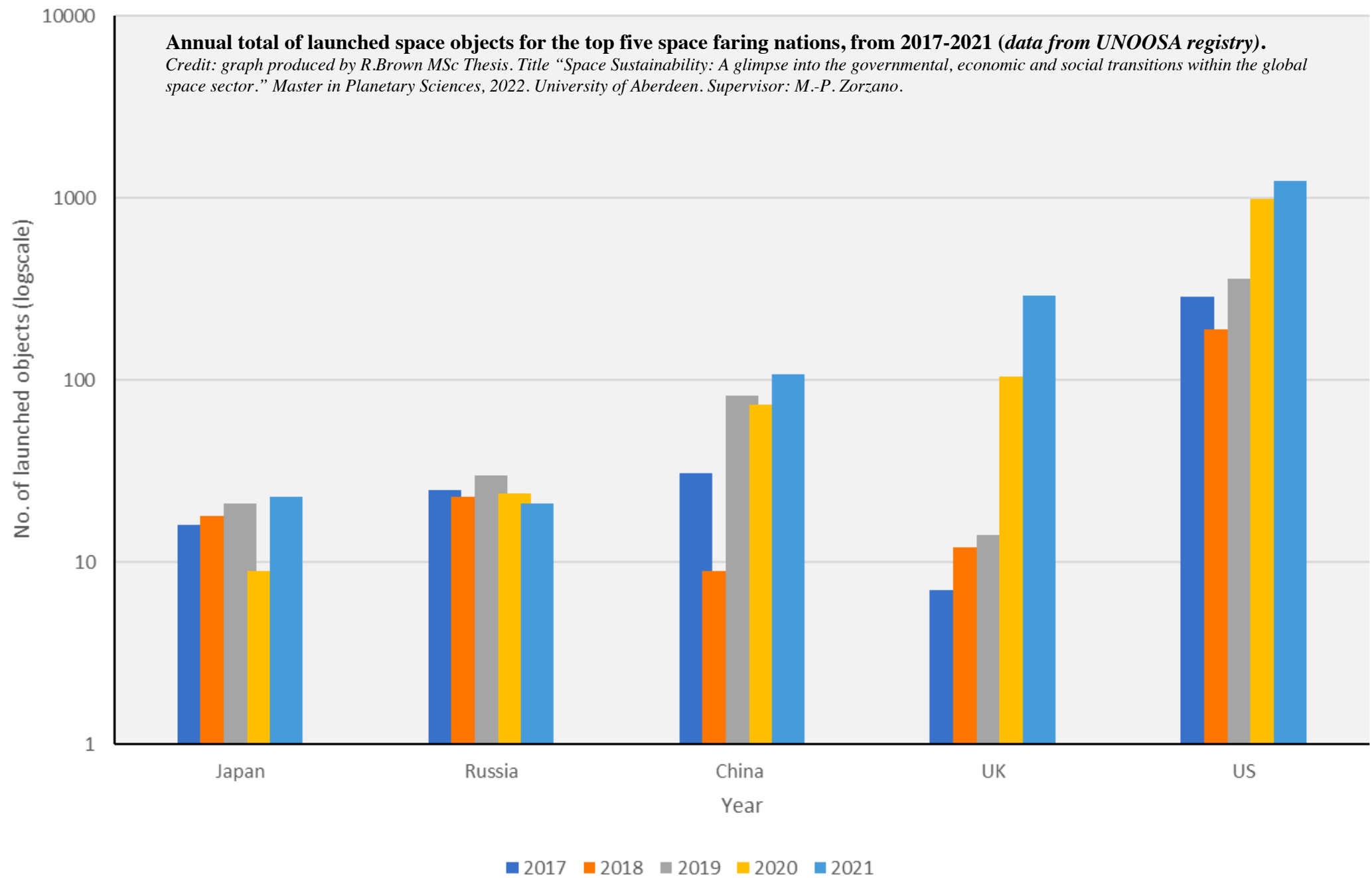
REGISTRATION SUBMISSIONS BY STATES AND ORGANIZATIONS



Maria-Paz Zorzano, UNOOSA Workshop

<https://www.unoosa.org/oosa/en/treatyimplementation/index.html>







