Robotic and Crewed Mars Missions Increasing the Demand for Planetary Protection Technology Needs

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October 12, 2023

Applied Space Environments Conference (ASEC)

Huntsville, Alabama

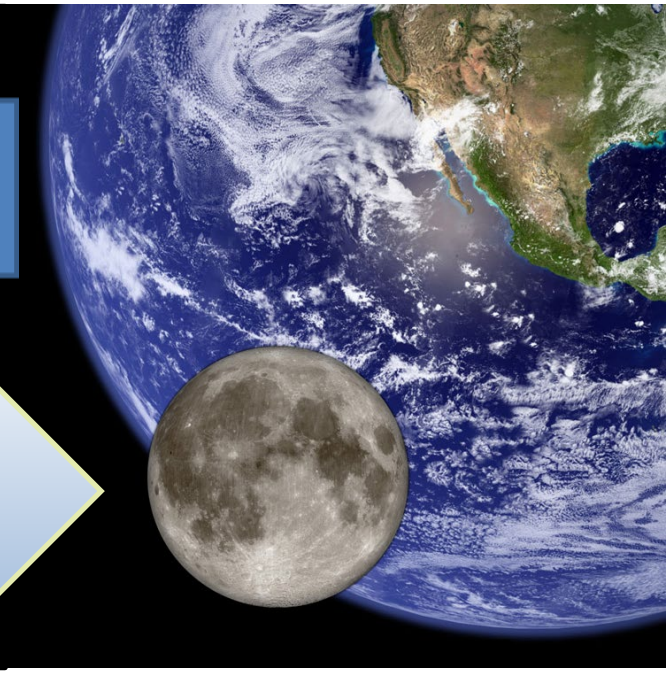
*James.N.Benardini@nasa.gov

What is Planetary Protection?

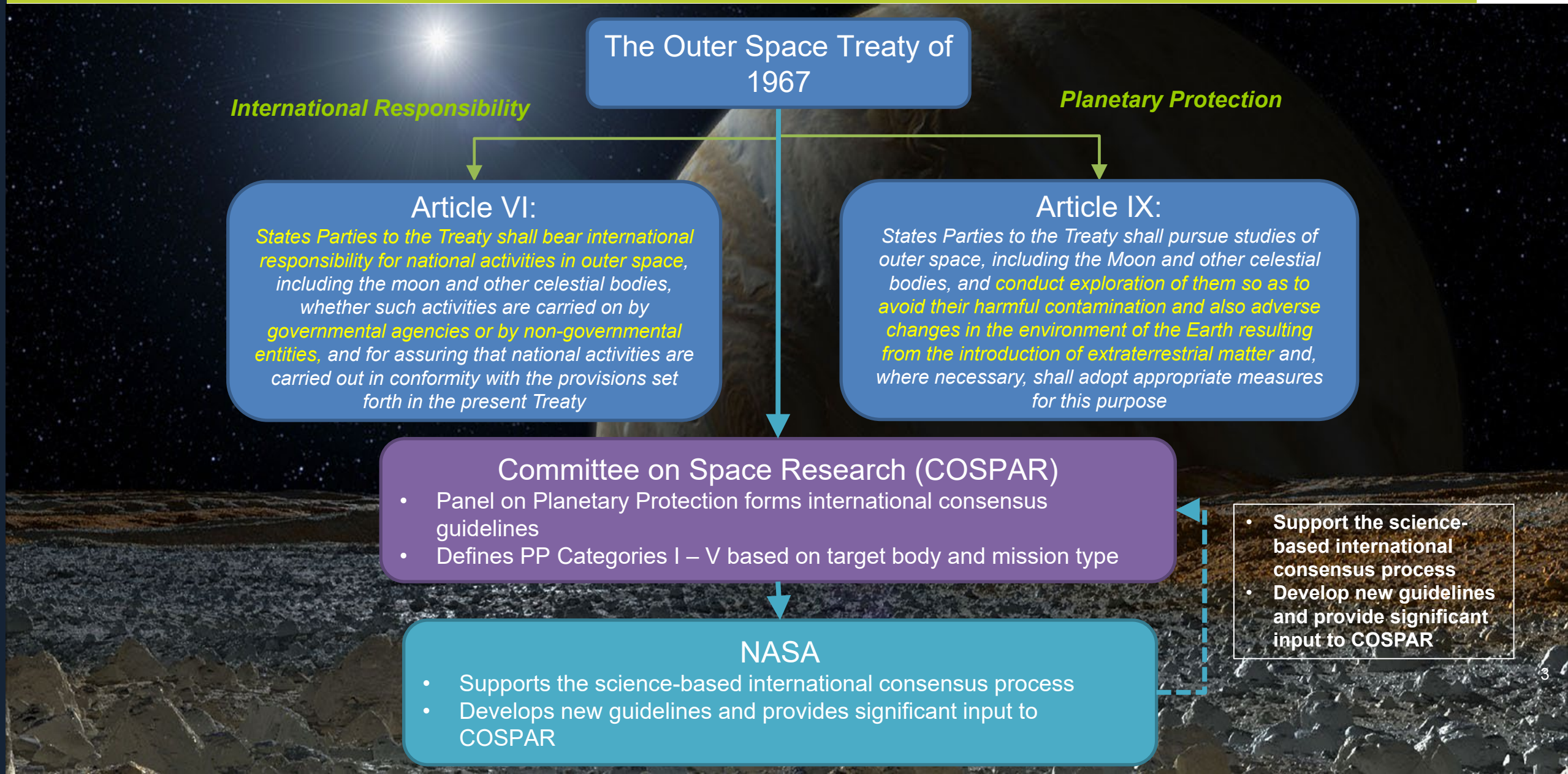
Protect current and future scientific investigations by limiting biological and relevant molecular contamination of other solar system bodies through exploration activities and protecting the Earth's biosphere by avoiding harmful biological contamination carried on returning spacecraft, as described in the Outer Space Treaty.

