# NASA Office of Planetary Protection Updates: Policies, Technology Development, Research & Communication

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# Overview of Updates

- NASA Policies, Standard, and Handbook
- Technology Development
  - Statistical Analysis Tools for Bioburden Assessment
  - Metagenomics
- Research Opportunities
  - PP Research to Practice, SBIR/STTR, EPSCoR
- International Communication & Collaboration
- Communications & Resources

# Updates to 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, 2023**

***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

***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

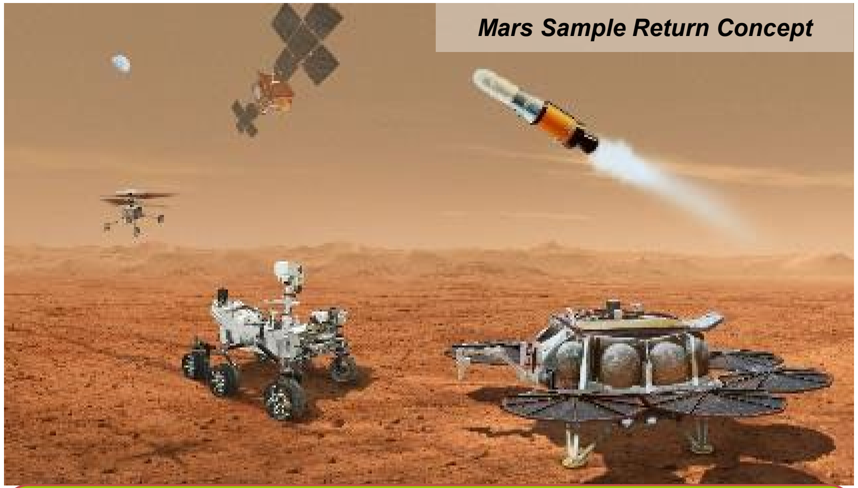
***NASA Handbooks***
- Companion documents to NPRs and NASA Standards
- Provide supporting material such as guidelines, lessons learned, procedures, and recommendations

All published documents found in NODIS: https://nodis3.gsfc.nasa.gov/ or the OPP website: https://sma.nasa.gov/sma-disciplines/planetary-protection

= New Documents

# Shifting the Approach to Requirements Development


**Prescriptive Requirements:**
Specifying "What to do" and "How to do it"




**Performance-based Requirements:**
Specifying "What to do" but not "How to do it"

- Allows for a better understanding and exploration of the trade space
- More flexibility to balance trades
- Ability to realize and implement technical and process innovations for resource, time, and cost savings
- It is <u>**NOT**</u> a relaxation of requirements or a "get out of jail free card"

# The Assurance Case Approach

- Allows for a combination use of prescriptive and performance-based requirements
- Brings forth the entire story and reasoning <u>why</u> the system is safe or will be successful in a cohesive, comprehensible, and transparent manner

- **Utilized by high-risk industries such as medical device, nuclear, rail service, & defense systems**

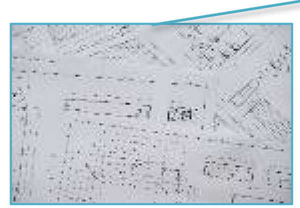


**<u>Claim</u>**
Statement about a property of the system/subsystem

**<u>Argument</u>**
Links the Evidence to the Claim

Deterministic
Quantitative
Qualitative

**<u>Evidence</u>**
Information that demonstrates validity of argument



*Design review records*

*Test results*

*Manufacturing process validation*

Technical Standards / Scientific Consensus

# NASA Standard 8719.27 – Implementing PP Reqs for Space Flight

**1 Scope**

**2 Applicable and Reference Documents**

**3 Acronyms and Definitions**

- Applicable to robotic and crewed missions
- Provides extensive list of recognized industry standards

**4 Control of Forward Contamination**
4.1 Purpose
4.2 Mission Design and Categorization
4.3 Biological Knowledge and Organic Contam.
4.4 Robotic S/C assembly, test, transport, launch & ops
4.5 Avoiding contam following inadvertent impact
4.6 Avoiding contam for robotic landed missions
4.7 End of mission disposition