“Sustainability” in Space Exploration

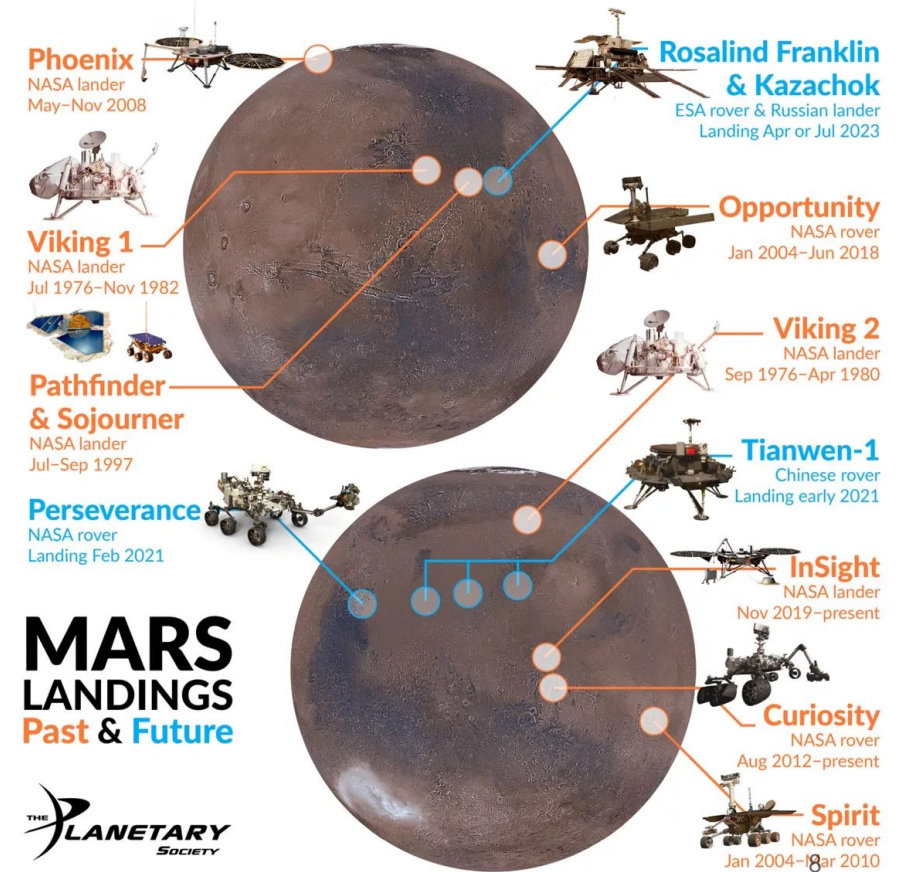
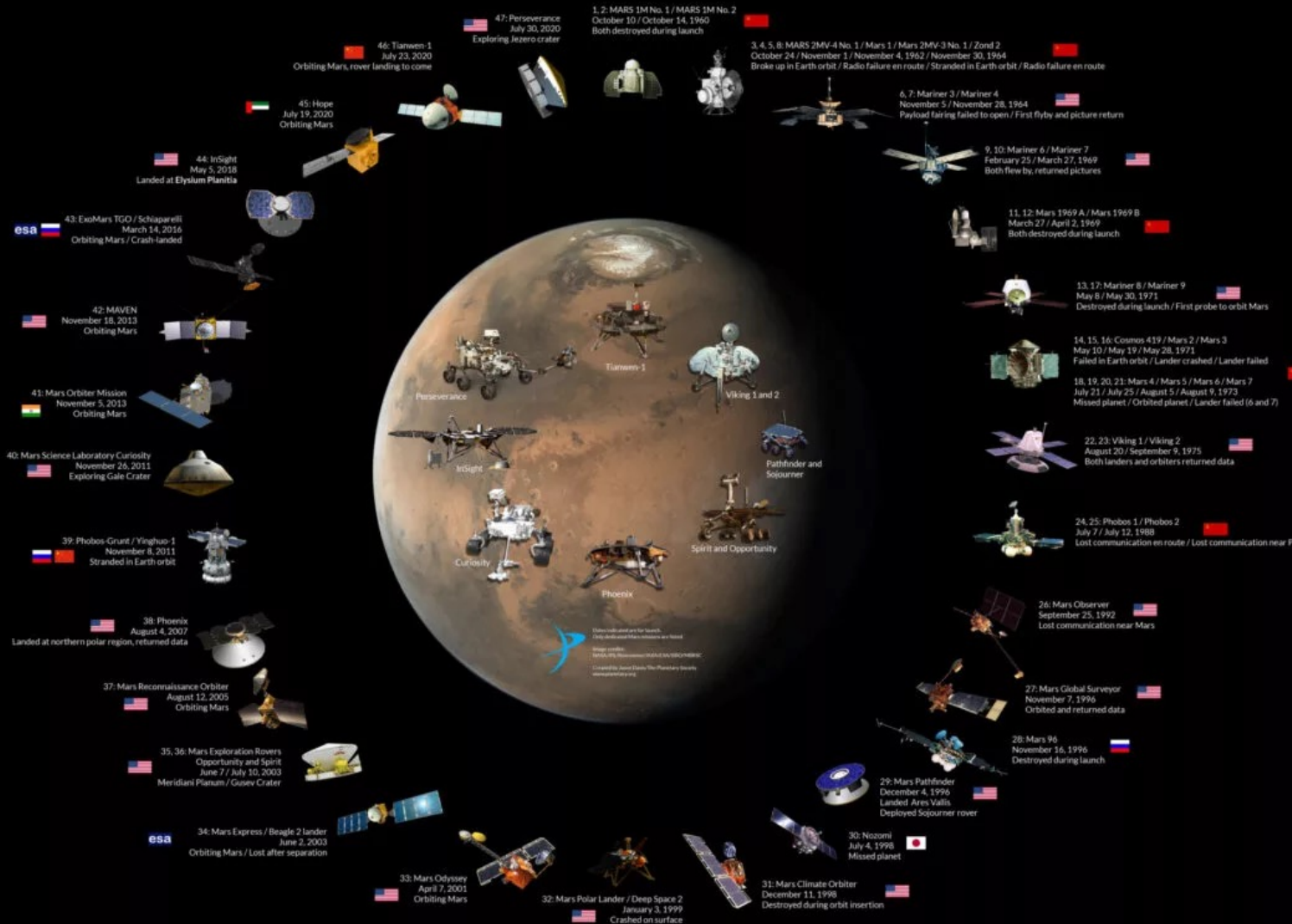
Deep space exploration (solar system)

