



NASA Planetary Protection Updates

J. Nick Benardini and Elaine Seasley

**October 19, 2023
NASEM CoPP Fall Meeting
Irvine, CA**

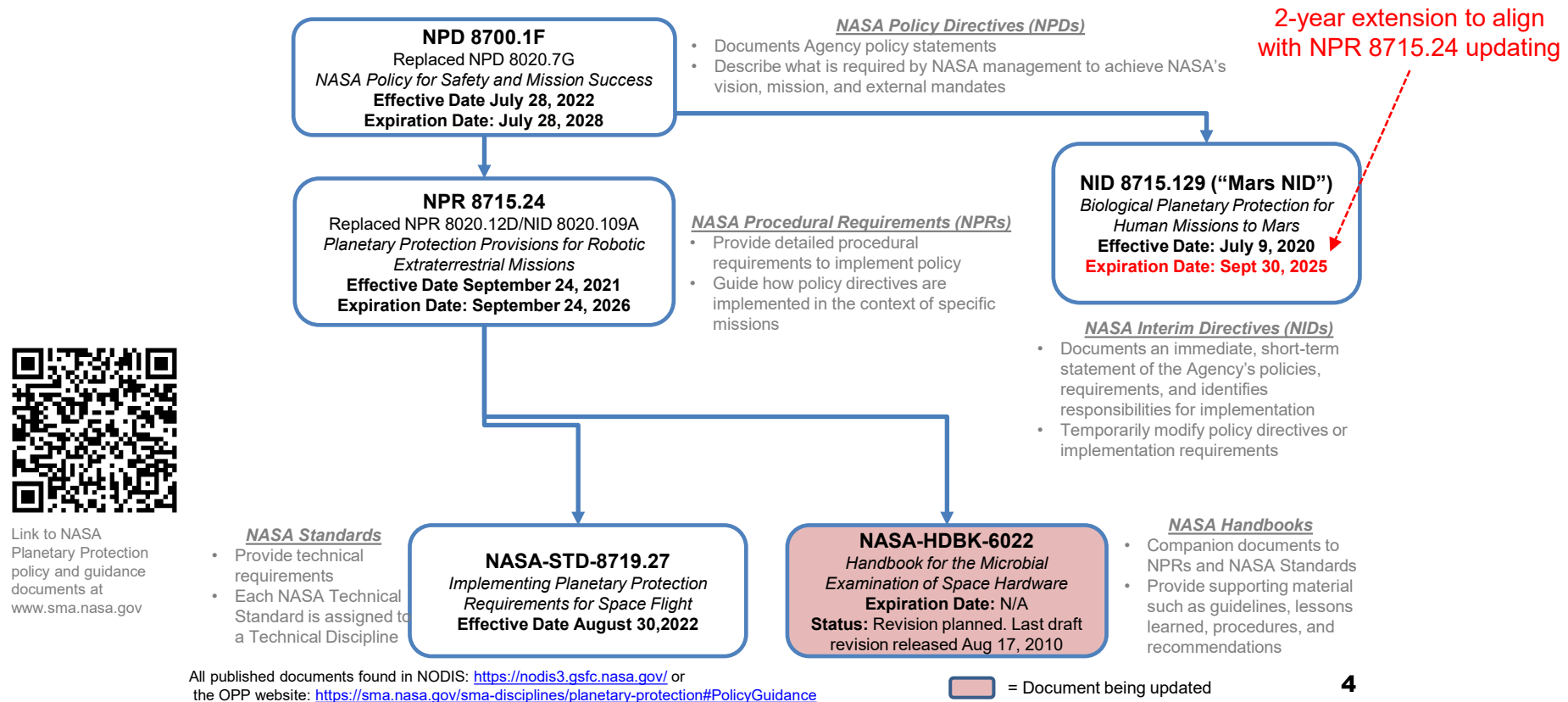
Overview

- PP Policy Updates and Background
- Europa Clipper
- Mars Sample Return
- OPP Research and Technology Updates
- Commercial Engagement
- PP Resources
- Backup