Forward PP - Understand and control harmful contamination of other worlds by terrestrial organisms, organic materials, and volatiles from spacecraft

Backward PP - prevent harmful biological contamination of the Earth-Moon system by potential extraterrestrial life and bioactive molecules in returned samples



International Planetary Protection Process



NASA's Planetary Protection Policy Documents

NPD 8700.1F
Replaced NPD 8020.7G
NASA Policy for Safety and Mission Success
Effective Date July 28, 2022
Expiration Date: July 28, 2028

NASA Policy Directives (NPDs)
- Documents Agency policy statements
- Describe what is required by NASA management to achieve NASA's vision, mission, and external mandates

NPR 8715.24
Replaced NPR 8020.12D/NID 8020.109A
Planetary Protection Provisions for Robotic Extraterrestrial Missions
Effective Date September 24, 2021
Expiration Date: September 24, 2026

NASA Procedural Requirements (NPRs)
- Provide detailed procedural requirements to implement policy
- Guide how policy directives are implemented in the context of specific missions

NID 8715.129 ("Mars NID")
Biological Planetary Protection for Human Missions to Mars
Effective Date: July 9, 2020
Expiration Date: July 9, 2025

NASA Interim Directives (NIDs)
- Documents an immediate, short-term statement of the Agency's policies, requirements, and identifies responsibilities for implementation
- Temporarily modify policy directives or implementation requirements

Link to NASA Planetary Protection policy and guidance documents at www.sma.nasa.gov

NASA Standards
- Provide technical requirements
- Each NASA Technical Standard is assigned to a Technical Discipline

NASA-STD-8719.27
Implementing Planetary Protection Requirements for Space Flight
Effective Date August 30,2022

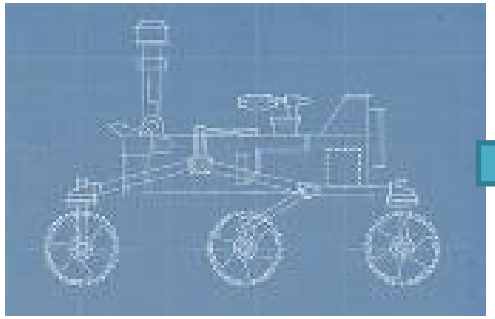
NASA-HDBK-6022
Handbook for the Microbial Examination of Space Hardware
Expiration Date: N/A
Status: Revision planned. Last draft revision released Aug 17, 2010