- Prescriptive and performance based options
- Revised clarification of organic reporting, inadvertent impact and Mars bioburden
- Paves the way for genomic use

**5 Preclude Backward Contamination**
5.1 Purpose
5.2 Cat elements for robotic and crewed Earth-Return
5.3 Robotic restricted-Earth return reporting reqs
5.4 Restricted Earth-Return implementation req

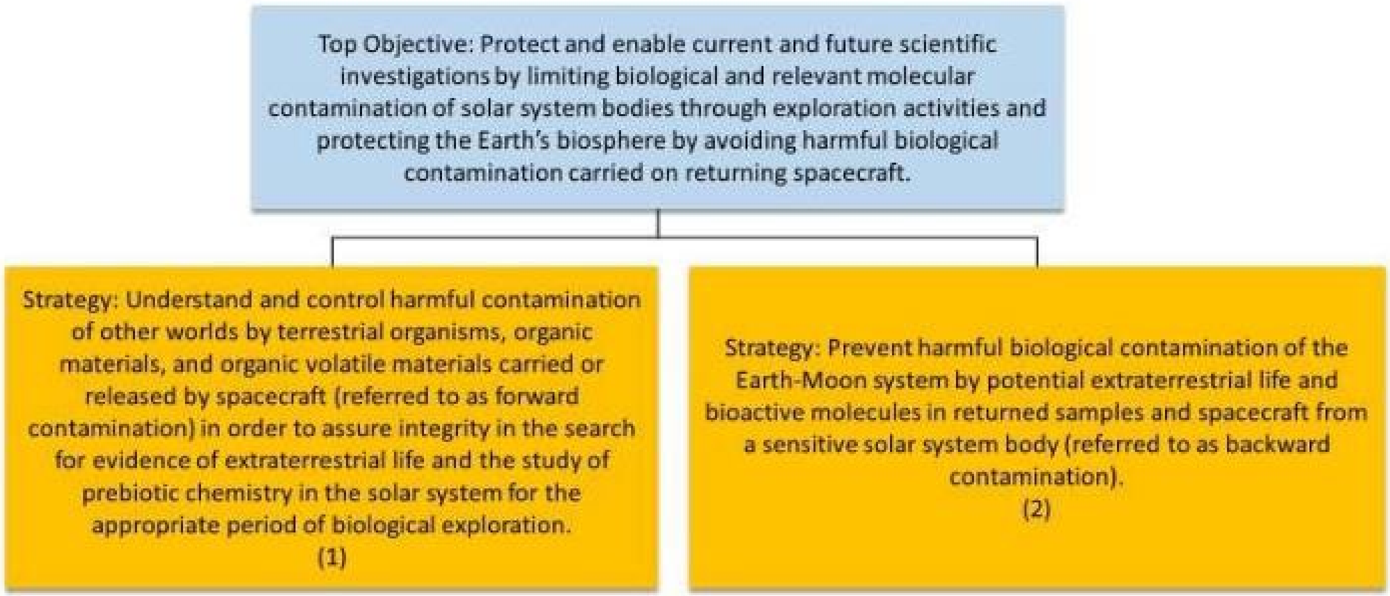
- Identifies elements required for categorization.
- Links compliance reporting to project reviews

**6 NASA Spore Assay**

- Added detailed technical standard due to lack of an industry standard.

**Appendices –** documentation elements, bio accounting

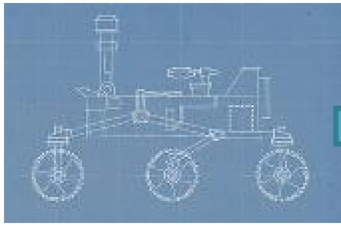
# Forward and Back PP Strategy




## <u>Enabling Objectives</u>

1. Transparency of operations and open communication
2. Application of best available science and scientific consensus
3. Leveraging consensus standard for implementation

