21st -24th November 2022 United Nations / China
2ND GLOBAL PARTNERSHIP WORKSHOP ON SPACE EXPLORATION AND INNOVATION.

Sustainable Space Exploration

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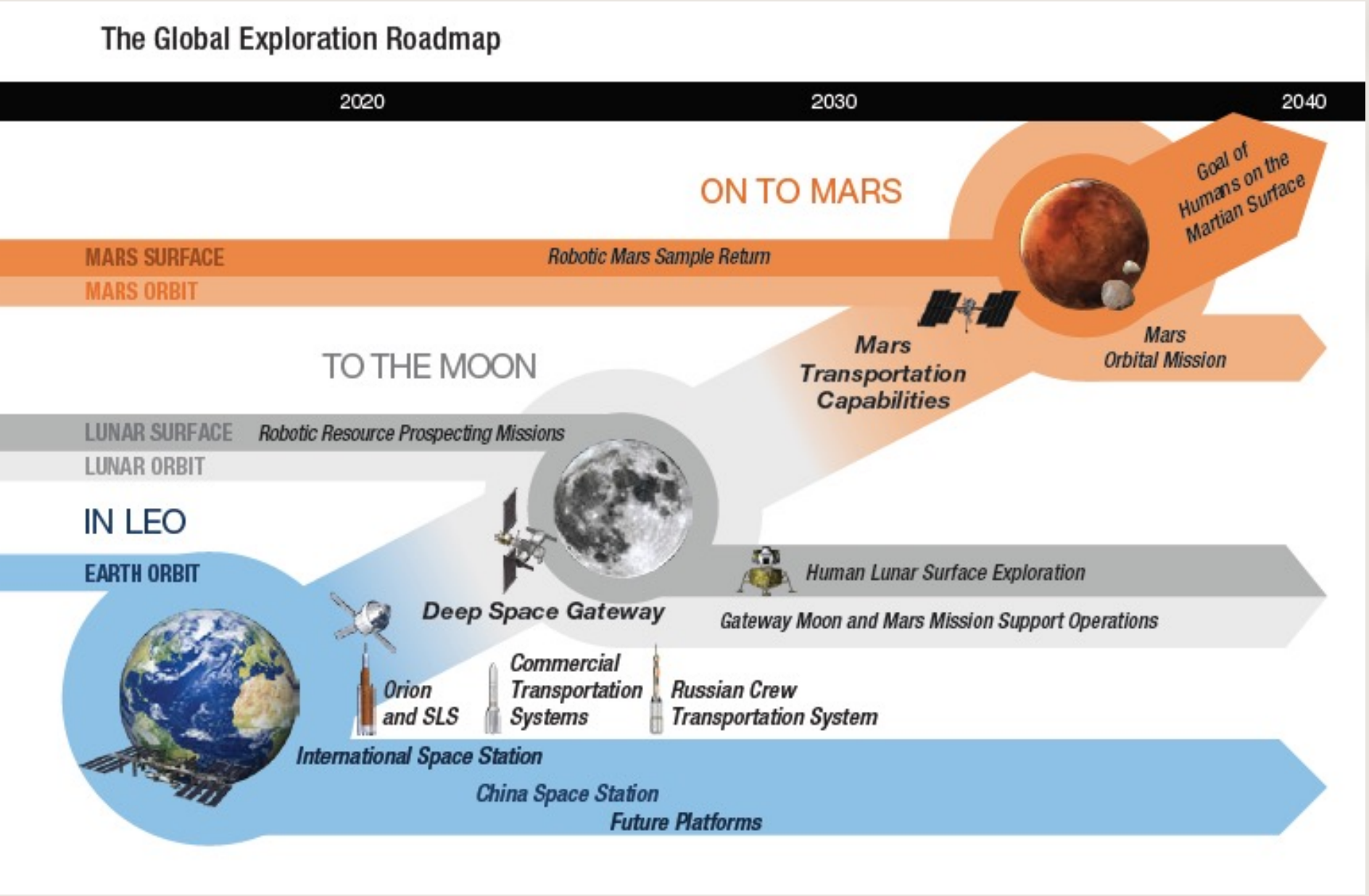
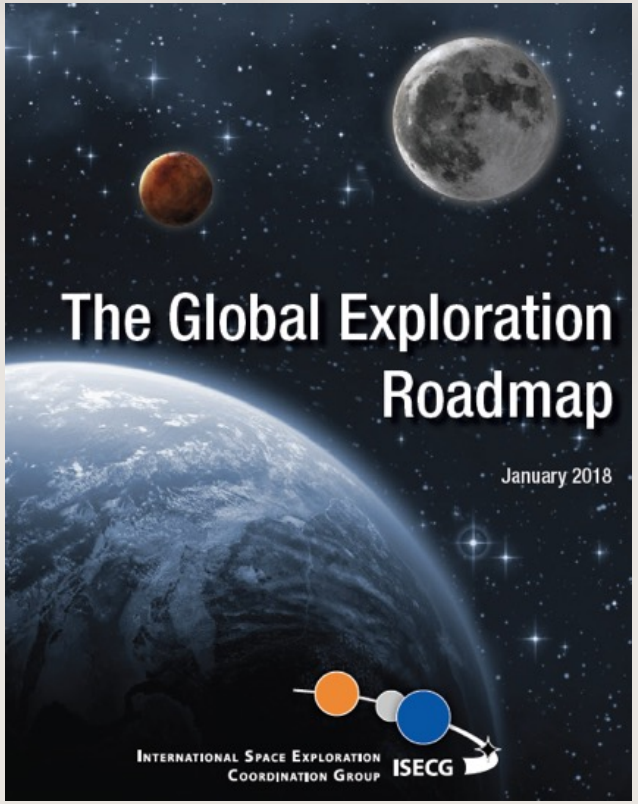
CENTRO DE ASTROBIOLOGÍA · CAB
ASOCIADO AL NASA ASTROBIOLOGY PROGRAM
CSIC

Gale crater, Mars. *Image credit Curiosity rover/JPL/NASA*



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 maneouvres,
2. negative impact on astronomy observation
3. end-of-life and debris