NASA Handbooks
- Companion documents to NPRs and NASA Standards
- Provide supporting material such as guidelines, lessons learned, procedures, and recommendations

All published documents found in NODIS: https://nodis3.gsfc.nasa.gov/

= Documents currently being updated

Control of Forward Contamination



Mission Design & Categorization

- Information to be included in the PP Mission Categorization Proposal
- Biological and organic contamination knowledge inventory materials



Spacecraft Assembly, Test, Transport, Launch, and Operations

- Controlled manufacturing environments and cleanrooms
- Bioburden Control Approach
- Analytical Approach
- Documentation requirements and communication of data/analysis updates



Avoiding Contamination following Inadvertent Impact

- Avoiding inadvertent impact of solar system bodies by spacecraft and launch elements during flyby, gravity assist, or orbital insertion
  - Jovian or Saturnian systems (Cat II)
  - Mars (Cat II-IV)
  - Sensitive Icy Worlds (Cat III or IV)
- Secondary and auxiliary payloads



Avoiding Contamination for Robotic Landed Missions

- Prevent occurrence of a biological inoculation event into a potentially habitable environment during landing and surface operations
  - Stationary and mobile activities
- Mars IVa, IVb, IVc requirements
  - Bioburden Control Approach
  - Analytical Approach
- Sensitive Icy World requirements



End of Mission Disposition

- Documentation of final disposition of hardware
- Updates to organic, biological, and combustion product inventories
- Information to be included in End of Mission PP Report

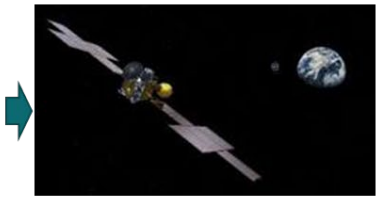
Prevention of Backward Contamination – Mars Restricted Earth Return

- Accepted controls include sterilization, isolation and containment of samples and hardware that contacted Mars.
  - *"Break the chain"*
  - *Per international and NASA standard for "restricted Earth return missions"*



Earth-Return Mission Categorization

- Inbound categorization for Earth-return missions
  - Robotic restricted Earth-return V(r)
- Notional timeline for sample receiving facility (SRF) for V(r) missions.



Contamination Avoidance Prior to Earth Entry

- **PP Requirements Document:**
  - Reports and reviews to support decision making process for Earth-return, Earth-entry, and sample release from containment
- **PP Implementation Plan:**
  - Approach to demonstrate avoidance of contamination of the Earth-Moon System
  - Data and analyses used to demonstrate compliance with requirements prior to samples returning to Earth
  - Containment facility readiness prior to samples returning to Earth



Contamination Avoidance during Earth Containment

- Demonstrate avoidance of harmful contamination of the Earth by release of unsterilized extraterrestrial material:
  - At landing site
  - During transport
  - During storage, curation, and sample safety assessment activities



