

# ESA Planetary Protection Updates

COSPAR Planetary Protection Panel –  
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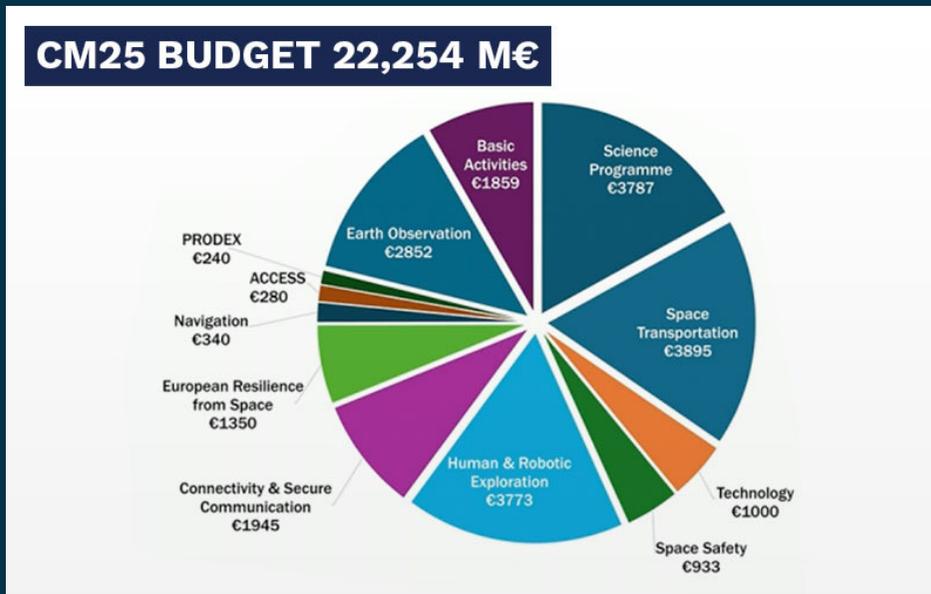
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# ESA Ministerial Council – CM25



The largest contributions in the history of the European Space Agency, have been approved at its Council meeting at Ministerial level in Bremen, Germany (Nov 2025) for the 2026-2028 period.



ESA's draft budget. Source: <https://europeanspaceflight.com>



# Why CM25 outcome is important for Planetary Protection?



On track to work and deliver the PP vision



Planetary protection is now part of the TEC2040 vision as supporting technology, and acknowledged by EXP and SCI visions



## PLANETARY PROTECTION FOR SUSTAINABLE AND RESPONSIBLE SPACE EXPLORATION

### Vision:

A combination of robotic and crewed missions has significantly increased humanity's presence in outer space. We can now explore the Solar System like never before—establishing a sustained presence on the Moon, searching for life on Mars and the Icy Worlds, and preparing for crewed missions to the Red Planet. Europe leads the way in sustainable and responsible space exploration, with planetary protection at the core of its efforts.

### Preservation of life in all forms

Ensuring that scientific research related to the chemical evolution and origin of life in our Solar System is not compromised and preservation of the Earth's biosphere from the return of unsterilised material from outer space has always been a priority for space exploration. This is the discipline of Planetary Protection (PP), and its mandate has been given by the United Nations - Outer Space Treaty (1967), Articles VI and IX.

As space becomes more accessible, new actors are investing in space and planning to launch complex, innovative missions. However, ESA's responsibilities towards its Member States and the international scientific community to protect pristine environments of the bodies we aim to explore, as well as safeguarding Earth's environment and public health, remains the same.

### Evolution of best practice

Planetary protection practices, initially developed for the Apollo missions, must evolve to meet the needs of ambitious missions. The ESA "Explore 2040" vision articulates precise plans for the next decades, aiming to increase European autonomy and leadership in space. The complexity of such missions calls for a

modernisation of planetary protection toolkits and the need to preserve collections of relevant samples in a consistent and standardised way.

The current culture-based methods used to verify biological contamination for space missions are unable to identify the overall biodiversity on space hardware, determine microorganisms of concern, and ultimately assess contamination risks. Similarly, for chemical contamination, there are no validated tools available to assess the risk of volatiles for scientific investigations.