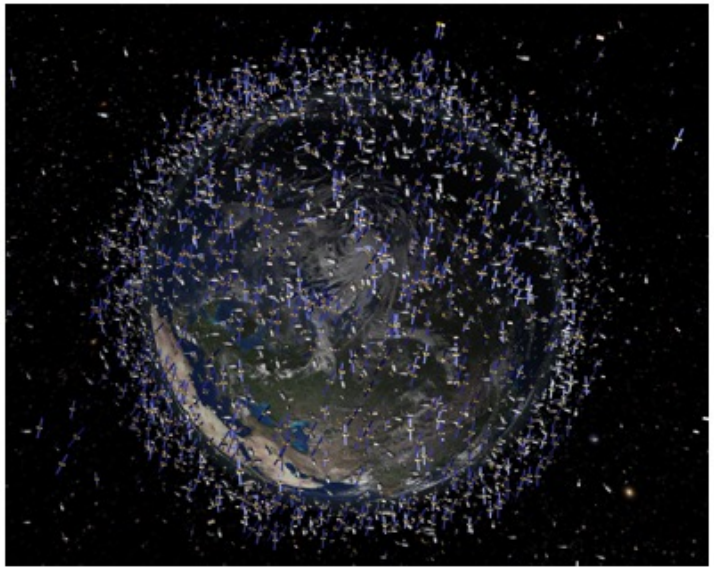
Earth view, from the International Space Station (NASA/JAXA/ESA/Roscosmos & CSA
Image credit: NASA

UNOOSA: Registry of objects

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

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 faciltate transparency in the conduct of outer space activities.



These obligations include the maintainence 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.

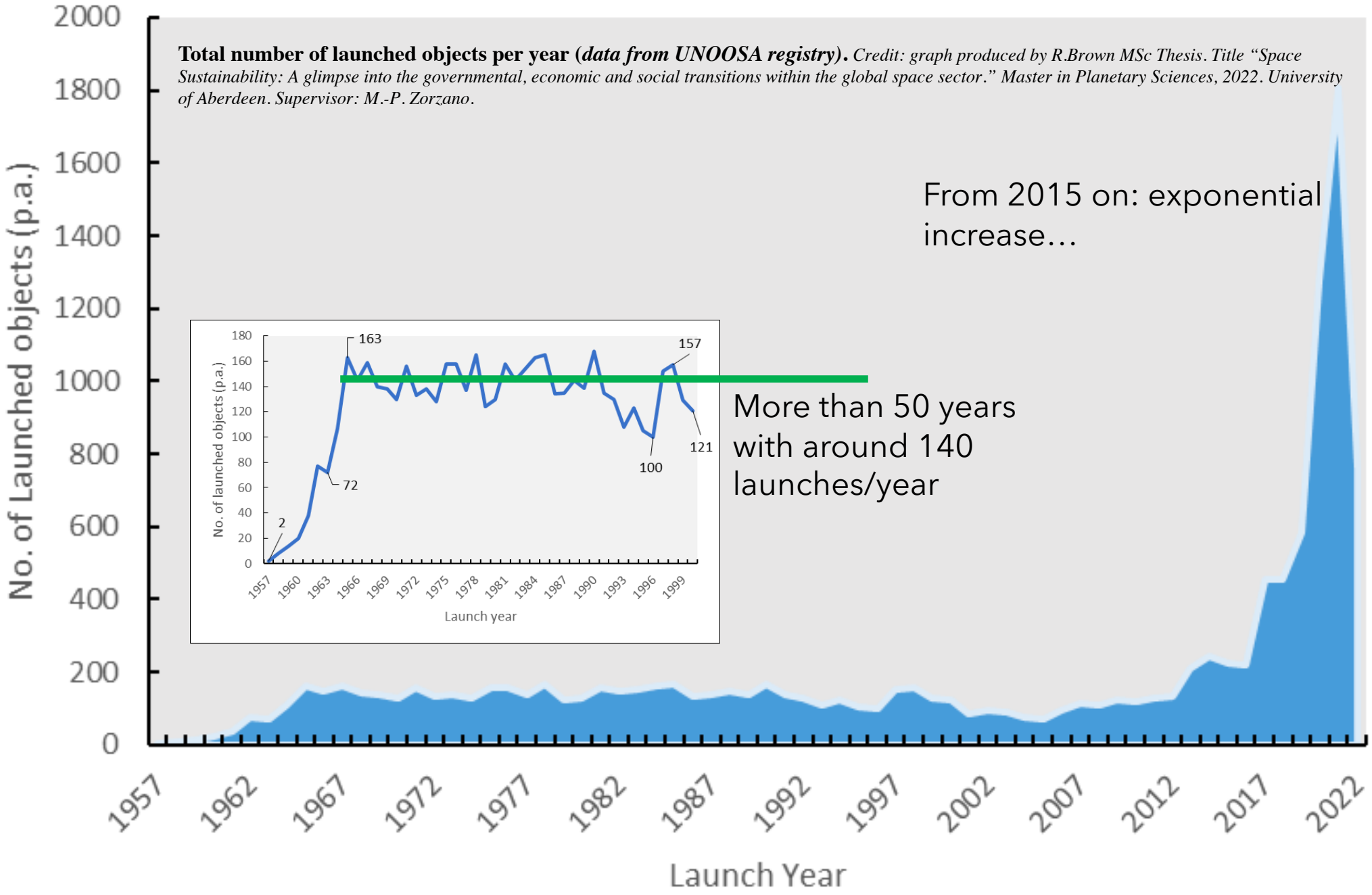
NOTIFICATIONS UNDER ARTICLE V OF THE OUTER SPACE TREATY

NOTIFICATIONS UNDER ARTICLE XI OF THE OUTER SPACE TREATY

NOTIFICATIONS UNDER ARTICLE V OF THE RESCUE AGREEMENT

REGISTRATION SUBMISSIONS BY STATES AND ORGANIZATIONS

Total number of launched objects per year (*data from UNOOSA registry*). *Credit: graph produced by R.Brown MSc Thesis. Title "Space Sustainability: A glimpse into the governmental, economic and social transitions within the global space sector." Master in Planetary Sciences, 2022. University of Aberdeen. Supervisor: M.-P. Zorzano.*