# Control of Forward Contamination



***Mission Design & Categorization***

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

***Robotic 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

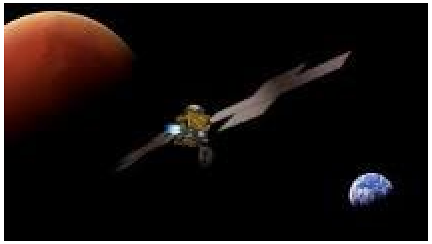
***Avoiding Contamination for Robotic Landed Missions***

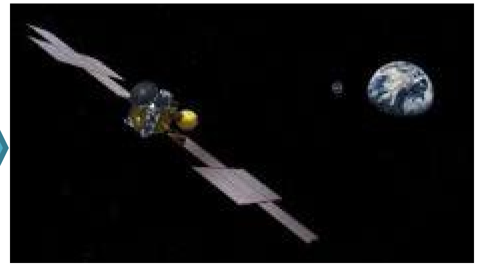
- Prevent occurrence of a biological inoculation event into a potentially habitable environment during landing and surface operations
  - Stationary and mobile activities
- Mars IVa, IVb, IVc requirements
  - Bioburden Control Approach
  - Analytical Approach
- Sensitive Icy World requirements

***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





***Earth-Return Mission Categorization***

- Inbound categorization for Earth-return missions
  - Robotic restricted Earth-return V(r)
  - Unrestricted Earth-return V(u)
- Notional timeline for sample receiving facility (SRF) for V(r) missions.
- No further PP considerations for the return phase of V(u) 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

# Planetary Protection for Ongoing NASA Missions

- **Solar / Lagrange Point Missions**
  - Solar Cruiser – Cat I
  - SunRISE – Cat I
  - Global Lyman-alpha Imagers of the Dynamic Exosphere (GLIDE) Category I
  - IMAP – Cat I (L1)
  - Solar Parker Solar Probe – Cat II (Venus flyby)
- **Lunar Missions**
  - ARTEMIS (THEMIS follow-on) – Cat II
  - Lunar Reconnaissance Orbiter – Cat II extended mission until 2025
  - CAPSTONE – Cat II (in partnership with NZ)
  - Artemis I – Cat IIa
  - Artemis I Secondary Payloads (ArgoMoon, BioSentinel, CubeSat for Solar Particles (CuSP), EQUULEUS, Lunar IceCube, Lunar Polar Hydrogen Mapper (LunaH-Map), LunIR, Near-Earth Asteroid Scout, OMOTENASHI, and Team MILES) – Cat II
  - Lunar Trailblazer – Cat II
  - Gateway – Cat II outbound, Cat I in NRHO operation, unrestricted Earth return
  - HLS – Category IIa or IIb depending on destination, with unrestricted Earth Return
- **Mars Missions**
  - Mars Odyssey - Cat.III orbiter in extended mission until 2025
  - Mars Reconnaissance Orbiter - Cat.III orbiter in extended mission until 2025
  - MAVEN - Cat.III orbiter in extended mission until 2025
  - Mars Science Laboratory/Curiosity Rover - Cat.IVa in extended mission until 2025
  - InSight - Cat.IVa lander, mission just recently extended until at least the end of 2022 (power dependent)