In contrast, a systematic use of non-cultured, DNA-based technologies, aided by AI for contamination predictions and development of new statistical models to assess biological and chemical contamination risks, will enable a transition from current prescriptive approaches to risk-informed decision-making frameworks. Developing the technologies above will give Europe increased flexibility when implementing planetary protection, while fulfilling ESA's corporate obligations to conduct sustainable and responsible robotic and human explorations.

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### Key technologies

Metagenomics, molecular biology techniques

AI-driven phenotypic / contamination predictions

Curation of samples

Bayesian statistics (applied to safety and contamination)

Probabilistic models for assessing contamination risks

Standardised biological and organic databases



# Documentation updates



ESSB-HB-U-006  
ESA Planetary Protection  
Compliance Verification  
Guidelines (WIP)

- Explains the rationale of PP requirements
- Describe the verification process for compliance

News: ESSB-HB-U-006 – Handbook for planetary protection

HB has been produced and sent internally to ESA wide for comments in Dec25.  
Waiting to receive comments for incorporation  
Plan is to publish the document when the review process is completed – expected by Q2 2026

- Complies with COSPAR PP policy
- General statements about ESA mandate, in line with Outer Space treaty (OST)



Levied on ESA Projects by the Planetary Protection Approval Authority

- Generated by the Projects
- Approved by the ESA Planetary Protection Approval Authority

- The Handbook is another milestone to make planetary protection more embedded within mission team and to increase transparency on the verification process

ESA-TECQI-PR-2023-001247  
The ESA Planetary Protection Review and Approval Process

ECSS-Q-ST-70-53  
ECSS-Q-ST-70-54  
ECSS-Q-ST-70-55  
ECSS-Q-ST-70-56  
ECSS-Q-ST-70-57

ECSSs helping with implementation of PP requirements

Procedural document, describing roles, responsibilities inside ESA; and the way PP shall be implemented within the agency



# ESA Planetary Protection Handbook



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## DOCUMENT

ESA Planetary Protection Requirements Compliance Verification Handbook

Prepared by: Silvio Sibilaldi & ESA Planetary Protection Working Group  
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### Table of contents

Introduction	11
1 Scope	12
2 References	13
3 Terms, definitions and abbreviated terms	14
3.1 Terms from other documents	14
3.2 Terms specific to this document	15
3.3 Abbreviated terms	16
4 Introduction	17
4.1 Planetary Protection overview	17
4.2 Governance of planetary protection	18
4.3 ESA planetary protection policy	19
4.4 Planetary Protection process within ESA	20
4.5 Planetary Protection categorisation	24
5 Planetary Protection requirements verification	29
5.1 Management requirements	29
5.2 Cleanroom	32
5.3 Probability of impact	43
5.4 Probability of contamination	48
5.5 Mars special regions	55
5.6 Bioburden control	65
5.7 Bioburden assessment	83
5.8 Bioburden reduction	99
5.9 Biodiversity assessment	113
5.10 Organic material inventory	120
5.11 Restricted Earth return: potential unsterilised contaminants release	125
Annex A Planetary protection implementation tools	137
A.1 Organic transport model for the Earth's Moon	137
A.2 Probability of contamination	139
A.3 Planetary Protection Analysis using CUDAJectory	159
Annex B Templates	166
B.1 Organic contamination template for bulk materials	167
B.2 Organic contamination template for propulsion system and/or life science support equipments	170
B.3 Biological inventory	171
Annex C Planetary protection requirements verification	173

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Figure 5.30 Examples of pretty bad (left) and good (right) bioburden control attire.

Explaining the "Why", the "DOs" and "DON'Ts", acceptable behaviours and attitudes inside bioburden controlled environments, limit the number of personnel working at the same time on flight hardware are all good practices that can be explained in trainings.

Figure 5.30 and 5.82 show some cleanroom actions.