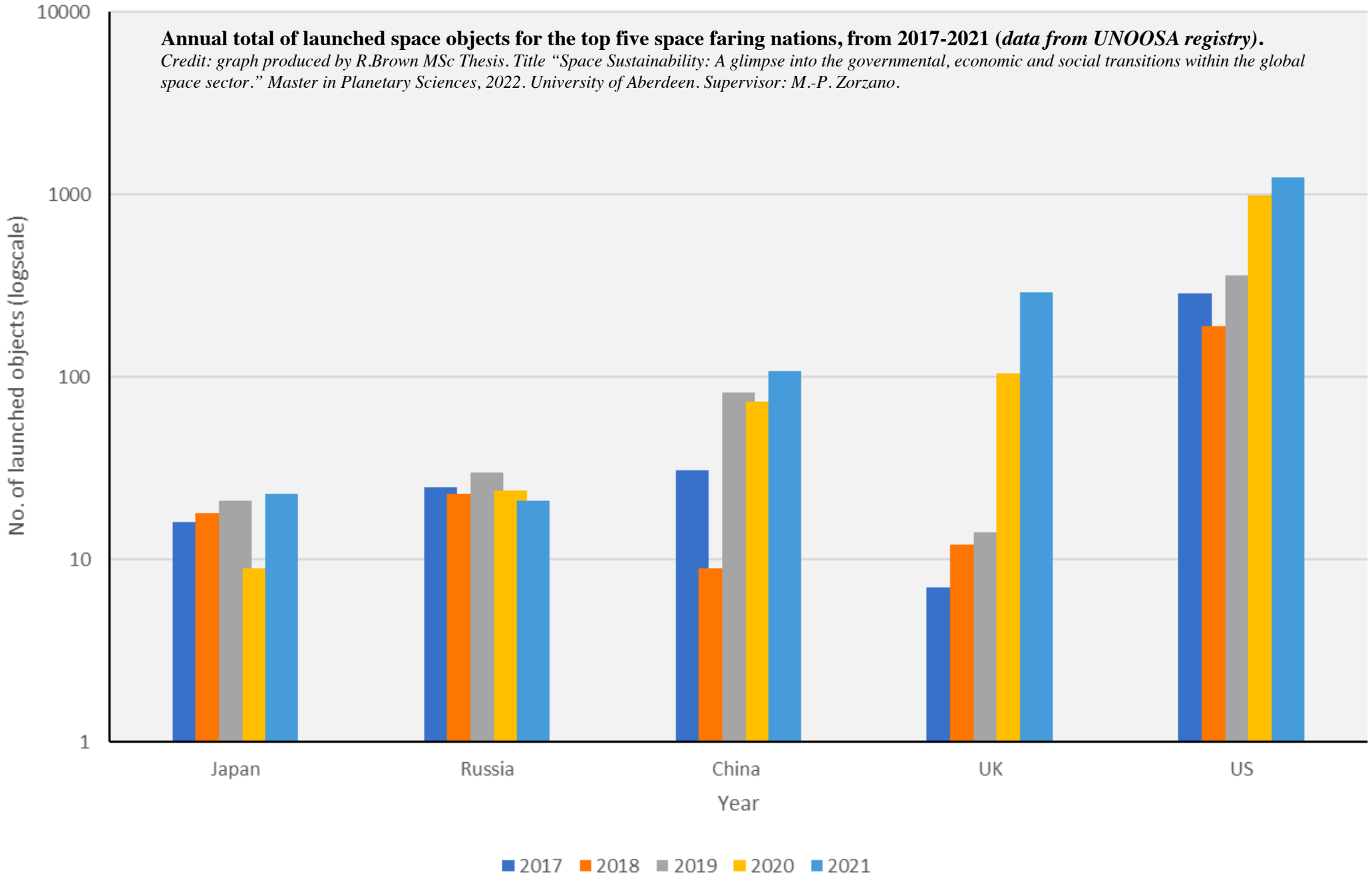


From 2015 on: exponential increase…

More than 50 years with around 140 launches/year

Annual total of launched space objects for the top five space faring nations, from 2017-2021 (*data from UNOOSA registry*).

Credit: graph produced by R.Brown MSc Thesis. Title "Space Sustainability: A glimpse into the governmental, economic and social transitions within the global space sector." Master in Planetary Sciences, 2022. University of Aberdeen. Supervisor: M.-P. Zorzano.



“Sustainability” in Space Exploration

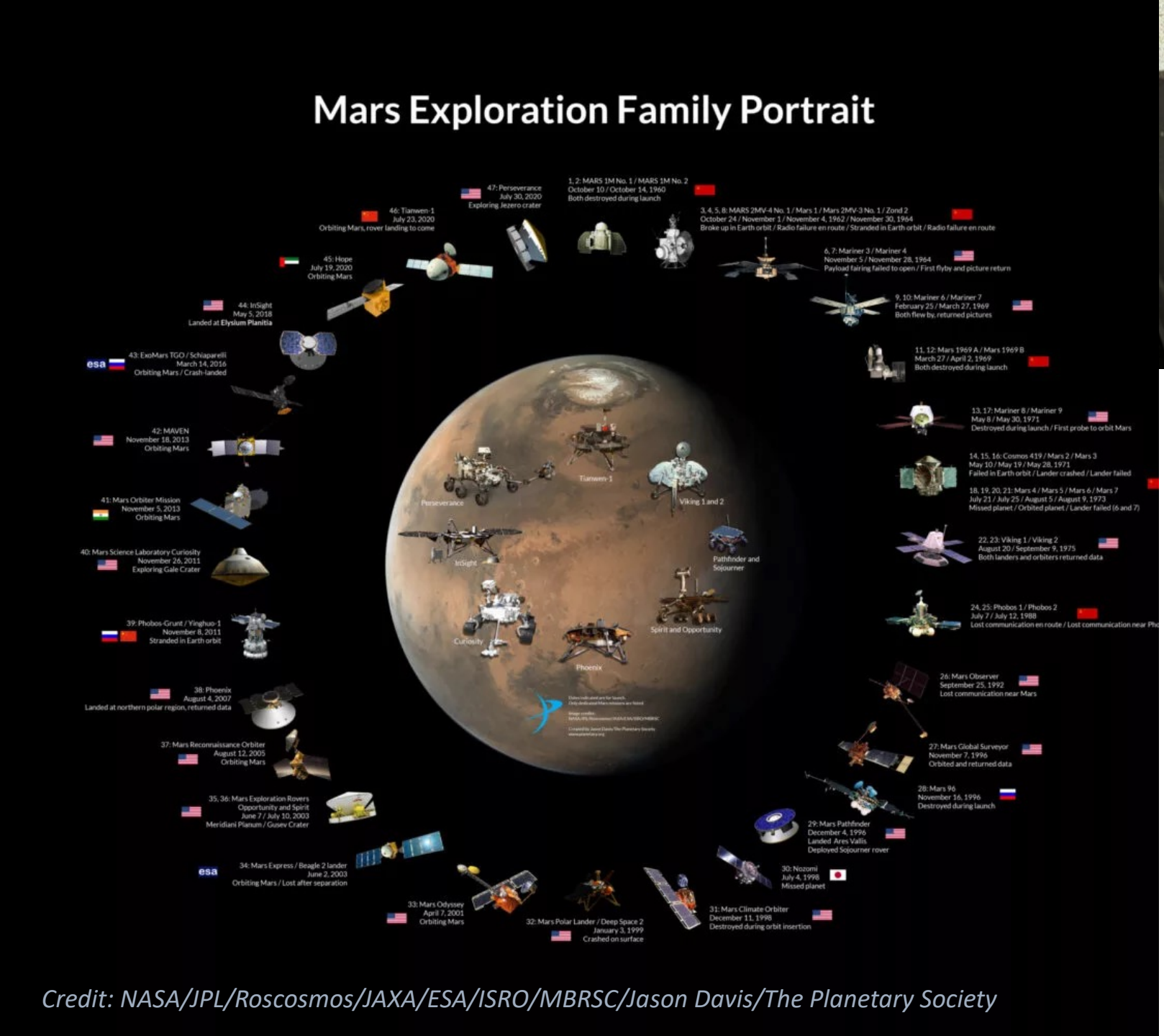
Deep space exploration (solar system)

