Charting Safety in the New Space Era: Planetary Protection considerations

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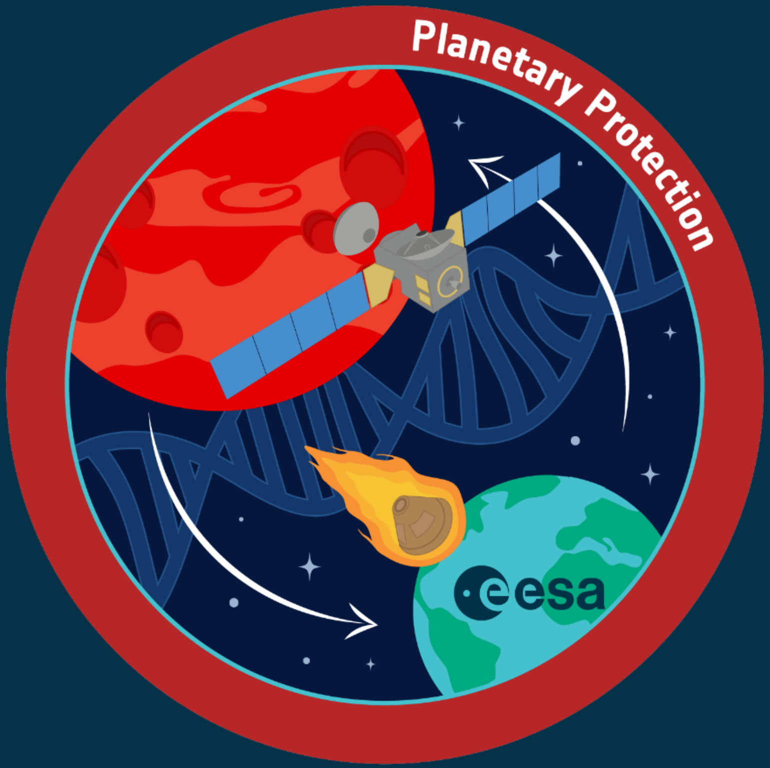
Objectives of planetary protection

Promoting the sustainable and responsible exploration of space by tackling the potential transfer of biological matter to and from Earth and other objects in the Solar System.



Principle 1: The conduct of scientific investigations of possible extra-terrestrial life forms, precursors, and remnants must not be jeopardized (forward planetary protection)

Principle 2: The Earth-Moon system must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission (backward planetary protection)