Very distant locations require deep space communications, in-situ resource utilization, life support systems

Implementing planetary protection practices

Open access to scientific data

Mars Exploration Family Portrait



Credit: NASA/JPL/Roscosmos/JAXA/ESA/ISRO/MBRSC/Jason Davis/The Planetary Society



World-wide open access to deep space exploration scientific data

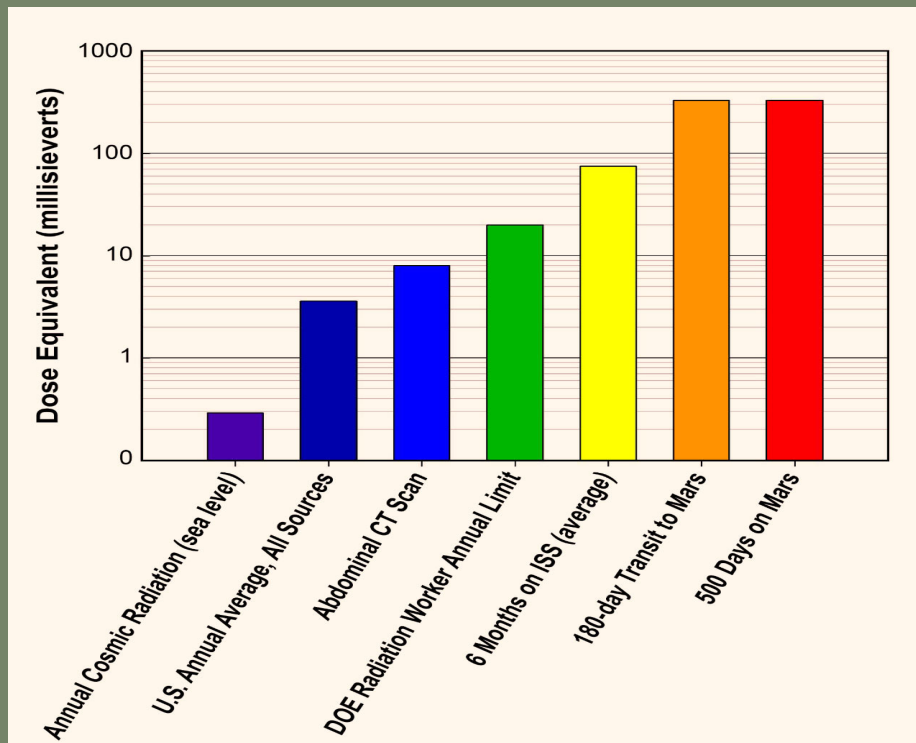


Image credit: RAD/Curiosity rover/ NASA.

- HOME
- DATA SEARCH
- TOOLS
- DATA STANDARDS

[Home](#)
[About PDS](#)
[Data Users](#)
[Data Proposers](#)
[Data Providers](#)

Announcements

[Community Announcement](#)

New Releases

November 8, 2022
[OSIRIS-REx Raw Radio Science Release](#)

October 31, 2022
[aperiodic PDS data releases in October 2022](#)

October 31, 2022
[Hayabusa2 ONC Release](#)

[Data Release Calendar](#)
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PDS Nodes

- Atmospheres (ATM)
- Cartography and Imaging Sciences (IMG)
- Geosciences (GEO)
- Navigational & Ancillary Information Facility (NAIF)
- Planetary Plasma Interactions (PPI)
- Ring-Moon Systems (RMS)
- Small Bodies (SBN)

Welcome to the PDS

The Planetary Data System (PDS) is a long-term archive of digital data products returned from NASA's planetary missions, and from other kinds of flight and ground-based data acquisitions, including laboratory experiments. But it is more than just a facility - the archive is actively managed by planetary scientists to help ensure its usefulness and usability by the world wide planetary science community.

Archive submissions are prepared by researchers under the guidance of PDS personnel. All products are peer-reviewed, well-documented, and easily accessible via a system of online catalogs that are organized by planetary disciplines.

Archived products are available on-line. When needed, PDS provides users access to staff to help with data selection. PDS also provides a variety of tools useful in producing, obtaining and using archived data. There is no cost associated with acquiring PDS archived data or tools or in getting reasonable amounts of PDS help. All PDS archived data may be exported outside of the United States under the U.S. Government's Technology and Software Publicly Available (TSPA) classification.