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

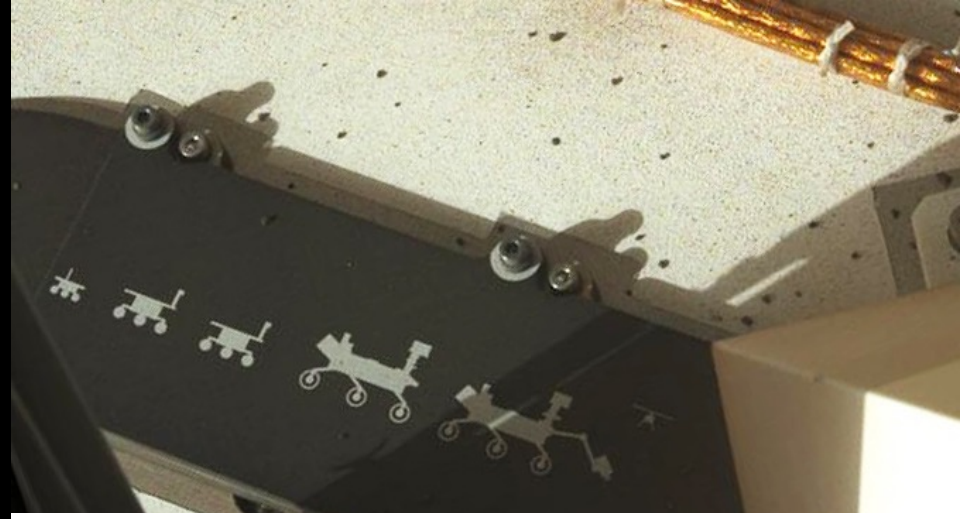
Implementing planetary protection practices