International framework

Article VI:
States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty

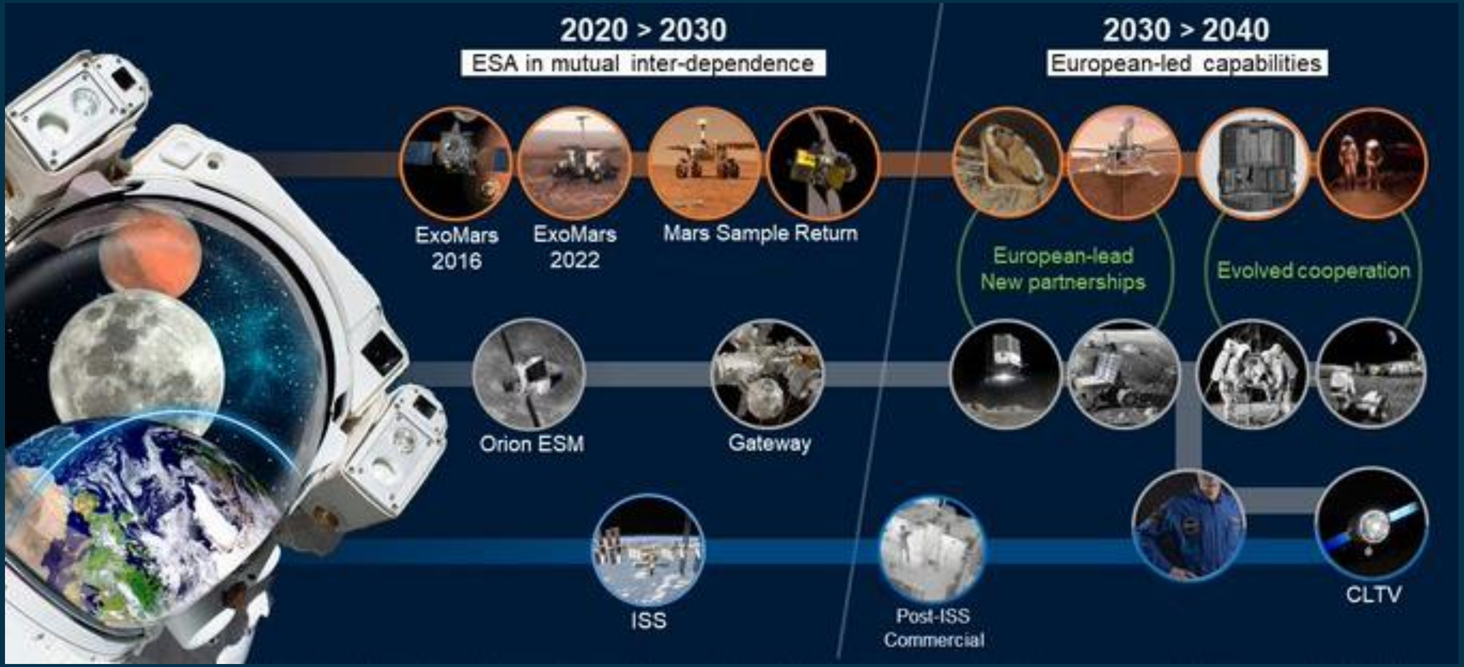
- Support the science based international consensus process
- Develop new guidelines and provide significant inputs to COSPAR

UN Outer Space Treaty (OST) 1967 → COSPAR (Planetary Protection Policy) → State parties to the UN OST or space agencies (i.e. ESA, JAXA, NASA)

Article IX:
States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose

Challenges and opportunities

Planetary protection is driven by objectives for specific missions and target bodies.
Complex mission, complex objectives



Charting planetary protection

Notional process flow:

Key assumptions based on science

Identification of hazards


EUROPEAN SPACE AGENCY

COUNCIL

ESA Planetary Protection Policy

Control of hazards: requirements, policies (constrains)

With the increased complexity of current and future mission, what do we lack and in which part of the process?

Earth’s Moon

Scientific interest on the Moon is mainly focussed on volatiles, likely to be trapped on ices in Permanent Shadowed Regions (PSRs) or poles:

- They might be a record of pre-biotic organic materials delivered to the Earth-Moon system
- Lunar polar ices irradiated by cosmic rays provide a natural laboratory for the synthesis of organic molecules (i.e. a natural Miller-Urey like experiment)

Great astrobiological interest, and lunar poles are the most easily accessible locations in the solar system