To learn more about PDS and the nodes, go to [About the PDS](#).

Below are links to important information for the various categories of PDS users.

Data Users (Researchers, Educators, Students and the General Public)

Data Users include researchers, students, and educators who are interested in obtaining, manipulating, and understanding PDS data products. They intend to locate data products, find tools to work with those data products, and understand how those data products are formatted and structured.

Some information in this collection may also be of interest to the general public.

Data Proposers

Data Proposers intend to submit a proposal for NASA funding, with the proposal including the intent to archive data in the PDS. The proposal might be prepared as part of a mission proposal, or as an individual researcher responding to a data analysis program call. A data proposer is looking for information on how to include PDS archiving in their proposal. A successful Data Proposer will later become a Data Provider.

Data Providers

Data Providers intend to submit data to PDS for peer review and subsequent archiving. They are looking for tools to develop their data products and archive bundles, and for documentation detailing PDS standards and bundle structure.

[EUROPEAN SPACE AGENCY](#)
[SCIENCE & TECHNOLOGY](#)
[COSMOS](#)

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planetary science archive

PSA 6.2.3

START SEARCHING YOUR DATASET!

Type a Target, Mission or Instrument, such as Mars, Rosetta, HRSC...

The European Space Agency's Planetary Science Archive (PSA) is the central repository for all scientific and engineering data returned by ESA's Solar System missions: currently Giotto, Huygens, Mars Express, Rosetta, SMART-1, ExoMars 2016, Chandrayaan-1, BepiColombo and Venus Express, as well as complementary ground-based observations. Future missions such as ExoMars 2022 and JUICE will also be hosted in the PSA. The PSA uses Planetary Data System standards as a baseline for the formatting and structure of all data contained within the archive... Learn more [HERE](#).

DATA ACCESS

- [TABLE VIEW](#)
- [IMAGE VIEW](#)
- [MAP VIEW](#)
- [DOWNLOADS](#)

PRODUCT INFO & TOOLS

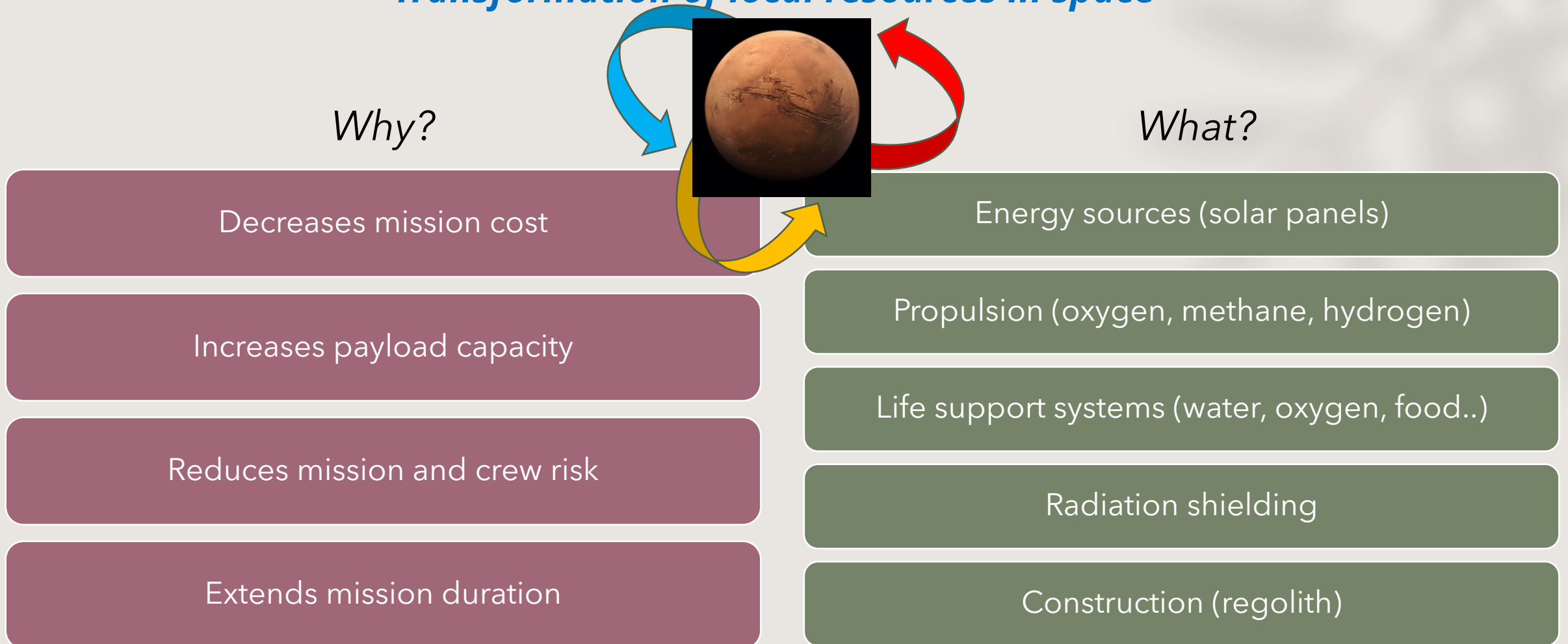
- [ANCILLARY DATA](#)
- [TOOLS](#)
- [DOCUMENTATION](#)
- [ESA MISSIONS](#)