- PP international and legal framework
- Roles and responsibilities at ESA
- Approval process



Figure 5.31 Best practice followed by personnel inside bioburden control cleanrooms. Credit: Airbus DS and Thales Alenia Space

Page: 81/173  
 ESSB-HE-U-006 Issue 6  
 Date: 14 November 2025 Issue 6 Rev 0



- Case studies
- PP tools
- Templates

The fragments are then sequenced and the raw sequence data analysed to identify microbial signatures present in cleanrooms/hardware and to assess the microbial diversity. In short, the raw forward and reverse sequence reads are first joined together, then several quality control steps, including screening based on quality and length, aligning 16S rDNA database (e.g. SILVA), preclustering and chimera checking, can be performed. The sequence data are clustered into operational taxonomic units (OTUs), and the OTUs classified using reference database.

Typical results from 16S rDNA gene sequencing are shown in Figure

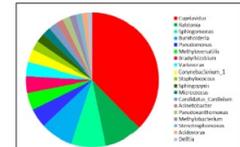


Figure 5.58 Piechart showing most abundant genera detected in dataset

Page: 107/173  
 ESSB-HE-U-006 Issue 6  
 Date: 14 November 2025 Issue 6 Rev 0



## Annex A Planetary protection implementation tools

### A.1 Organic transport model for the Earth's Moon

This annex summarizes a methodology proposed by Pym et al. (2020) to predict organic molecules trajectory based on the lunar lander fuelled by a propellant mixture of N2O4 and UDMT. Full information is contained in the paper Pym, F. S., & Zaslavsky, G. (2020). Can spacecraft - borne contamination compromise our understanding of lunar ice chemistry? *Journal of Geophysical Research: Planets*, 125, e2019JG003032. <https://doi.org/10.1029/2019JG003032>

Please see below the relevant extracts from the paper:

The model is based on the one proposed by Pym et al. (2020) and considered the last 601.3 s of descent of a simulated landing provided by the Argonaut team (Carpelito & Zaslavsky, 2024). Based on a Chemical Equilibrium with Applications (CEQA) analysis of the Argonaut lunar lander engine under ambient conditions,  $\text{CO}_2$  is identified as the most abundant organic compound present in the plume. The plume height when the lander is oriented 45° relative to the axis normal to the lunar surface, the exhaust gases are channelled toward the lunar surface. The modelled descent starts at an initial altitude of 30 km and ends at a final altitude of 0 km, covering a total trajectory length of 148 km. The landing is assumed to occur in 2021, in the lunar South Pole 90° 16.9° E. The spacecraft's exhaust gas emission is simulated by generating, at every time step  $\Delta t = 5 \times 10^{-4}$  s, a new molecule, representing  $1 \times 10^6$  real molecules, within a spherical source region with the radius centered at the nozzle exit.

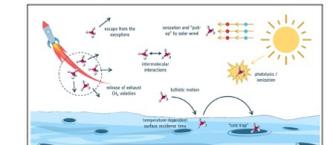


Figure A.1 Schematics of the physical processes and pathways used to model C1x molecules (extract from Sibilaldi and Parra (2025))