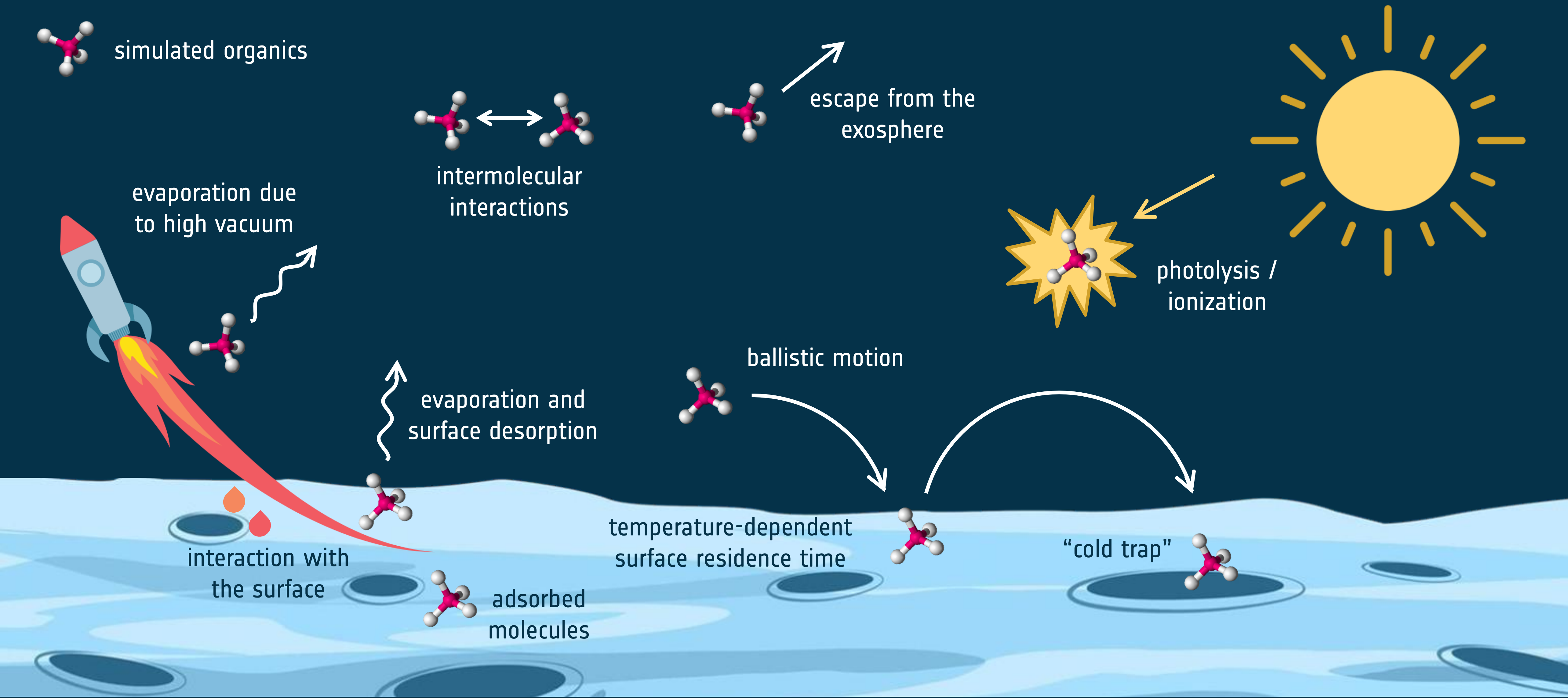
Earth's Moon

Current requirements, from COSPAR PP policy (2021)

MOON	Type of mission	Requirements
Category II	Orbiter and Fly-by	Simple documentation as per Cat II
Category IIa	Lander not on Permanently Shadow Regions and lunar poles (79S and 89N latitudes)	Organic inventory of propulsion and attitude control system
Category IIb	Lander on Permanently Shadow Regions and lunar poles (79S and 89N latitudes)	Organic inventory of propulsion and attitude control system and entire spacecraft (quantity greater than 1.0 kg).