USEFUL INFORMATION

- [WORKSHOP](#)
- [USER GROUP](#)
- [HELP & FAQ](#)
- [CONTACT](#)

In-Situ Resource Utilization (ISRU)

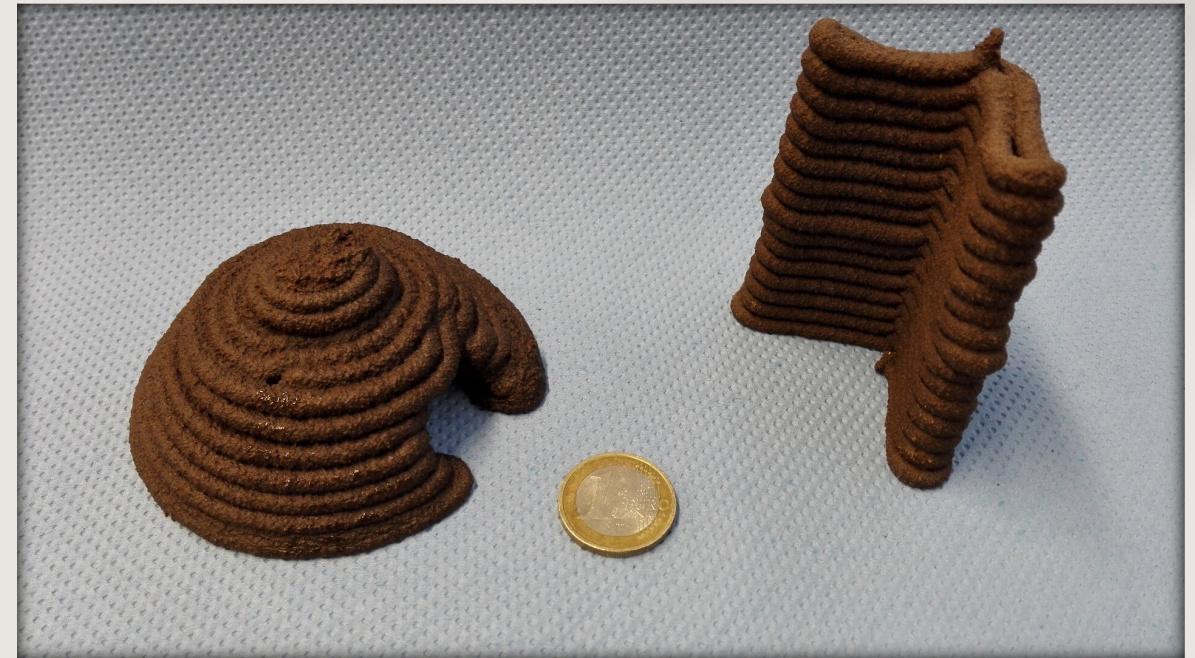
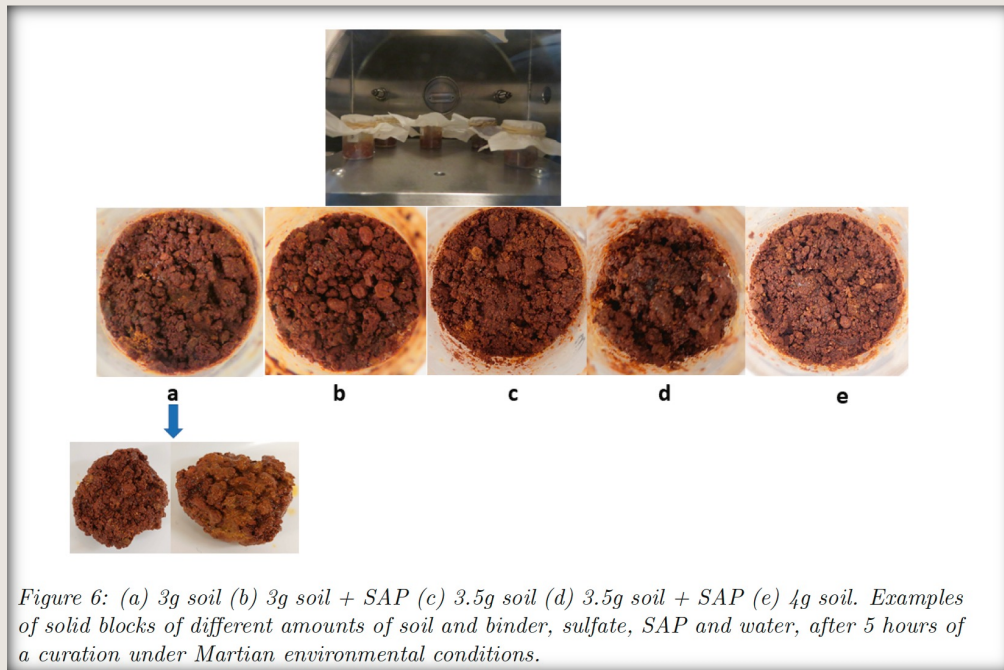
Transformation of local resources in space