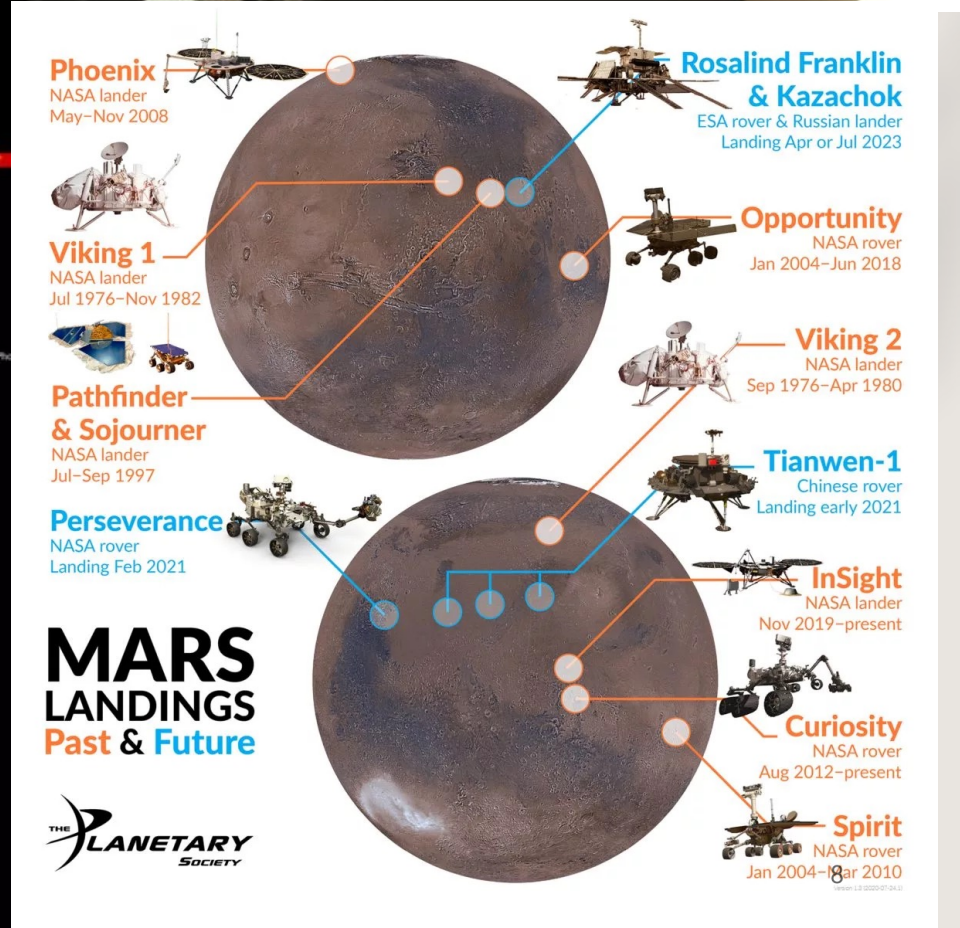
Open access to scientific data

Aurora Programme - artist's impression. *Image credit: ESA*



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





World-wide open access to deep space exploration scientific data

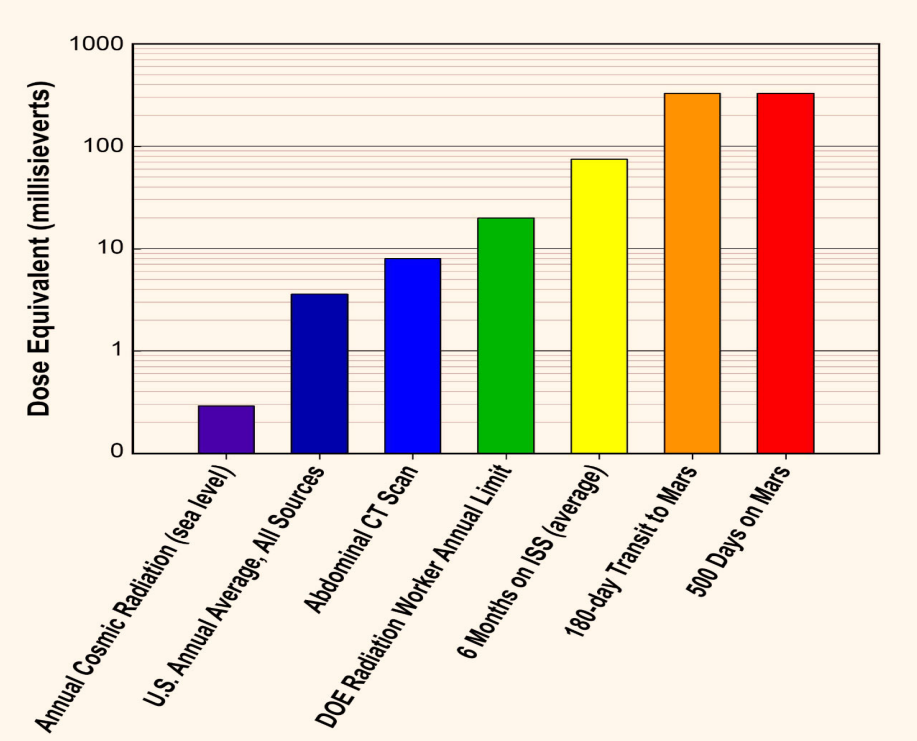
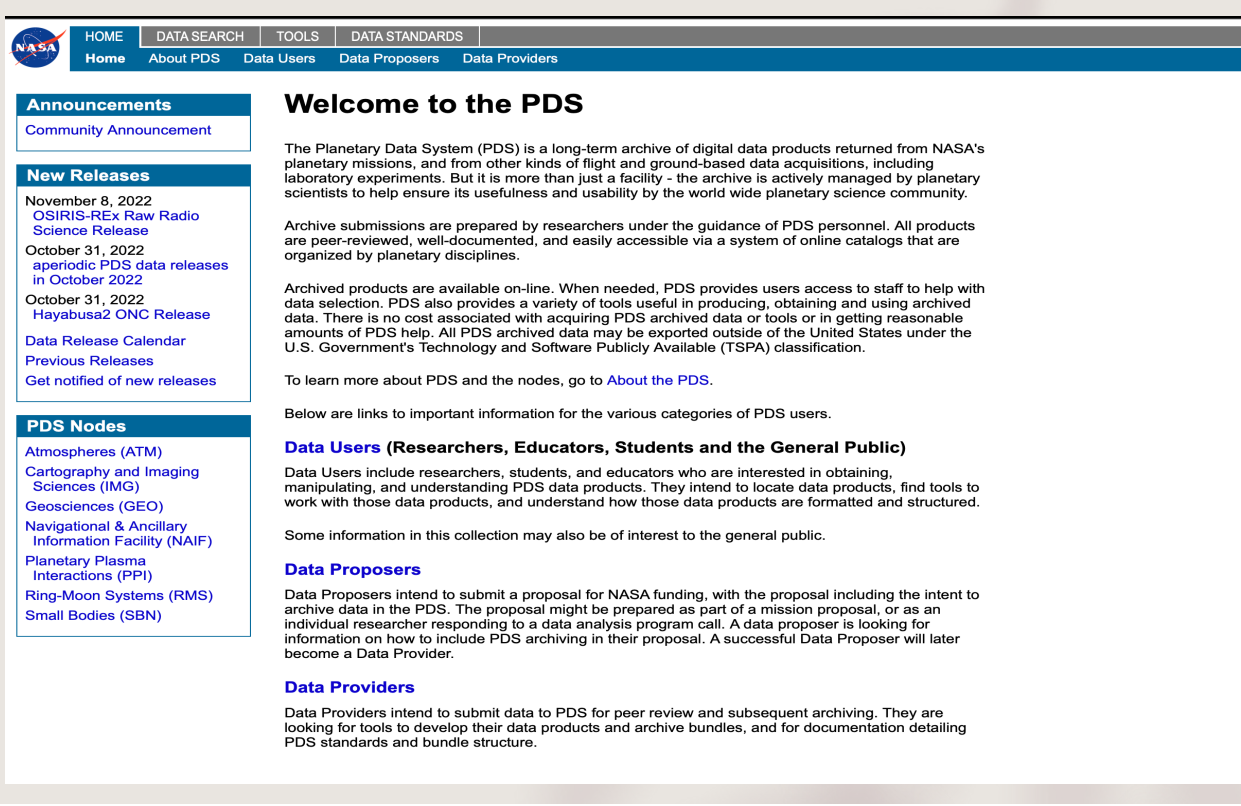
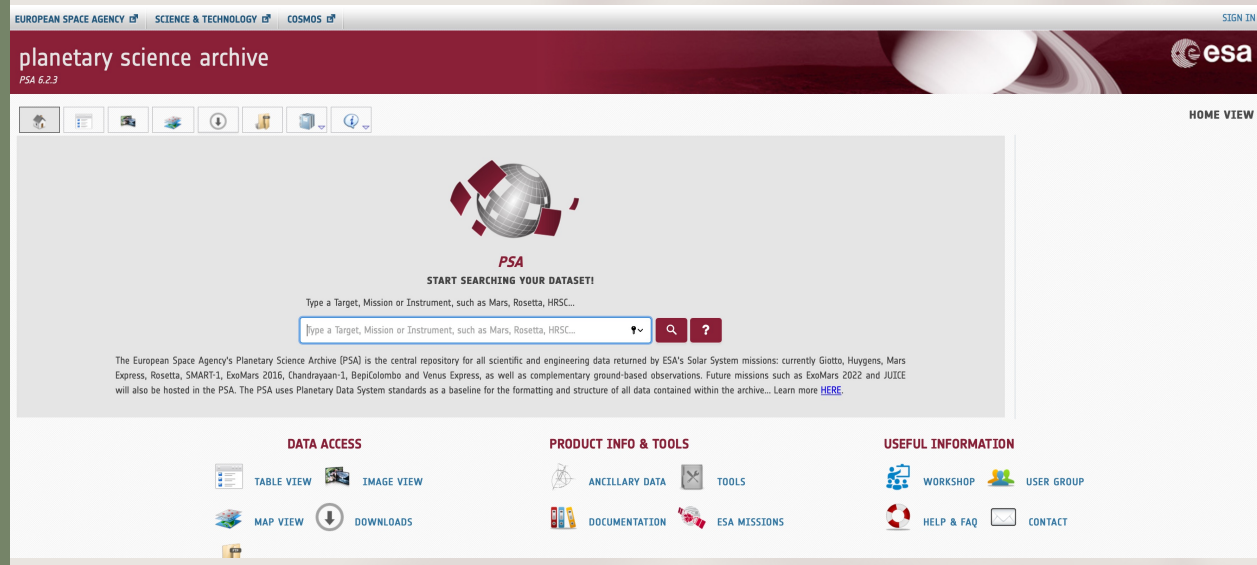


Image credit: RAD/Curiosity rover/ NASA.