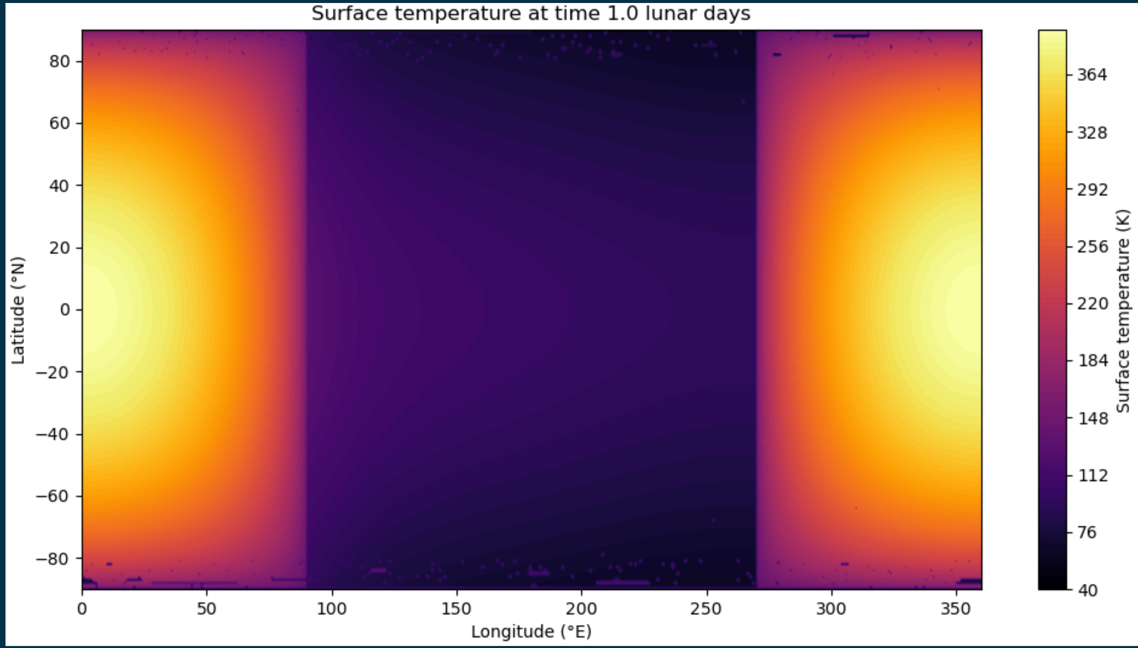
Given the exponential interest on the Moon, an assessment is on-going at ESA on utility of current requirements. This is an objective-driven study, based on planned scientific investigations on Earth's Moon (Argonauts)

