

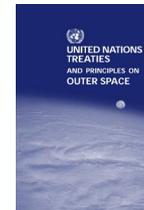
2025 ESF MSR study - Review of Biological Impact Assessments for Mars Sample Return

Luca Stoll, 15th January 2026

The need for the study

ESA projects tailor both!

UN Outer Space Treaty



The COSPAR Policy on Planetary Protection



The ESA Planetary Protection Policy



ECSS-U-ST-20 Planetary Protection Requirements



ESA project Planetary Protection Requirements



“ESA missions shall comply with the COSPAR guidelines”

Requirements implementing the COSPAR guidelines

Requirements tailored for the specific ESA project/mission

ECSS-U-ST-20 Planetary Protection Requirements

Requirements implementing the COSPAR guidelines



ECSS-U-ST-20C (1 August 2019) Requirement 1430033:

The probability that a single unsterilized Martian particle of $\geq 0.01 \mu\text{m}$ in diameter is released into the terrestrial environment shall be $\leq 1 \times 10^{-6}$ for the first 100 years after launch from Mars.

NOTE 1 Rational for this requirement is to “break the chain of contact” between Mars and Earth.

NOTE 2 Source and context for numerical values in [5].

[5] Mars sample return backward contamination – strategic advice and requirements, Report from the ESF-ESSC study group on MSAR planetary protection requirements, Strasbourg, 2012

NOTE 3 The term ‘particle’ includes material from Mars and flight hardware exposed to material from Mars.

NOTE 4 If the size requirement of $0.01 \mu\text{m}$ cannot be met without decreasing the overall level of assurance for the non-release of such a particle, the release of a single unsterilised particle of up to $0.05 \mu\text{m}$ can be considered as a potentially tolerable systems-level adjustment, assuming that it has been demonstrated that this size is the lowest achievable at a reasonable cost (BAT approach) and it has been independently reviewed.

The need for the study

- a) The ESA Planetary Protection officer (PPO) has the mandate from the ESA Director General to review the compliance of the ESA missions with the ESA PP Policy.
- b) The PPRSRP (Planetary Protection Re-Entry Safety Review Panel) is established by the PPO to support this review of compliance.
- c) PPRSRP ERO/MSR review 2023 (ref. ESA-TECQI-RP-2023-001540) found the need to update the 2012 ESF study regarding Mars Sample Return missions.



The 2012 study (ESF - ESSC Study Group, 2012)

Existence of Harmful Biological Material

The baseline concern was whether Mars could harbour lifeforms or biological entities that may be harmful to Earth's biosphere. While no evidence of life on Mars had been found, the possibility could not be ruled out.

Particle Size Constraint

The report recommended a minimum containment threshold of 0.05 micrometres (μm), corresponding less than half of the smallest diameter of any free-living self-replicating microorganism observed.

Probability of Release Threshold

The study proposed a maximum acceptable probability of release for a hazardous Mars particle at less than one in a million (10^{-6}). This threshold was aligned with international standards for biosafety and risk management.



Objective 1: Assess if ECSS-U-ST-20C (1 August 2019) requirement 1430033 is still adequate considering scientific knowledge progression since 2012

Objective 2: Assess the risk posed by the specific matter returned from Mars via the ESA/NASA MSR campaign for Earth’s biosphere

Study results: Existence of Harmful Biological Material

Recommendation

Until returned samples from Mars can be proven to be harmless to the Earth biosphere, their study should be restricted to physically sequestered high containment facilities.

Recommendation

The probability of extant or dormant life on or near the Martian surface should be periodically reviewed in light of new findings, notably from the Rosalind Franklin rover.

Recommendation

Case studies involving harmful effects of invasive species or unintended microbial introduction into Earth ecosystems (e.g. thawing permafrost) should inform potential contamination scenarios.

Recommendation

Categorical assumptions about the harmlessness of extremophiles should be avoided and adaptive biosafety criteria should be maintained, informed by ongoing discoveries from Mars missions, space-borne experiments and terrestrial cryo- and permafrost analogues.

Recommendation

The previous assumption that life forms from extreme environments on Earth have not been found to be pathogenic to humans should be weakened, as although generally not highly virulent, they could still pose risks to immunocompromised individuals.

Recommendation

Scientific discoveries related to the pathogenicity of extremophiles, prions and other non-genetic agents should be continually monitored and integrated into backward contamination protocols.

Recommendation

The particle size threshold of 0.01 μm corresponding to a maximum allowable release probability of 10^{-6} , and 0.05 μm as the zero-release threshold should be maintained, and periodically reassessed to reflect advances in synthetic biology, environmental microbiology, and aerosol science.

Recommendation

Synthetic biology should inform the definition of the lower limit for functional, self-replicating cells, particularly through the use of JCVI-syn3.0 and its derivatives as reference models.