In-Situ Resource Utilization (ISRU)

Transformation of local resources in space

Why?

- Decreases mission cost
- Increases payload capacity
- Reduces mission and crew risk
- Extends mission duration

What?

- Energy sources (solar panels)
- Propulsion (oxygen, methane, hydrogen)
- Life support systems (water, oxygen, food..)
- Radiation shielding
- Construction (regolith)

Mars I: Laboratory simulation of ISRU

Regolith + binder curation under Martian conditions

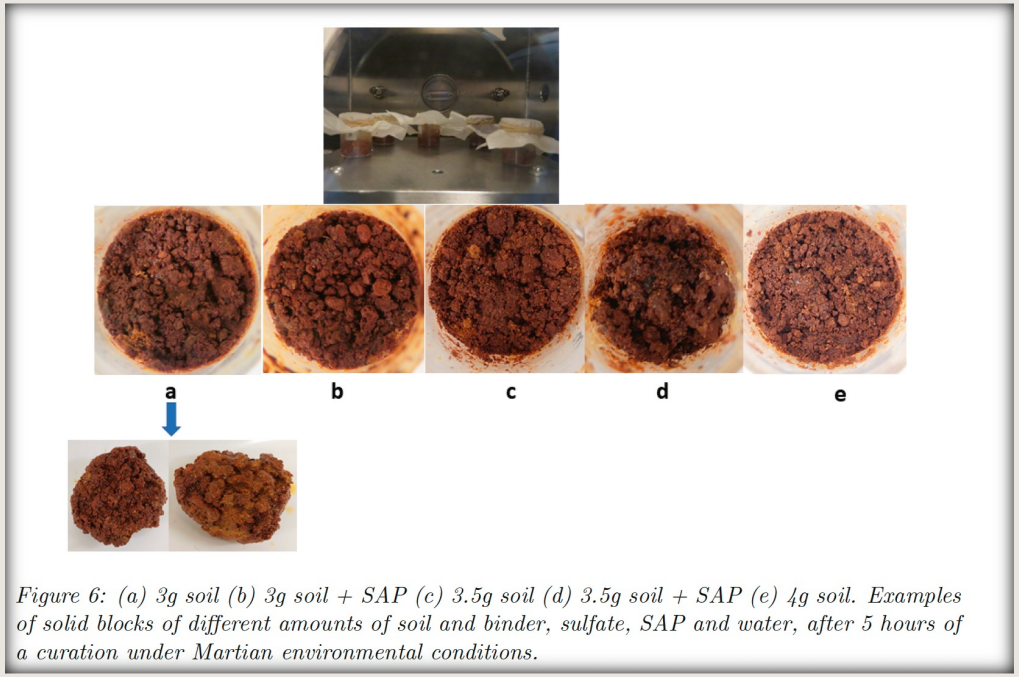
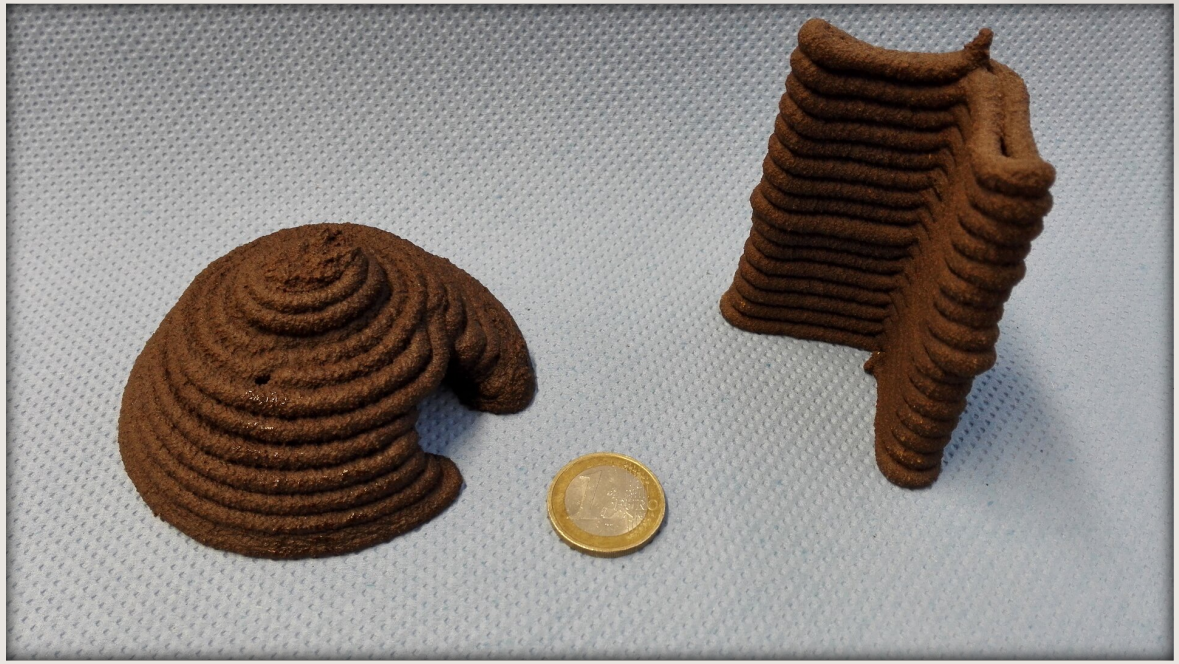


Figure 6: (a) 3g soil (b) 3g soil + SAP (c) 3.5g soil (d) 3.5g soil + SAP (e) 4g soil. Examples of solid blocks of different amounts of soil and binder, sulfate, SAP and water, after 5 hours of a curation under Martian environmental conditions.

A. Vakkada Ramachandran, M. I. Nazarious, T. Mathanlal, M.-P. Zorzano, and J. Mart´ın-Torres, “Space Environmental Chamber for Planetary Studies,” Sensors, vol. 20, p. 3996, jul 2020. using MMS soil simulant.