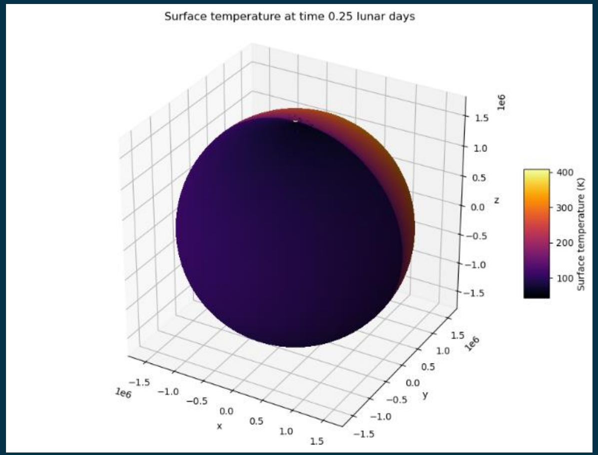
TRANSPORT OF ORGANIC VOLATILES ON THE MOON - MODEL

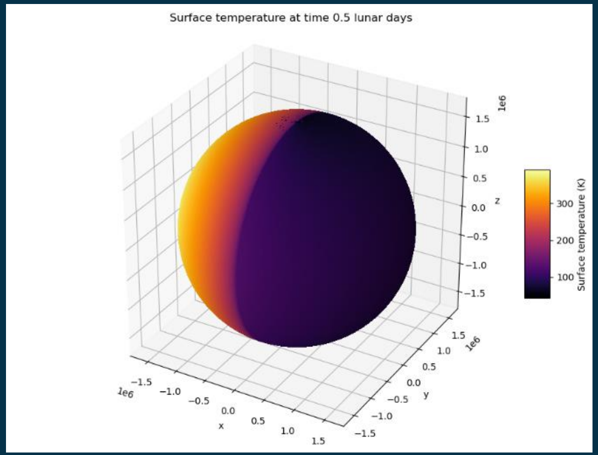


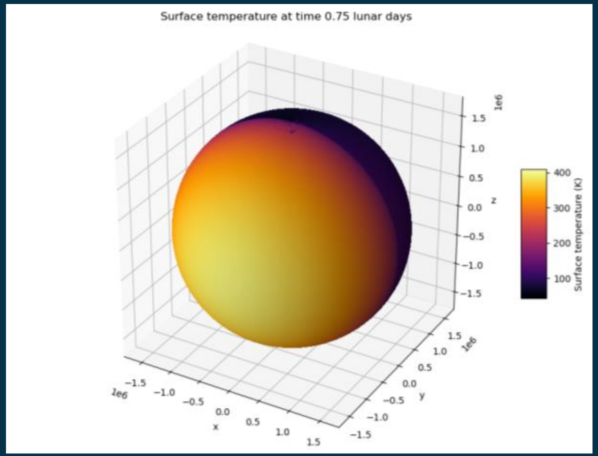
TRANSPORT OF ORGANIC VOLATILES ON THE MOON - MODEL