Mars I: Laboratory simulation of ISRU

Regolith + binder curation under Martian conditions

3D printing with regolith

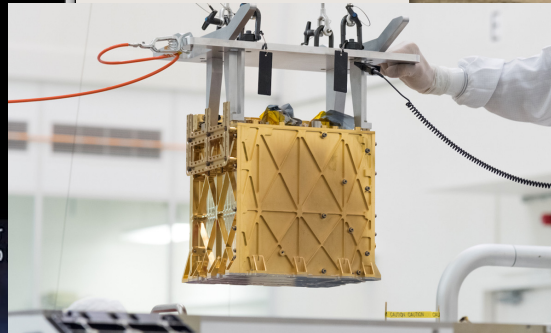
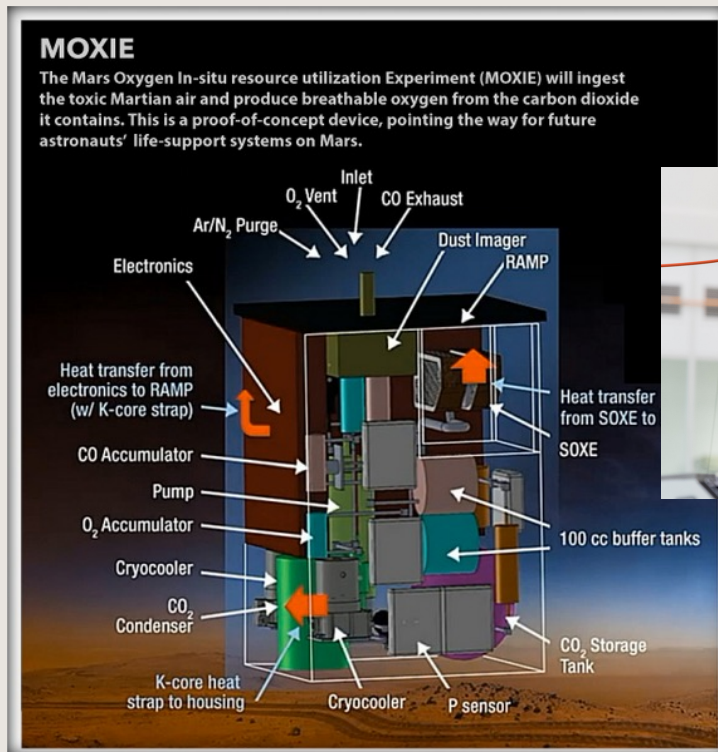


A. Vakkada Ramachandran, M. I. Nazarious, T. Mathanlal, M.-P. Zorzano, and J. Mart'ín-Torres, "Space Environmental Chamber for Planetary Studies," *Sensors*, vol. 20, p. 3996, jul 2020. using MMS soil simulant.

A miniature igloo and a corner wall were manufactured as examples of designs that might be required by colonists, produced from JSC volcanic soil simulant. Credit: ESA/ Fotec