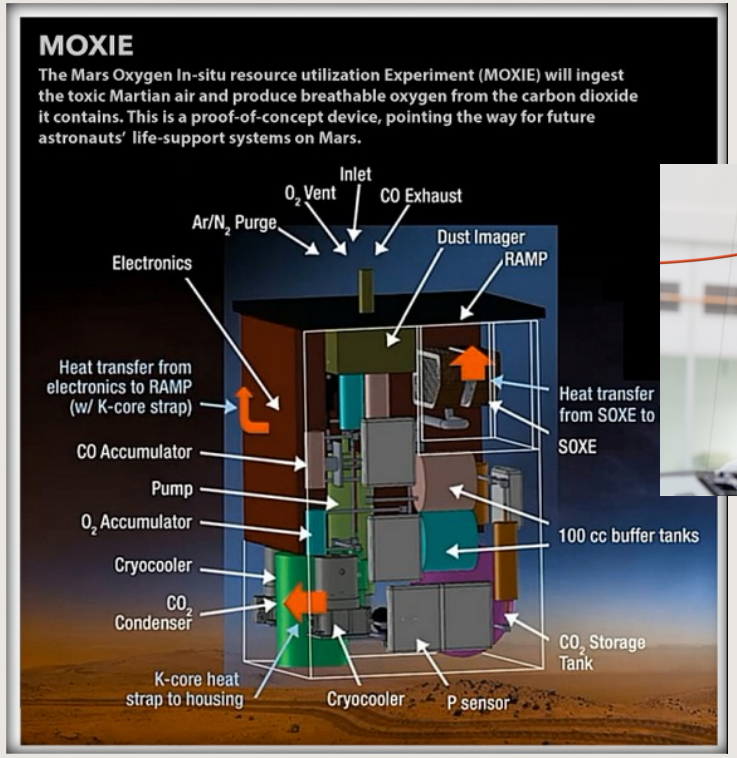
3D printing with regolith

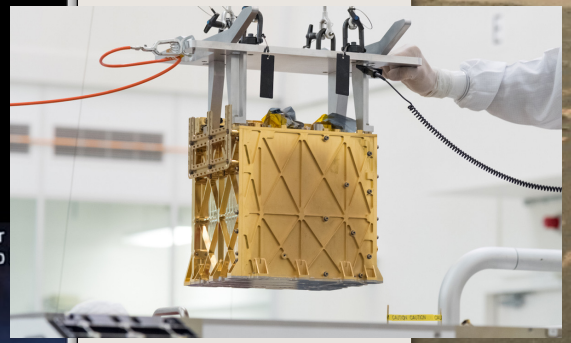


A miniature igloo and a corner wall were manufactured as examples of designs that might be required by colonists, produced from JSC volcanic soil simulant. Credit: ESA/ Fotec

Mars II: Technology demonstrators of ISRU

Oxygen production: MOXIE





Credit: MOXIE team

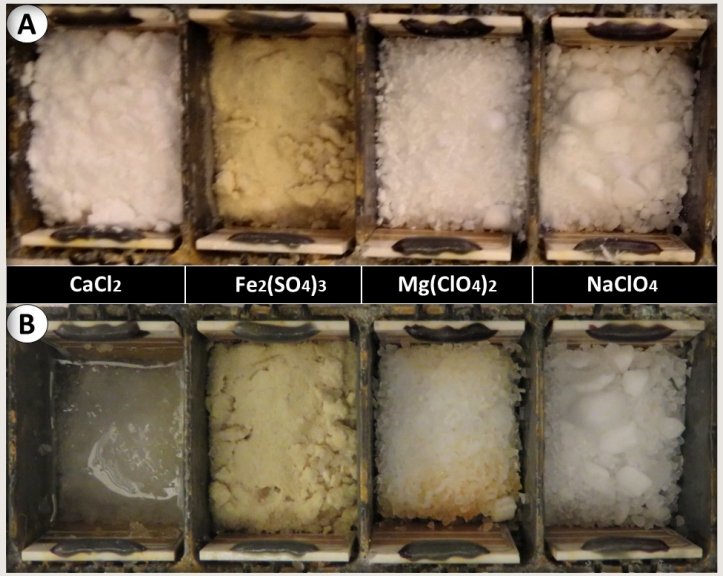
Perseverance rover, at Jezero, Mars NASA

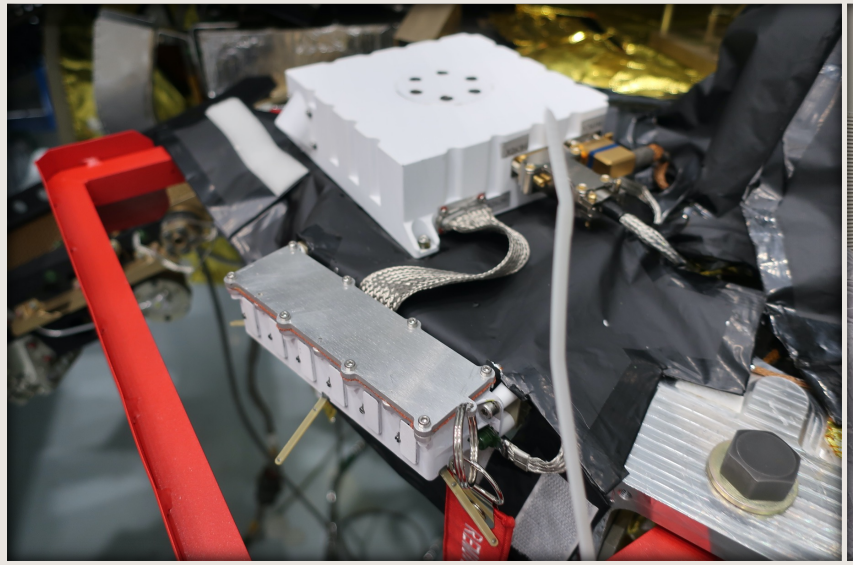
Hoffman, Jeffrey A., et al. 'Mars Oxygen ISRU Experiment (MOXIE)–Preparing for Human Mars Exploration'. Science Advances, vol. 8, no. 35, Sept. 2022, p. eabp8636. DOI.org (Crossref), https://doi.org/10.1126/sciadv.abp8636.