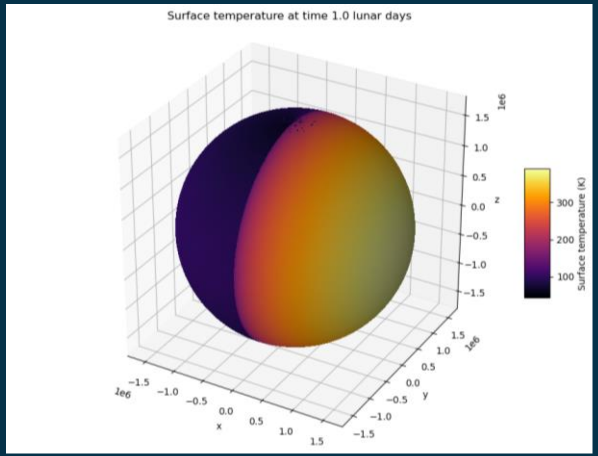
SIMULATED LUNAR ENVIRONMENT







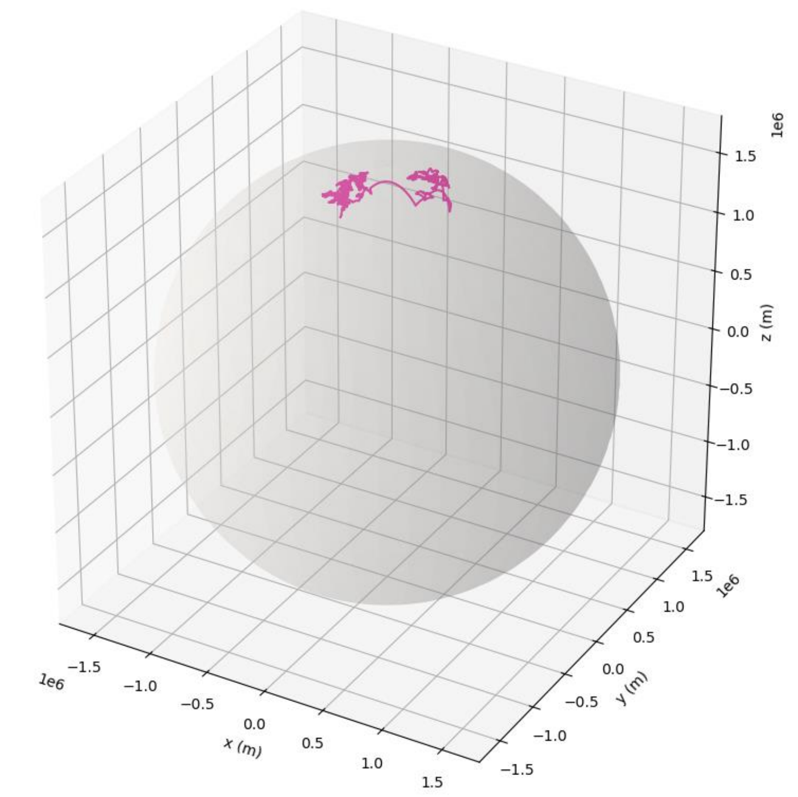




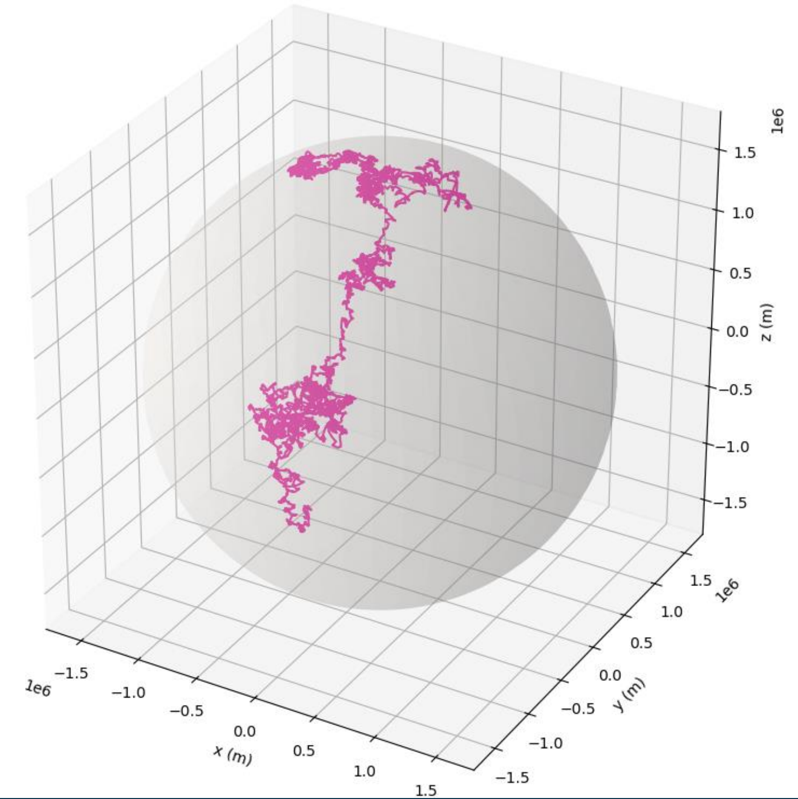
TRANSPORT OF ORGANIC VOLATILES ON THE MOON - MODEL