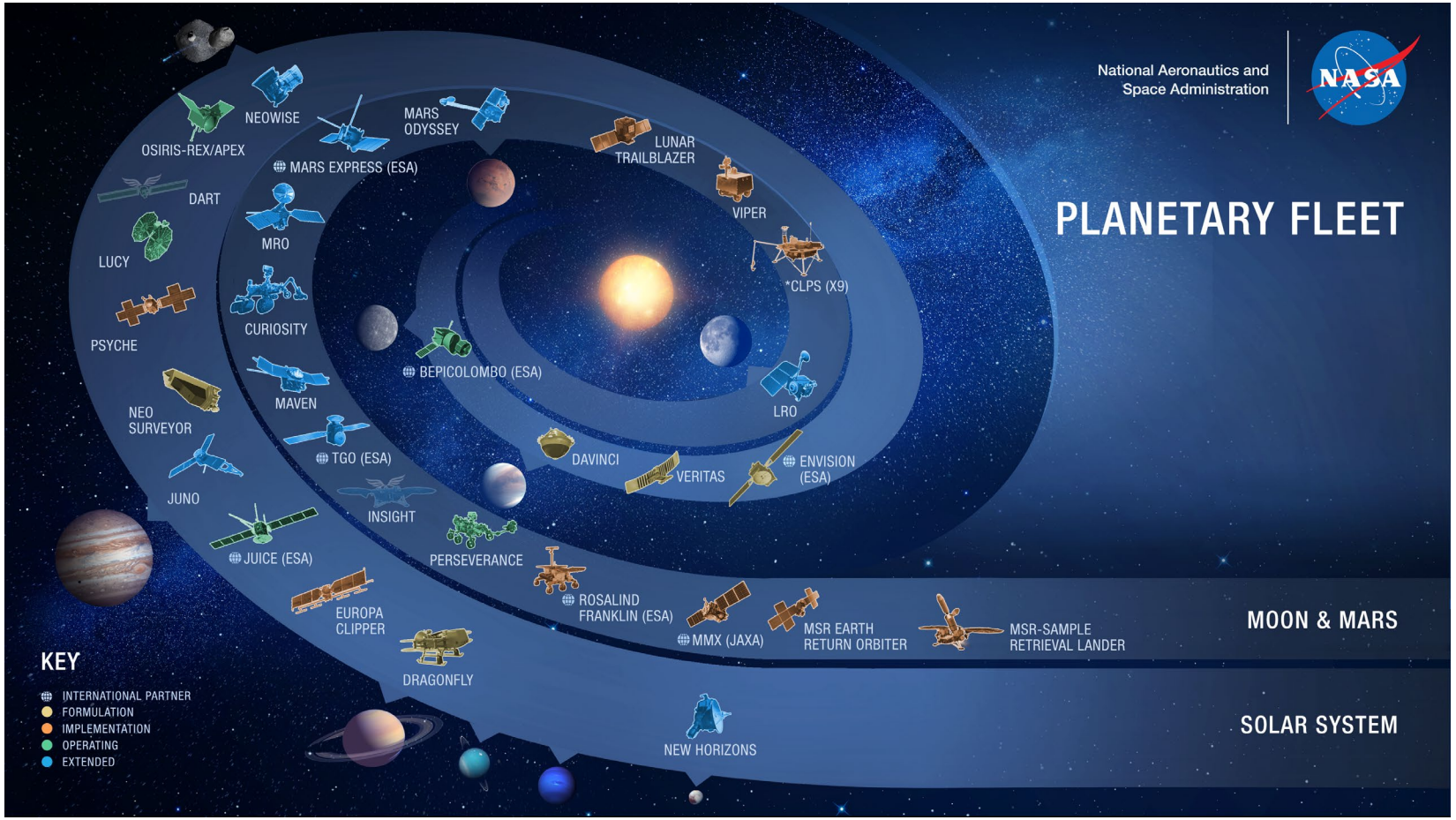
Sample Safety Assessment

- Sample sterilization to inactivate terrestrial bioactive molecules
- Strategies to avoid "false positives" and "false negatives" in life detection investigations or sample safety assessments
- **Sample Pre-Release Report:**
  - Approach to demonstrate avoidance of contamination of Earth
  - Feeds into the decision-making process for releasing samples out of containment

Increased Demand for Planetary Protection Based on Agency Priorities

- Crewed Moon to Mars
- Mars Sample Return
- Outer planets?





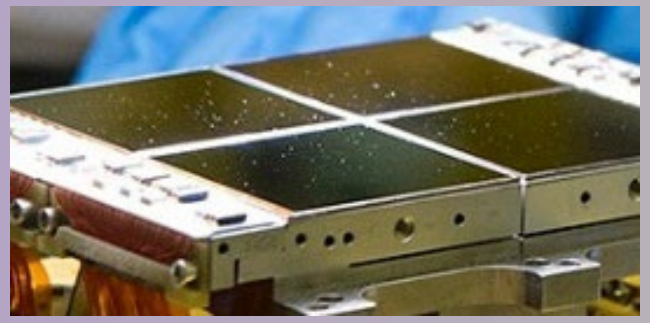
Planetary protection policy at NASA allows us to be adapted to enable missions and evolve with design, implementation and operational needs while meeting our international obligations.