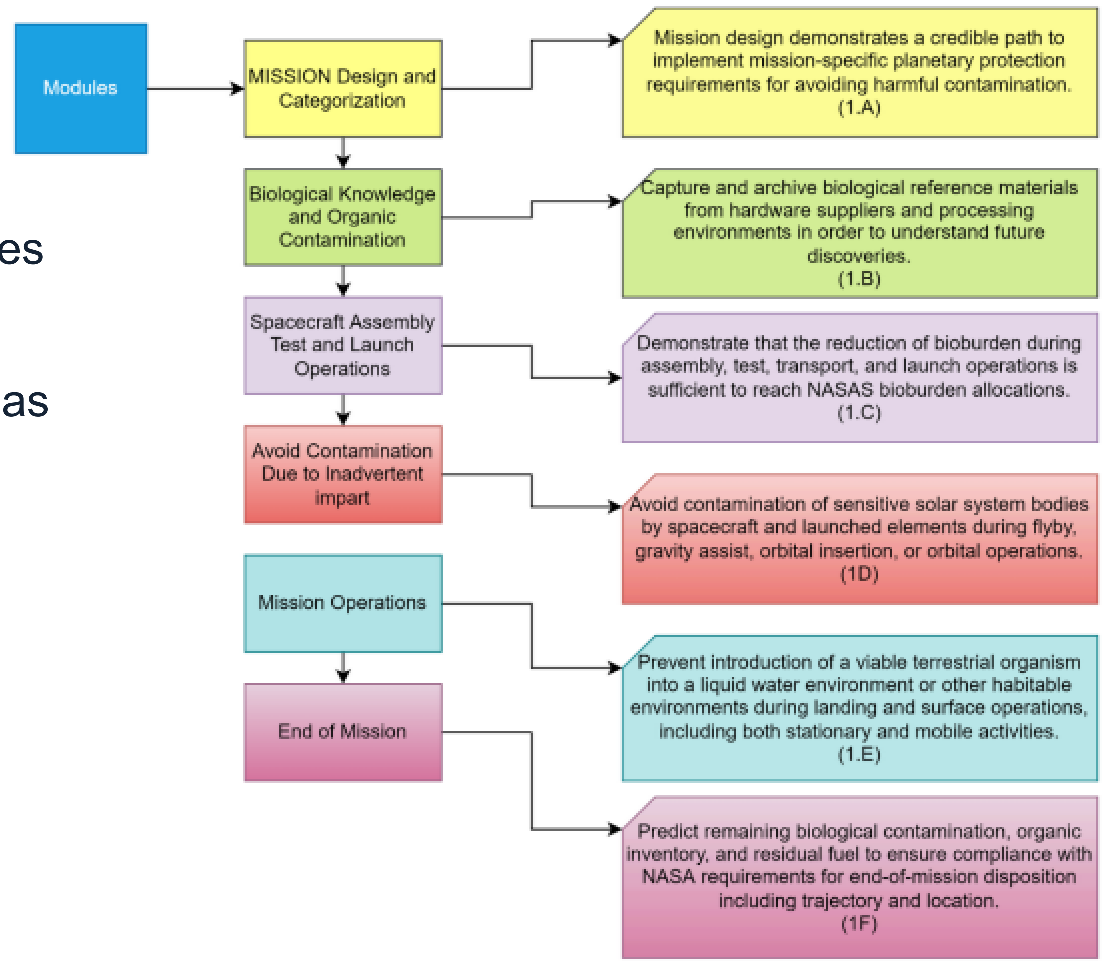
(Missions not launched)

- **Mars Missions (continued)**
  - Mars 2020/Perseverance - Cat.IVb (subsystem sterilization) mission, w/ restricted Mars sample return
  - MMX – P-Sampler – Cat III, unrestricted Earth return (in partnership with JAXA)
  - The Escape and Plasma Acceleration and Dynamics Explorers (EscaPADE), Category III
  - Mars Sample Return Campaign –
    - Earth Return Orbiter Cat III (in partnership with ESA),
    - Sample Return Lander Cat IVb with restricted Earth Return
- **Asteroid Missions**
  - OSIRIS-Rex – Cat II with unrestricted sample return (2023) in extended mission until 2031 (OSIRIS –APEX [APophis EXplorer])
  - Lucy – Cat II
  - DART – Cat II
  - Psyche – Cat III (Mars flyby)
  - JANUS – Cat II
- **Jovian Missions**
  - JUNO – Cat III (recategorized from Cat II due to Europa, Ganymede, Io flyby)
  - Europa Clipper – Cat III
- **Saturian Missions**
  - Dragonfly – Cat II
- **Other**
  - New Horizons – Cat II (Pluto system)

All operating NASA missions continue to be consistent with international planetary protection guidelines and NASA PP Policy.