SIMULATED MOLECULE TRAJECTORIES - EXAMPLE

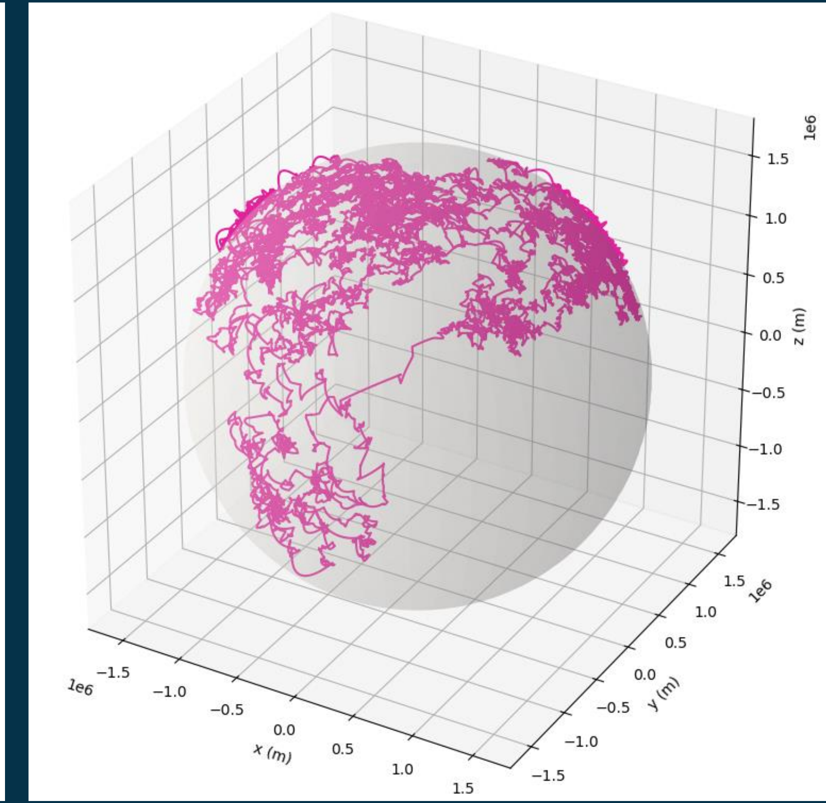
1 day



7 days



30 days



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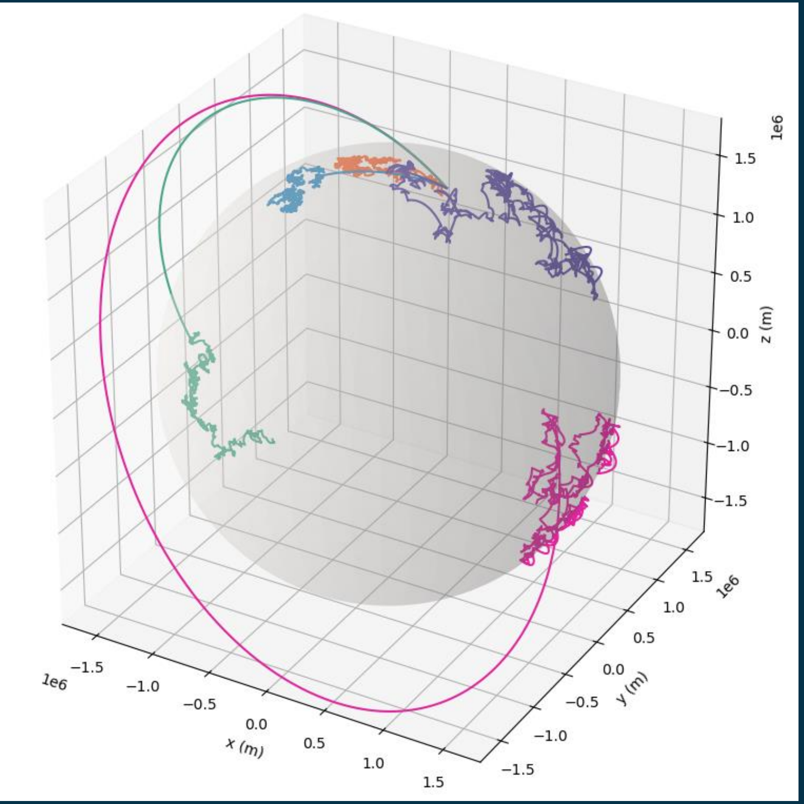

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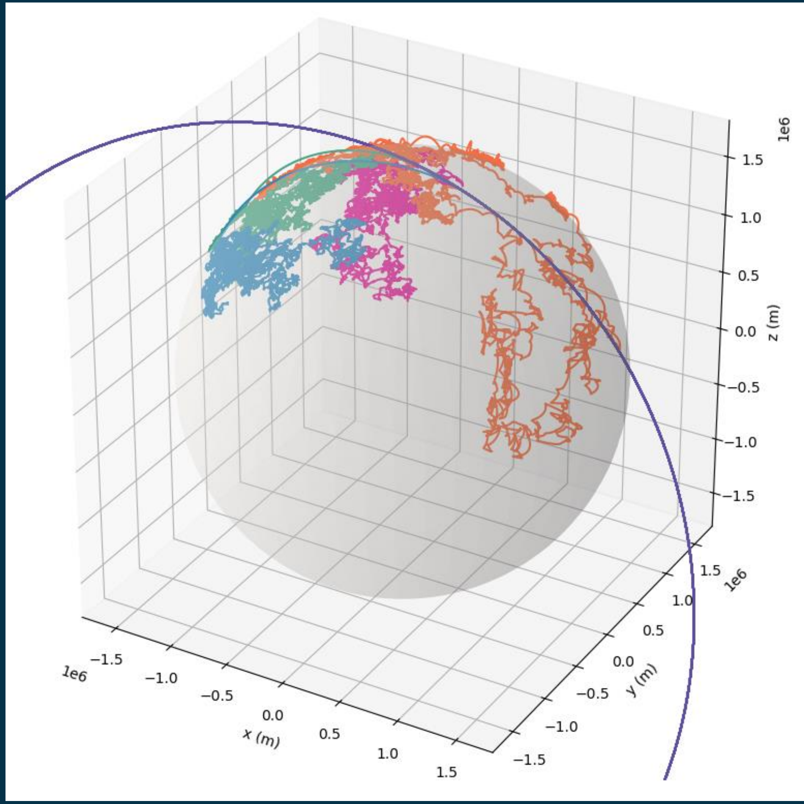