Close Connection Between the Contamination Control and Planetary Protection

Contamination Control (CC)

Planetary Protection (PP)

Particulate Contamination



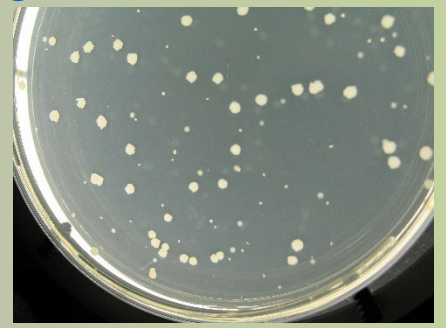
NASA/Goddard/Chris Gunn

Molecular Contamination



NASA/Langley/Elaine Seasly

Biological Contamination



NASA/KSC/Jason Johns

Core principle is the same for both:
Enable scientific studies and exploration by reducing contamination effects

Planetary Protection Crewed Moon to Mars Knowledge Gaps

Key technology development areas for planetary protection include:

1) microbial and human health monitoring,

2) technical and operations needed for contamination control, and

3) natural transport of contamination on Mars.



Credit: NASA

Microbial (?) Mysteries on the ISS

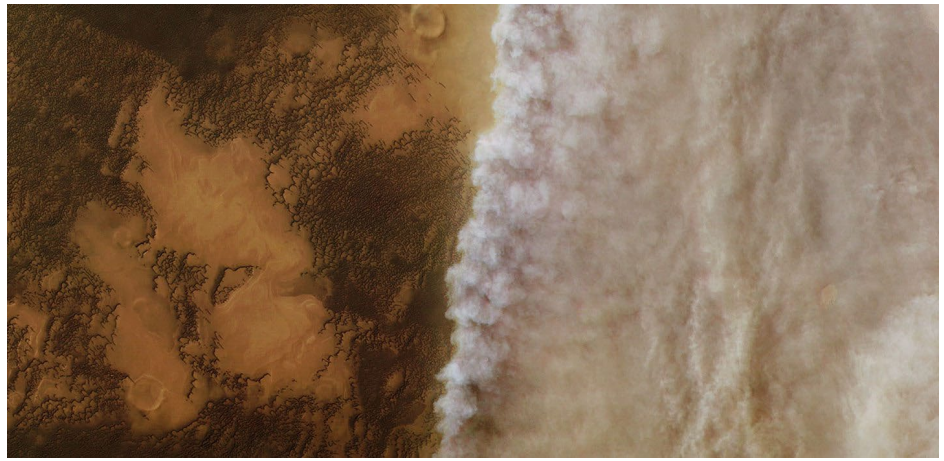








Credit: NASA



Credit: ESA, DLR, FU BERLIN (CC BY-SA 3.0 IGO)