Mars II: Technology demonstrators of ISRU

Oxygen production: MOXIE



Credit: MOXIE team

Perseverance rover, at Jezero, Mars NASA



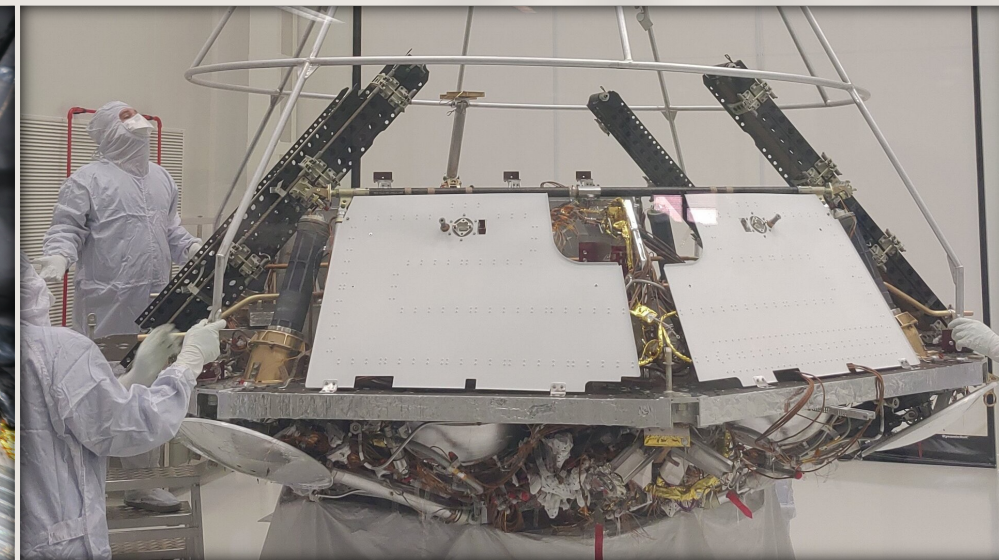
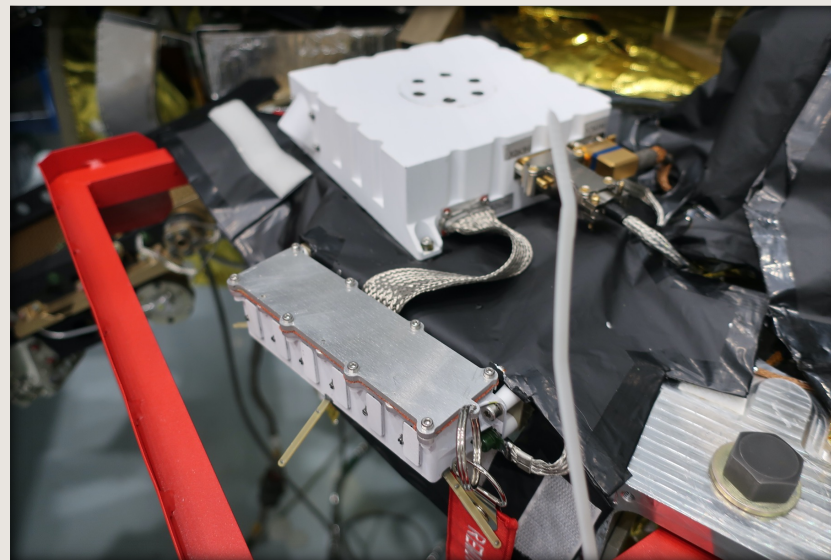
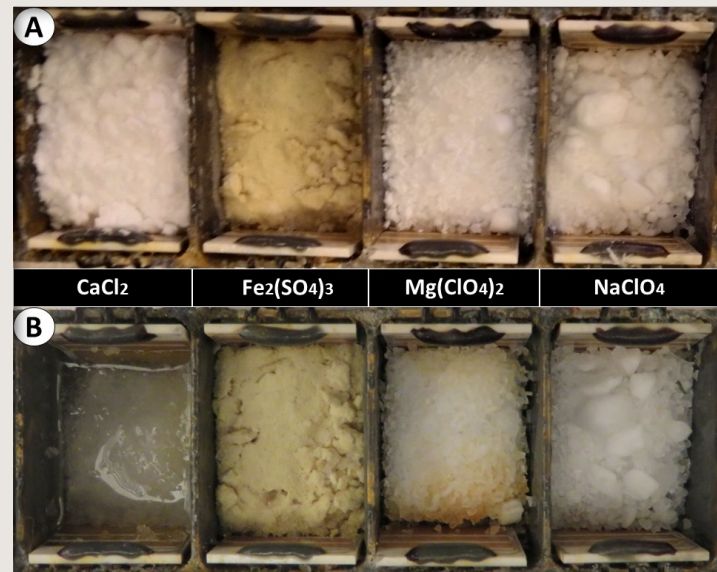
Hoffman, Jeffrey A., et al. 'Mars Oxygen ISRU Experiment (MOXIE)–Preparing for Human Mars Exploration'. Science Advances, vol. 8, no. 35, Sept. 2022, p. eabp8636. DOI.org (Crossref), <https://doi.org/10.1126/sciadv.abp8636>.