Mars

Current requirements – forward contamination from COSPAR PP policy (2021)

MARS		Surface spore [bacterial spores]	Spore density [spores/m2]	Organic inventory	Probability of Impact
Fly-by, gravity assist manoeuvres	Cat. III	* ≤ $5x10^5$	NA	NA	* ≤ $1x10^{-4}$ * ≤ $1x10^{-2}$ * ≤ $5x10^{-2}$
Lander systems not carrying instruments for searching life	Cat. IVa	≤ $3x10^5$	≤ 300	YES	NA
Lander Systems searching for Martian life	Cat. IVb	≤ 30 or driven by search-for-life instruments	≤ 0.03 or driven by the nature and sensitivity of search-for-life	YES	NA
Lander Systems in special regions	Cat. IVc	≤ 30	i.a.w. surface spore	YES	NA
		* Either probability of impact or number of spores (i.e. NOT BOTH)		An organic materials inventory of bulk constituents ≥1 kg	

Work on-going to shift from “historical” spore numbers to probability of contamination, aided by metagenomic and risk informed decision frameworks

Mars

Current requirements for ESA ERO (Earth Return Orbiter) – backward contamination

Quantitative	The probability of releasing unsterilized Martian particles with diameters ≥ 10 nanometers (TBC) into Earth's biosphere shall be **≤ 1.10^{-6}** for the first 100 years after launch from Mars.
Qualitative	PP critical functions shall be designed as **2-Failure tolerant**
	PP critical functions shall be operationally **1-Failure tolerant** during PP Critical phases
	SW involved in critical functions shall be **Category A**

Investing on PRA tools, assurance case, Bayesian statistics and support from international community, i.e. PP re-entry safety panel

Backward planetary protection – Earth Return Orbiter

<u>Planetary protection re-entry safety panel:</u>

- Objective: to ensure all the biological risks to public safety and Earth's environment, as a result of potential unsterilised Martian material being in contact with our biosphere, are fully mitigated
- The outcome of the planetary protection re-entry safety review will be used as input for certification at ERO - launch and decision to release the EEV (Earth Entry Vehicle).

9 international recognised experts coming from public safety, astrobiology, space agencies and COSPAR PP Panel members

co-chair is an external member, Public Health to give a more independent weight to the review

Setting clear roles and responsibilities in industrial organisation

ESA independent members covering a wide range of engineering and mission discipline, including RAMS, Operations, Product Assurance, Safety, Materials, etc. to assess planetary protection re-entry aspects from all angles

Designing planetary protection for the future

Considerations, summary:

- Complexity of current space exploration missions need a rethinking of planetary protection approaches, tools used, and measures taken
- International scientific consensus is of great benefit for the discipline, i.e. science inform policies
- However, some of the requirements are not fully driven by science, but also by societal & political risk "appetite", acceptance (i.e. MSR – one in a million probability)
- For this reason, a communication strategy and coordination among agencies is essential
- Not much time left until the next big leap for humanity, which is crewed missions to Mars. This constitutes a big challenge for PP, but also our greater opportunity
- Working in synergies with different disciplines, investment on molecular biology (metagenomics), probabilistic models, Bayesian statistic are deemed essential
- Policy/requirements updates foreseen in the next future to include state-of-the-art methodologies to give flexibility to project teams
- Requirements are not credible without considering the implementation phase. Synergy among ESA, NASA & JAXA, particularly in front of COSPAR PP Panel, is considered strategic