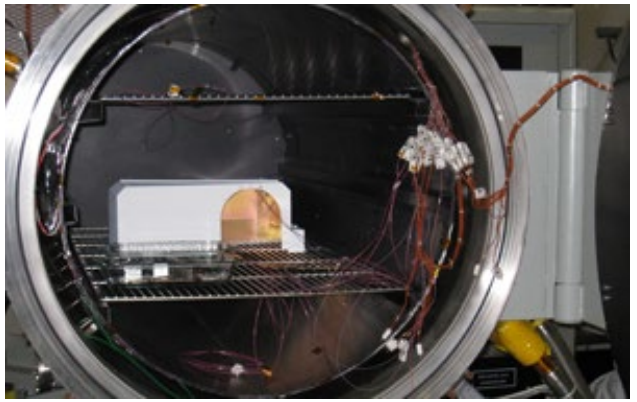
Credit: NASA/JPL-Caltech



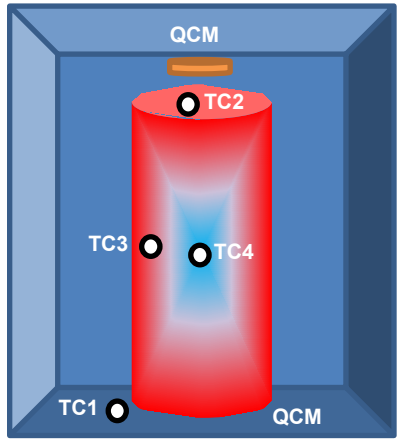
Credit: JPL-CALTECH/NASA, MALIN SPACE SCIENCE SYSTEMS

Standard Space Environments for PP/CC – Hardware Bakeouts

- Bakeouts utilized to reduce contamination of hardware
  - CC: Reduce molecular contamination
  - PP: Reduce biological contamination
- Thermocouple (TC) placement on hardware is critical in data collection
  - CC monitors for hardware temperatures, especially for hardware sensitivities
  - PP can apply biological reduction credits only if there is supporting data, time at temperature required (continuous)
    - Quartz Crystal Microbalance (QCM) may determine when "done" for CC but PP needs time & temp data
- ***Example:*** TC1 on oven wall, TC2 on HW surface, TC3 between HW surface and center, TC4 at center of HW



NASA/JPL-Caltech



Example Hardware Bakeout

Biological Testing of Organisms to Extreme Environments

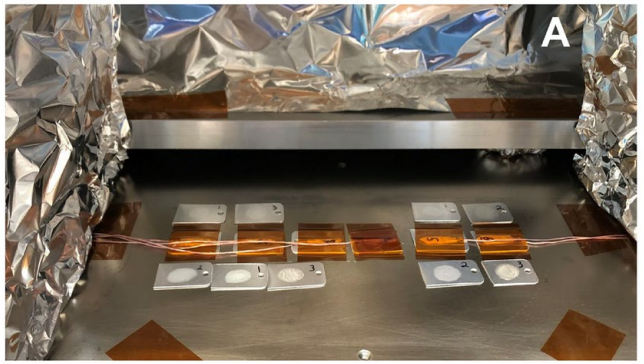
Planetary atmospheric chambers used to create simulations of interplanetary conditions to test biological survival.

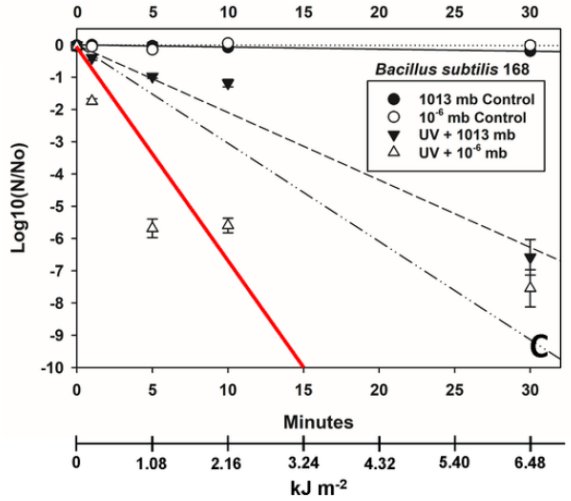
- Orbit (LEO, cruise to Mars, Lunar, Mars)
- Lunar surface
- Mars

Example of the environmental parameters used for Mars testing.

Parameter	Range
High-vacuum	$5x10^{-2}$ - $2x10^{-6}$ mbar
Solar heating	-10 - 100°C
Solar ultraviolet	200-280nm, 0.672 Wm^{-2} - 3.6 W m^{-2}