Mars III: Technology demonstrators of ISRU

Water production: HABIT

ExoMars rover and surface platform ESA/IKI

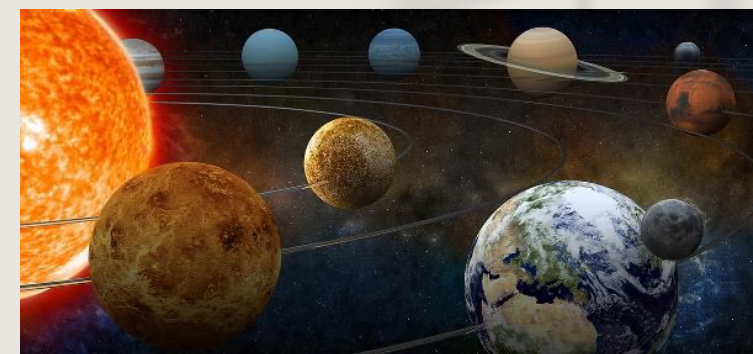
Credit: HABIT team, ExoMars ESA/IKI

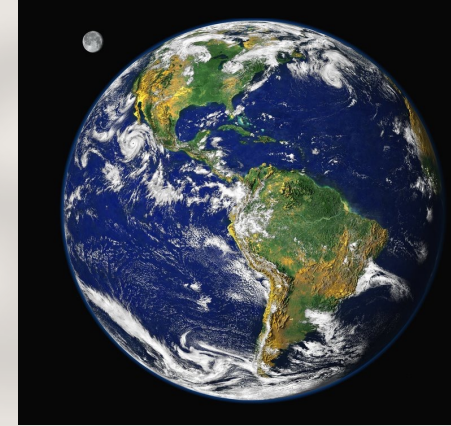
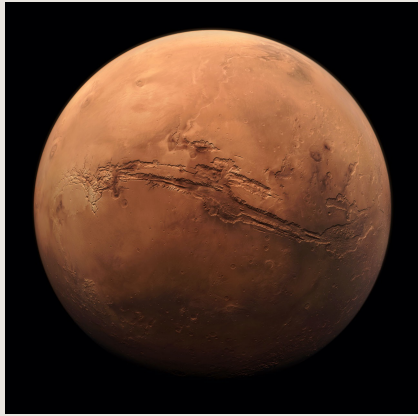


J. Martín-Torres, M.-P. Zorzano, A. Soria-Salinas, M. I. Nazarious, S. Konatham, T. Mathanlal, A. Vakkada Ramachandran, J. Ramirez- Luque, R. Mantas-Nakhai, The HABIT (HabitAbility: Brine Irradiation and Temperature) environmental instrument for the ExoMars Surface Platform 2022, Planetary and Space Science 2020, 104968 (<https://doi.org/10.1016/j.pss.2020.104968>)



Planetary protection:
avoid the cross-contamination of the bio-spheres





Spores

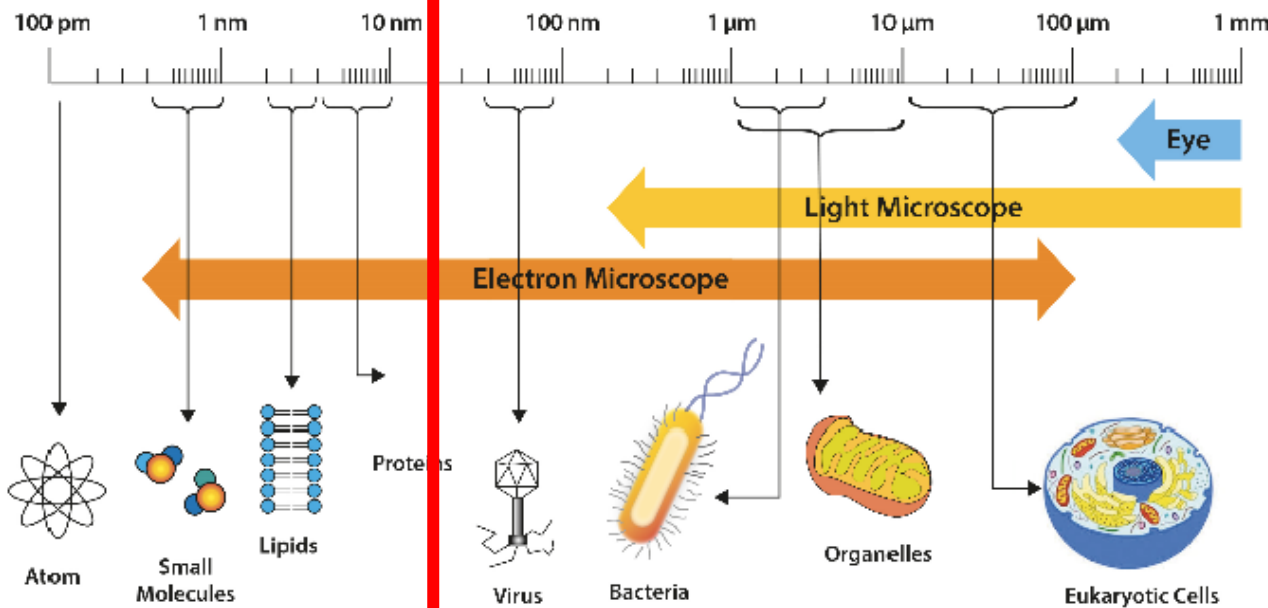


Figure 8 – Different size, shape and arrangement of bacterial cells.

Where?	How many?
Garden soil, 1g	2.5×10^{10} (25,000,000,000)
Milk (raw), 1l	2.5×10^9
Air, 1 m ³	2000
Drinking water, 1 ml	< 100 (nonpathogenic)
Sea- and freshwater	1.2×10^{29}
Total (on Earth)	10^{30} (~ 10^{14} kg = 100 billion tons = 1430 billion humans (each 70 kg; currently 7 billion living humans on Earth))
Human skin	10^{12}
Human body - Own cells - Microbes	10^{13} 10^{14-15}

Table 2 – Microbial distribution and abundance in various environments.

Sustainable Space Exploration

Summary



Research

More research and development needed for: In-situ resource utilization and life support systems

Partnership

Need international cooperation for: planetary protection, deep space communications, end-of-life satellite & debris management and open accessibility to scientific data

Framework

Space exploration offers a unique framework to: educate the next generation, develop new sustainable technologies, and expand our scientific knowledge.