Page: 107/173  
 ESSB-HE-U-006 Issue 6  
 Date: 14 November 2025 Issue 6 Rev 0



# ESA & ESF Studies



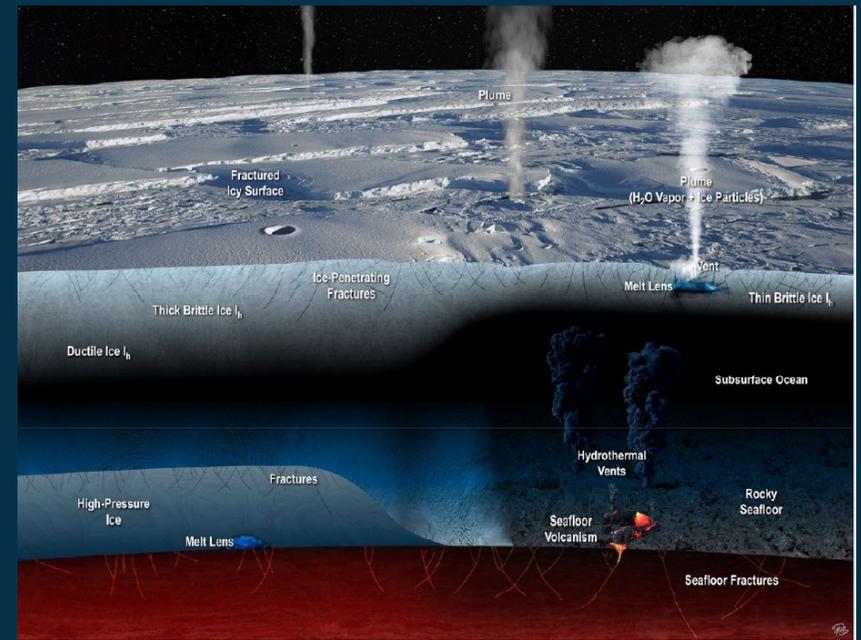
## Icy Worlds study

### Overall objective:

ESA contribution to scientific knowledge advancement, as inputs for consideration to the overall COSPAR PPP discussion

### Specific objectives include providing inputs on:

- New definitions of Icy Worlds (outermost layer predominantly believed water ice) vs their protection
- Lower limits of Earth life with regards to water activity (LLAw) and temperature (LLT)



Credit: National Academies of Sciences, Engineering, and Medicine (2023)



## Earth's Moon

### Overall objective:

Assess the consequences for scientific investigations (aimed at understanding chemical evolution and origin of life in our Solar System), as a result of contaminant introduction from the Moon's orbiters and landers

### Specific objectives include providing inputs on:

- What other means, in addition to (or in lieu of) an organic material list, should be considered in future ESA requirements
- Does the introduction of biological entities (living or dead) in the lunar environment constitute a problem for scientific investigation aiming to understand the chemical evolution and origin of life in the solar system?
- What other contaminants (i.e. nuclear, inorganics, biological) should be considered in future ESA PP requirements?



Speyerer et al. (2013)

# ESA & ESF Studies



Overall objective: Update the study that led to the current PP requirements for ESA ERO (Earth Return Orbiter) – **backward contamination**



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



ESA/ESF study 2012

Requirements were drivers for the design  
 Investing on PRA tools, assurance case, Bayesian statistics and support from international community, i.e. PP re-entry safety panel



# Project updates

## ExoMars Rosalind Franklin Mission

Planetary protection Cat IVb

MPTS CDR held

System level CDR is on going

Maintenance/refurbishment

Launch 2028



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→ THE EUROPEAN SPACE AGENCY

# ESA Planetary Protection Course



2025 edition

Workshop / September 30, 2025 - October 02, 2025

## Introduction to Planetary Protection

### Course summary

This course provides an overview of international policies, standards and methodologies used to implement planetary protection measures in space missions. It includes discussions on compliance to UN Outer Space Treaty requiring space explorations to avoid harmful contamination of celestial bodies (including the Moon) and adverse changes in the environment of Earth (as a result of introduction of extra-terrestrial matter). Emphasis will be put on both theoretical, management and practical aspects of planetary protection, with hands-on laboratory training in microbial sampling and cleanroom activities. The course is taught by international experts in the field of planetary protection, with knowledge across multiple disciplines, as well as direct involvement in state-of-the-art astrobiology missions.

### Who should attend

- Space industry or space agencies personnel dealing with planetary exploration;
- Astrobiologists interested in understanding key aspects of planetary protection framework and implementation activities;
- Anyone wishing to gain insight into the importance of planetary protection for sustainable space explorations.

### What you will learn

- What is Planetary Protection and how it was originated
- International planetary protection policies (i.e. COSPAR)
- Basics of microbiology
- Implementation of Planetary Protection requirements
- Hands on laboratory techniques and practices
- Personnel behaviour in cleanrooms
- ESA ECSS standards for bioburden control
- Backward contamination: overview on probabilistic risk assessment and curation facility
- Lessons learned from previous astrobiology missions



Thanks JAXA, Airbus, TASI, DLR, Medical UniGraz, COSPAR PPP members for great contribution



# Terrae Novae

## Elevating the future of Europe



Science & exploration



Europe's exploration vision

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