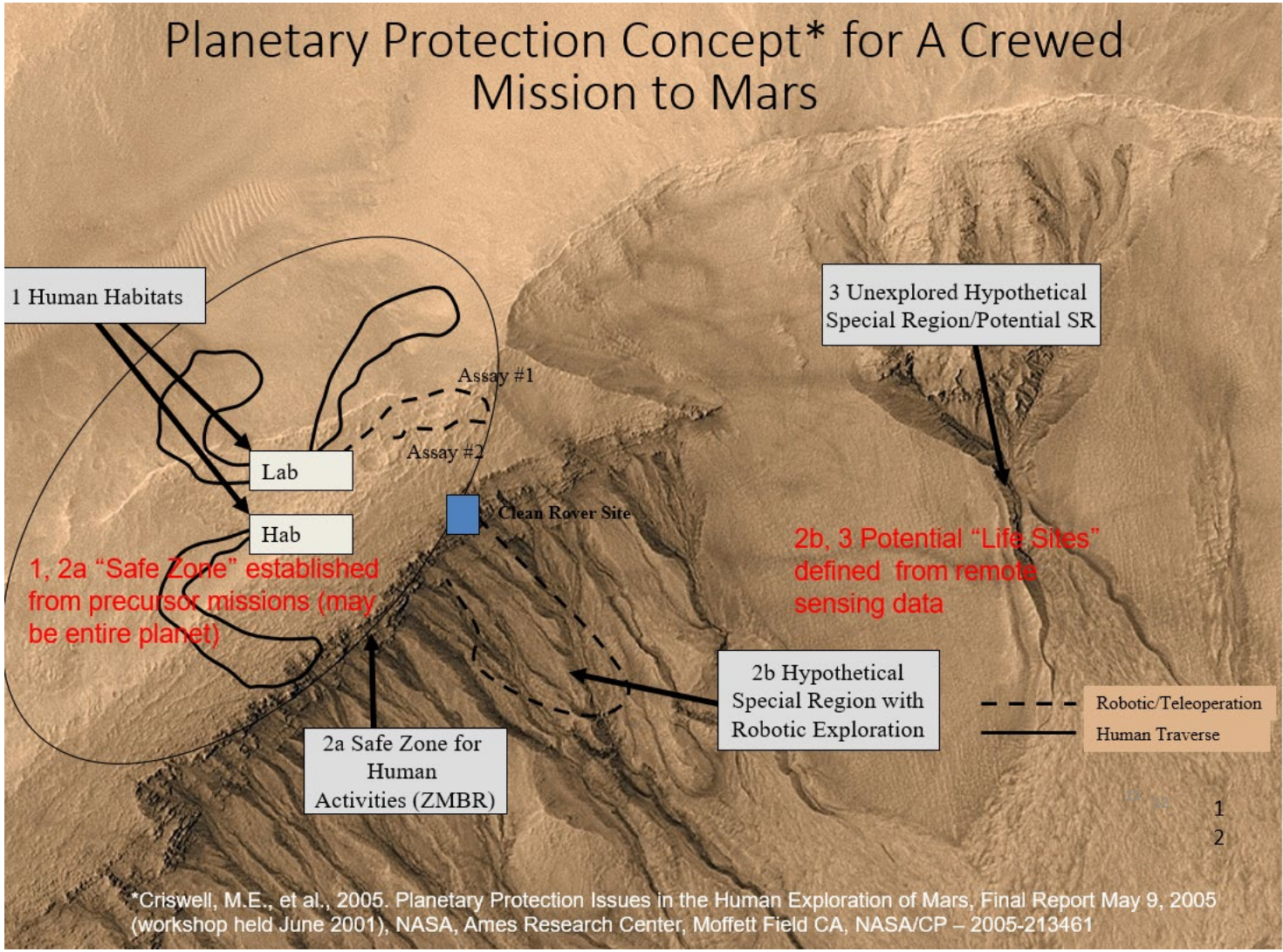


University of Florida Environmental Mars Test Chamber

https://doi.org/10.21203/rs.3.rs-3258716/v1

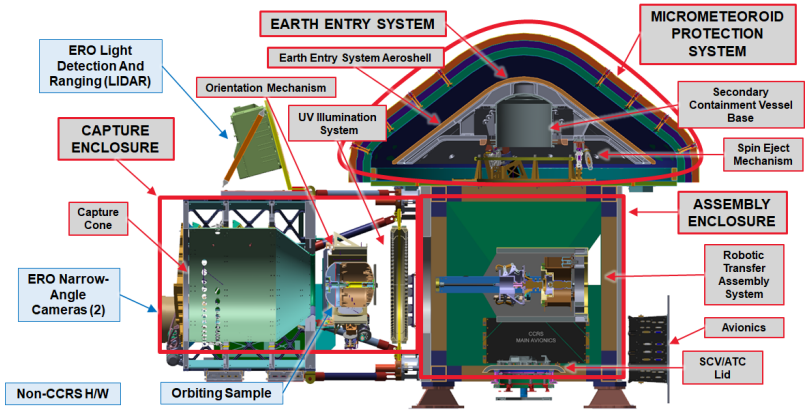
Particle Transport Model Validation and Verification

- NPR 8715.1296 Guidance for Crewed Missions to Mars
  - §1.2.2 c "*For landed missions conducting surface operations, it will not be possible for all human-associated processes and mission operations to be conducted within entirely closed systems*"
  - §1.2.2. d *"[Humans] exploring Mars, and/or their support systems, will inevitably be exposed to martian materials."*
- Vertical and horizontal particle analysis needed to understand human risk/impact on Mars.
- Habitat and environmental life support testing for particle movement to assess transport risk of Mars material to crew.
- If biological test chambers are used additional precautions need to be considered (*e.g., HEPA* filtered, redundant filtration, closed system) to ensure biosafety protocols are being met.



Technology Development for Flight

- Building scientific consensus requires independent testing – need multiple labs to perform testing!
- Test as you fly validation and verification of decontamination systems in a relevant on-orbit and Mars environment
  - Active Plasma Systems, Portable Plasma Reactors, Vapor Hydrogen Peroxide, UVC systems, ionizing radiation
- Containment testing of seals and filters (*e.g.,* vent testing of waste containers)
- Others?



Overview of the MSR Containment, Capture and Release System. Credit: NASA