# Updating the PP Handbook

- Will document additional background, guidelines, lessons learned and the "how to" processes to support mission developers
- Updated with new methods such as membrane filtration for bioburden assays and metagenomics
- Increased focus of Quality Assurance and Quality Control (QA/QC) processes
- Online wiki format currently being explored



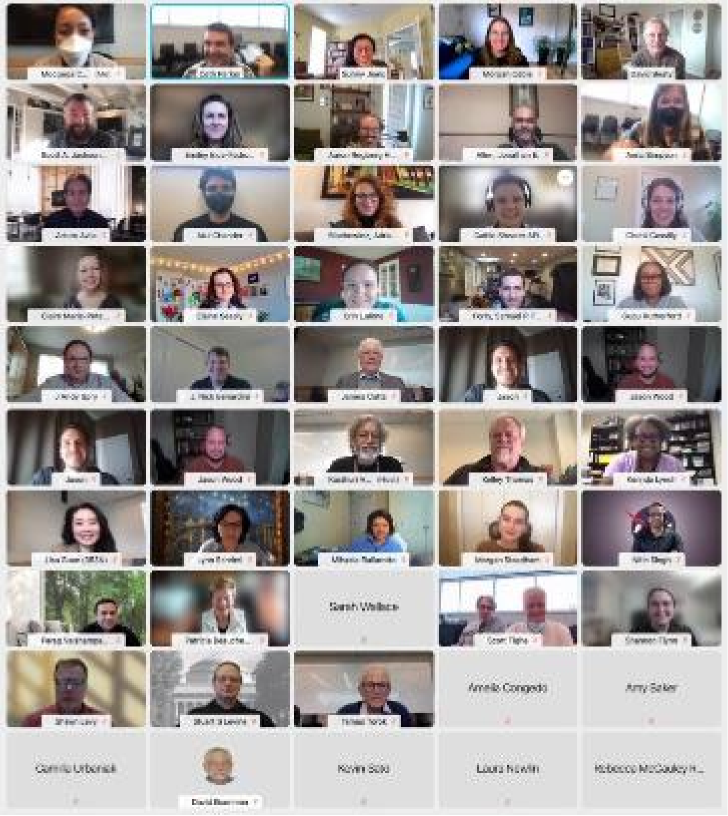

***Modular strategy ensures alignment to PP Technical Standard and enables future training development***

# Statistical Analysis Tools for Bioburden Assessment

- Statistical evaluations of swabs and wipes
  - Clean spacecraft: average 93% of the swabs and 63% of the wipes have no colony forming units (CFU) count at 72 hours
    - Shrinkage estimators developed to deal with large variance and estimate inconsistencies that can arise from low CFU counts and small sampling areas
    - “Performance of Shrinkage Estimators for Bioburden Density Calculations in Planetary Protection Probabilistic Risk Assessment”. Probabilistic Safety Assessment and Management (PSAM16) 2022
  - Investigation on how recovery efficiencies differ by inoculum amount and species.
    - “Modeling of Recovery Efficiency of Sampling Devices used in Planetary Protection Bioburden Estimation”. Probabilistic Safety Assessment and Management (PSAM16) 2022 and COSPAR 2022
    - Application of an end-to-end Bayesian Statistical Framework for Performing Bioburden Accounting on the InSight Mission – COSPAR 2022