Recommendation

The size threshold should no longer be viewed solely in terms of organism dimensions but as a proxy for functionally relevant transport vectors.

Recommendation

Contamination control strategies should prioritise carrier dynamics, since these particles ultimately define the size, aerodynamic behaviour, and filtering efficiency relevant to engineering design.

Recommendation

Conditional policy responses should be considered. For example, a confirmed biosignature detection on Mars before the samples are returned would require an immediate re-evaluation of the probability framework and may necessitate the implementation of additional sterilisation and containment measures.

Study results: Particle size and probability of release threshold



Recommendation

The one-in-a-million risk threshold is a practical convention, but future assessments should acknowledge that societal perceptions of acceptable risk may be shifting in view of recent global pandemics and increasing systemic fragility of the biosphere. In that respect, targeted studies should be conducted on public perception, comparing past assessments and examining how institutional trust influences public support for planetary protection measures.



Study results: Risk posed by the specific matter returned via the ESA/NASA MSR campaign

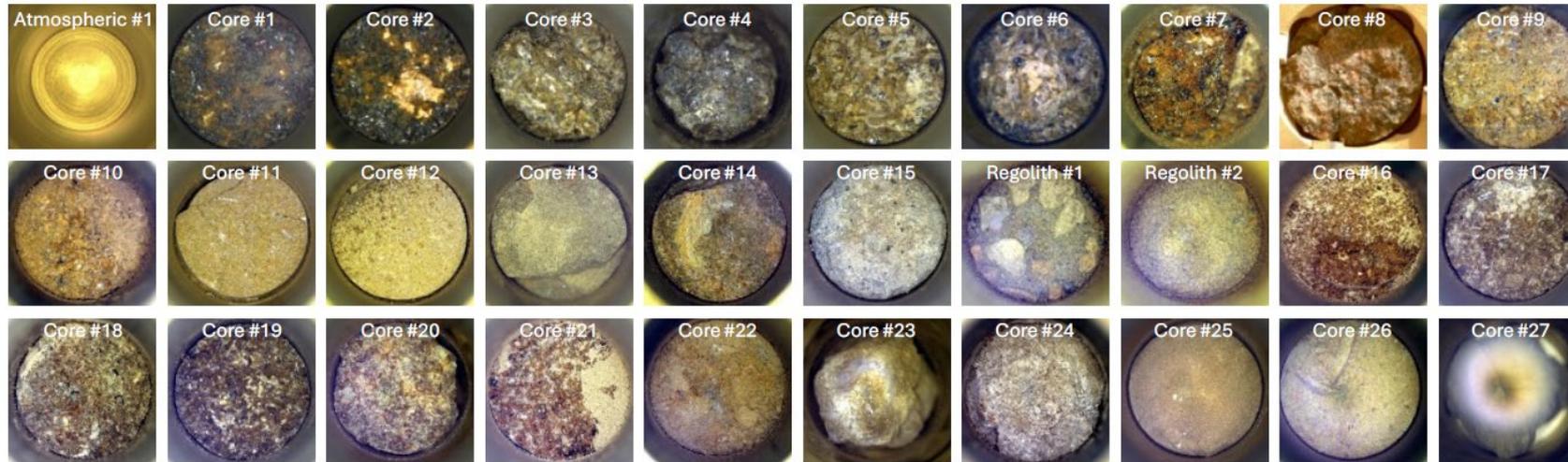


Figure 4.1: Samples collected to date by Perseverance (adapted from NASA/JPL-Caltech)

Probability of returning harmful material through the [ESA/NASA] MSR campaign

The probability of sampling extant life is considered very low due to the lack of deep drilling capabilities for accessing material shielded from harmful cosmic radiation.

Considering the global mixing of Martian dust and current surface conditions, which are incompatible with biological activity or replication, the probability of harmful environmental contamination from the Martian atmosphere or dust particles is considered to be extremely low.

Recommendation

Sampling of ancient or dormant life should be considered as a possibility, as it is not possible to assert that the samples are entirely free of harmful biological content.

Objective 1: Assess if ECSS-U-ST-20C (1 August 2019) requirement 1430033 is still adequate considering scientific knowledge progression since 2012

Result: ECSS-U-ST-20C (1 August 2019) Requirement 1430033 is still adequate:

The probability that a single unsterilized Martian particle of $\geq 0.01 \mu\text{m}$ in diameter is released into the terrestrial environment shall be $\leq 1 \times 10^{-6}$ for the first 100 years after launch from Mars.

Result Objective 2: Asses the risk posed by the specific matter returned from Mars via the ESA/NASA MSR campaign for Earth's biosphere

Result: The risk posed by the specific material returned via the ESA/NASA MSR campaign is considered lower than from other regions on Mars (e.g. deeper sub-surface), but no reduction in precaution/requirements can be concluded.

Thank you!