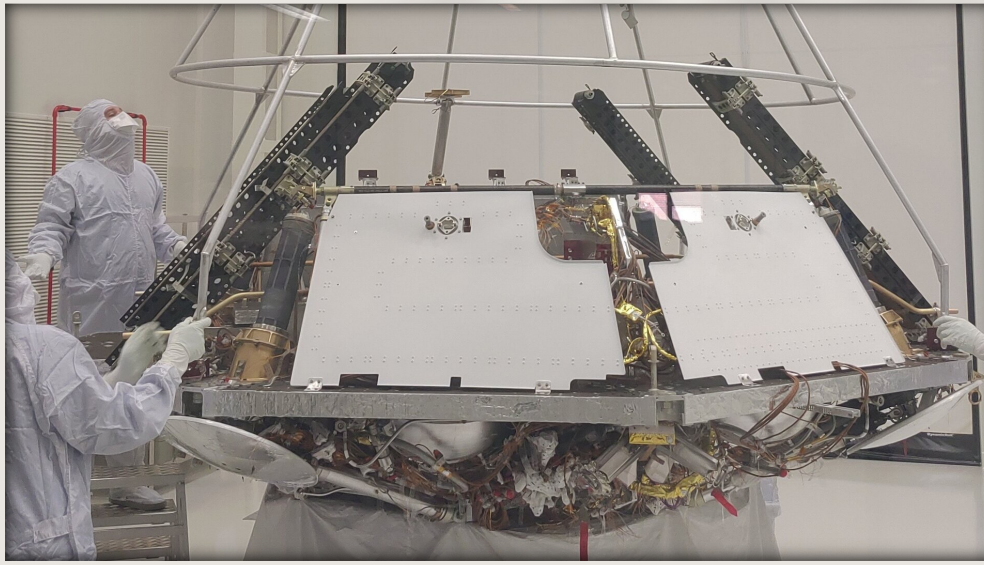
Mars III: Technology demonstrators of ISRU

Water production: HABIT *ExoMars rover and surface platform ESA/IKI*

Credit: HABIT team, ExoMars ESA/IKI



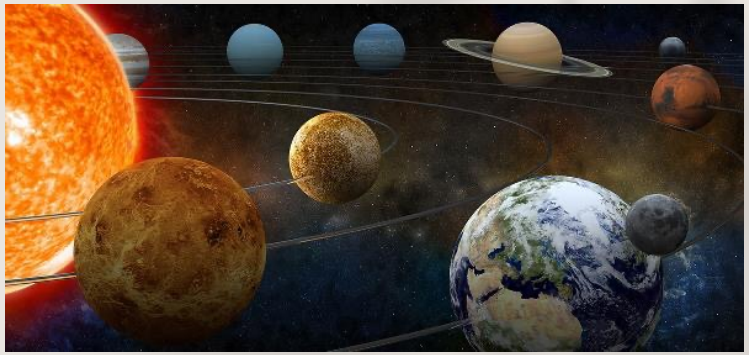




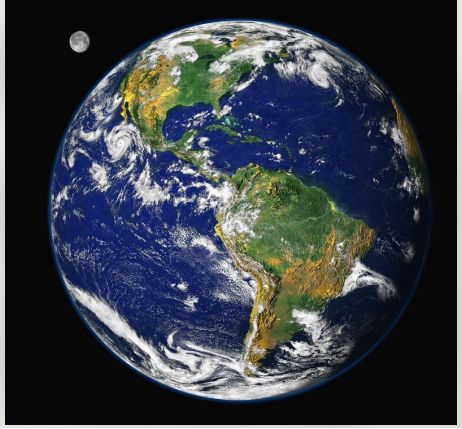
J. Martín-Torres, M.-P. Zorzano, A. Soria-Salinas, M. I. Nazarious, S. Konatham, T. Mathanlal, A. Vakkada Ramachandran, J. Ramirez- Luque, R. Mantas-Nakhai, The HABIT (HabitAbility: Brine Irradiation and Temperature) environmental instrument for the ExoMars Surface Platform 2022, Planetary and Space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

Planetary protection:

avoid the cross-contamination of the bio-spheres



Spores



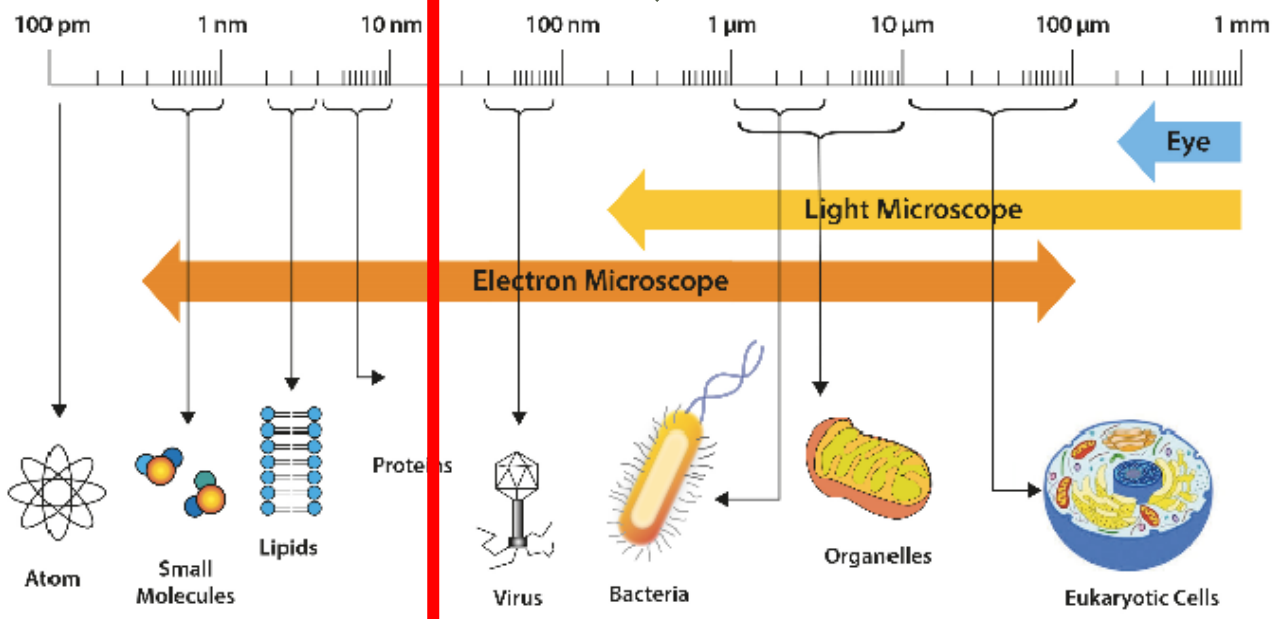


Figure 8 – Different size, shape and arrangement of bacterial cells.

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.

The Planetary Protection of Outer Solar System (PPOSS) Project *The PPOSS project Coordination and Support Action has received funding from the European Commission's H2020 Program (2016-2018) under grant agreement 687373. -- pdf in EU portal* http://pposs.org

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.