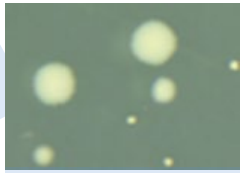
TRL 9	Actual system "flight proven" through successful mission operations
TRL 8	Actual system completed and "flight qualified" through test and demonstration (ground or space)
TRL 7	System prototype demonstration in a space environment
TRL 6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)
TRL 5	Component and/or breadboard validation in relevant environment
TRL 4	Component and/or breadboard validation in laboratory environment
TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 2	Technology concept and/or application formulated
TRL 1	Basic principles observed and reported

NASA Technology Readiness Levels. Credit: NASA

Resources Available Through The OPP Website

NEW

Articles



What Are Spores?



How to Build a Clean Spacecraft



Cleanroom Gowning or How to Dress in the Cleanroom



Ground Support Equipment

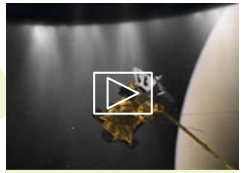


Protecting the Planet: Planetary Protection vs. Planetary Defense

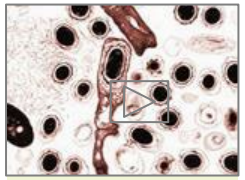


OSIRIS REx Sample Return Doesn't Pose a Risk to Earth's Biosphere

Videos



Planetary Protection: An Introduction



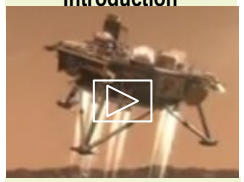
Just How Small is a Spore?



Forward and Backward PP Overview



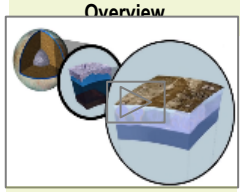
Behind the Spacecraft Perseverance



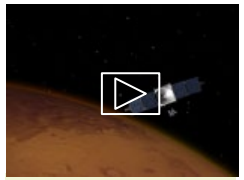
Mission Design and PP Categorization



Probability of Impact



Ocean Worlds



End of Mission Disposition

https://sma.nasa.gov/sma-disciplines/planetary-protection/explore

Thank You!

Questions?