# Molecular Biology Technology Development Workshop – Jan 19th

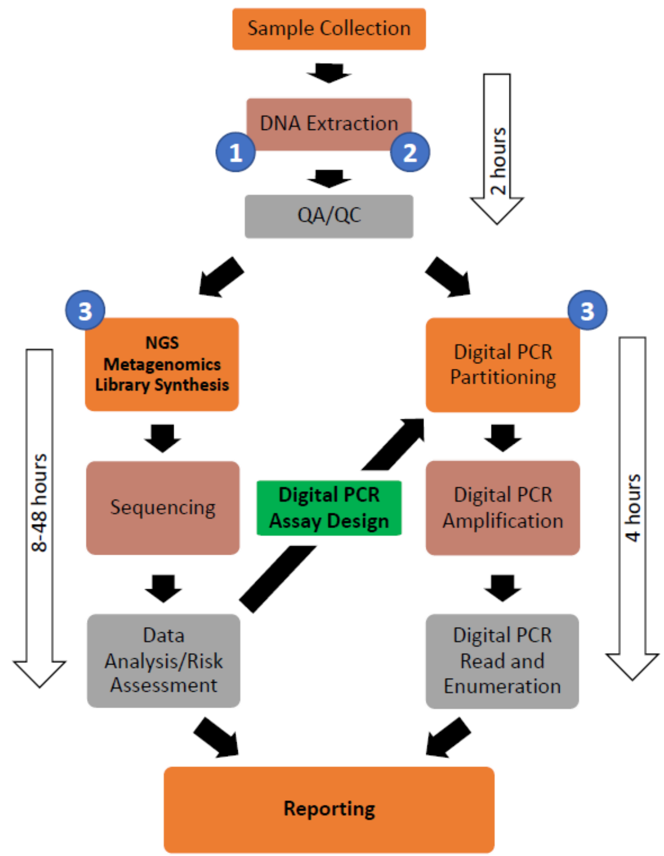
- Goals of the workshop were to:
  - assess the state of the practice of metagenomics and other advanced molecular techniques in the context of providing a validated framework to supplement the NASA spore assay and
  - to identify knowledge and technology gaps.
- Participants across NASA, Academia industry and USG.
- Panelists were a non-advocate board.
  - Stefan Green, Rush U (Chair)
  - Scott Tighe, UVM (co-Chair)
  - Tamas Torok, LBNL (co-Chair)
  - Scott Jackson, NIST
  - Emiley Eloe-Fadrosh, JGI
  - Jonathan Allen, LLNL
  - Shawn Levy, Hudson Alpha
  - Stuart Levine, MIT
  - Lynn Schriml, U. Maryland
  - Kelley Thomas, UNH
  - Sunny Jiang, UC Irvine



# Workshop Findings

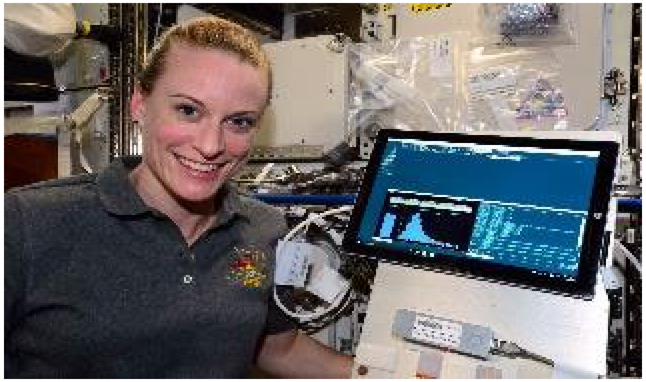
Green, S. et. al. 2022 "Metagenomic Methods for Meeting NASA's Planetary Protection Policy Requirements on Future Missions – a Workshop Report" Astrobiology *In review*.

- *"Participants at the metagenomics workshop agreed that there is a clear opportunity to incorporate molecular assays into the NASA PP efforts and identified a viable workflow to provide an unbiased assessment of the composition and gene content of microbial communities and quantitative analysis of bioburden…metagenome sequencing can provide all-inclusive phylogenetic and functional characteristics of the microorganisms present. When rapid and quantitative measurements are needed, quantitative digital PCR was strongly recommended"*.
- Recommendations include technology developing in sample collection, sample processing / sequencing, bioinformatic analysis and quantitative risk assessment areas to PP relevant organisms.



# PP Research Opportunities Continue to Grow

- PP Research in NASA's **Research Opportunities in Space and Earth Science (ROSES) program**
  - **"Planetary Protection in Practice" workshop** hosted by the Lunar and Planetary Institute (LPI) and held online October 18-19, 20222.
  - Workshop brought together mission teams and planetary protection researchers to discuss the current state of their respective research and technology development fields to assist the community in meeting planetary protection guidelines. *(Workshop report forthcoming)*
    - Research areas or technology development and their potential for applicability to mission planning
    - Presentations from mission teams on challenges faced and/or overcome in meeting planetary protection requirements
    - Insights into mission needs for future planetary missions
- CC&PP Sub-Topic S4.05 in NASA's **Small Business Innovative Research (SBIR) program**
- Two PP topics included in Appendix K of NASA **Established Program to Stimulate Competitive Research (EPSCoR)** FY22 Rapid Response (R3) Solicitation
  - 1) -Omics based approaches for microbial and human health monitoring, and
  - 2) Modeling natural transport mechanisms for contamination on Mars
  - Three awardees: : Louisiana State University, University Of Idaho, Moscow; Nevada System of Higher Education.



***NASA Astronaut Kate Rubins sequenced DNA in space for the first time ever for the Biomolecule Sequencer investigation, using the MinION sequencing device.***

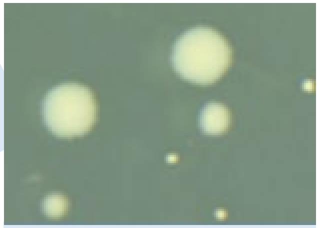
# International Communication & Collaboration

- **COSPAR Scientific Assembly Panel on Planetary Protection Sessions (July 20-22, 2022)**
  - NASA PP Program Overview and Update – F. Groen
  - PP Compliance of NASA Missions Past, Present and Future – N. Benardini
  - NASA's Revised PP Policy and Implementation – E. Seasly
  - COSPAR Workshop Series on Refining PP Requirements for Human Missions to Mars – A. Spry
- **UNOOSA 9th Workshop on Space Technology for Socio-Economic Benefits (Sept 16-17, 2022)**
  - Planetary Protection: Exploration of the Solar System in Support of Sustainable Space – E. Seasly & N. Benardini
- **73rd International Astronautical Congress (Sept 18-22, 2022)**
  - NASA's Planetary Protection Program to Assure Mission Safety and Success – N. Benardini
  - Adopting an Objectives-Driven Assurance Case Approach for Achieving Space Flight Mission Planetary Protection Objectives – E. Seasly
  - Thinking Inside the Box: A Hands-on Student Activity for Building a Contamination Containment Glovebox to Encourage Problem Solving in a Collaborative Environment – E. Seasly
- **ESA Planetary Protection Course (Sept 27-29, 2022)**
  - Implementation of Planetary Protection at NASA – N. Benardini & E. Seasly
- **NASA, ESA & JAXA continue communication and collaboration through the SMA Trilateral process**

*2022 ESA Planetary Protection Course, Fraunhofer Institute, Stuttgart, GE*

# Resources Available Through The OPP Website

Articles



What Are Spores?

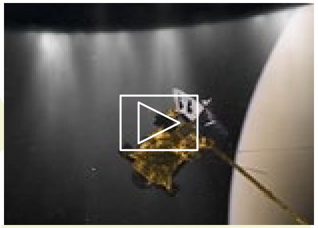
How to Build a Clean Spacecraft

Cleanroom Gowning or How to Dress in the Cleanroom

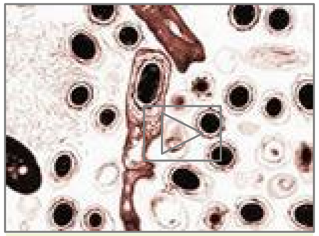
Ground Support Equipment

Protecting the Planet: Planetary Protection vs. Planetary Defense

Videos



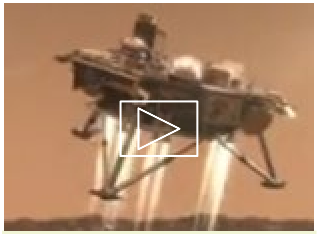
Planetary Protection: An Introduction



Just How Small is a Spore?

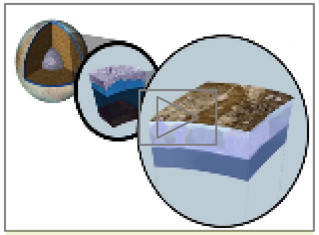
Forward and Backward PP Overview

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