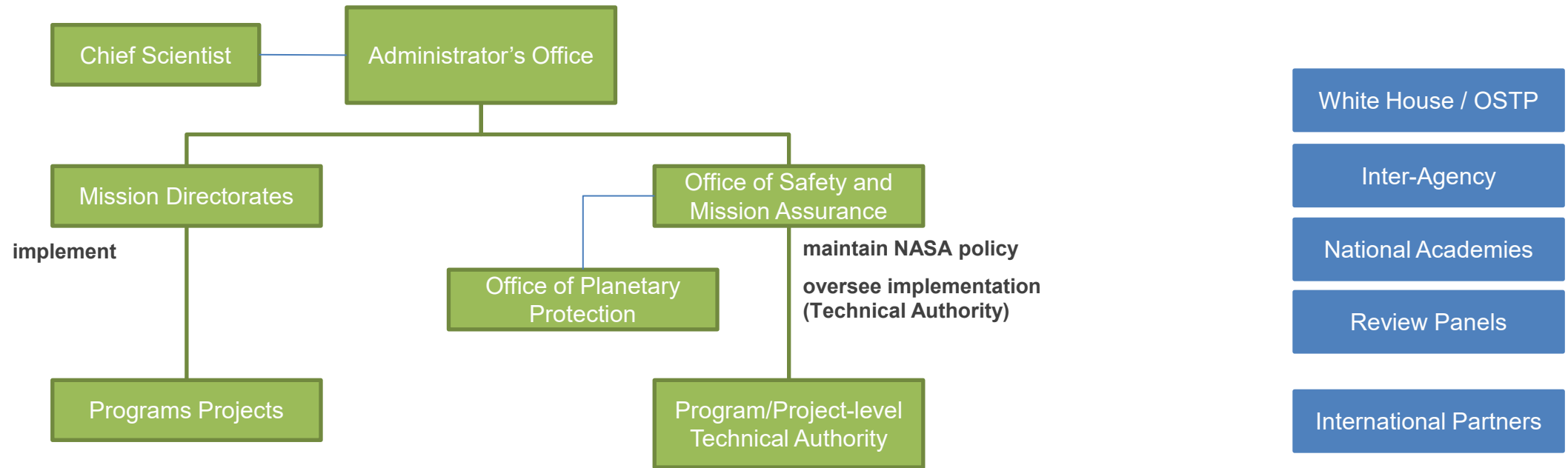


PP Policy Updates and Background

Updates to NASA's Planetary Protection Policy Documents



NASA's Planetary Protection Roles



NPD 1000.3 §4.13.2 “OVERALL RESPONSIBILITIES. The Chief, Safety and Mission Assurance reports to the NASA Associate Administrator and advises senior leadership, including the Administrator, on matters related to risk, safety, and mission success. Serves as the lead Technical Authority for safety and mission assurance, providing independent oversight of programs and projects in support of safety and mission success. Serves as the designated Agency-level "official voice" for institutional safety and the associated requirements established by NASA policy, law, and other external mandate aimed at protecting the public..”

Programmatic, Implementing

Mission Directorate Associate Administrator (MDAA)

- Provides PP Mission Categorization
- Provides resources for PP compliance
- Negotiates missions-specific process for partnered missions (consults with interagency, commercial and international partners)
- Supports R&TD to close knowledge gaps and develop PP requirements to enable future missions.

NASA Project Manager

- Submits PP Category Request to MDAA
- Identifies Agency PP requirements and standards
- Establishes planned implementation approach
- Coordinates verification and assurance activities with PPO
- Documenting implementation activities
- Coordinates extended mission activities and requirements

SMA Technical Authority

Chief, SMA

- Concurrence on PP category proposals
- Consults with Chief HMO and Engineer on restricted Earth-return
- Monitors and tracks PP requirements
- Oversees extended mission activities
- Advises MDAA on partnered missions
- Office of PP established

Planetary Protection Officer

- Represent NASA in external activities
- Maintain policy
- Concurrence on PP category proposals
- Advise projects on PP approach
- Oversee and verify PP implementation
- Independent verification
- Coordinate with MDAA on R&TD
- Advises MDAA on partnered missions

Project-Level SMA TA

- Advises project to notify PPO
- Assures formulation and execution of implementation is sound
- Facilitates independent verification
- Coordinates with project to identify events of conditions for further investigation

NASA Policy Enabling Missions

- Increased flexibility for gate products and reviews
 - **Enables** missions to streamline PP reporting into the standard project life cycle reviews.
- Risk-informed decision-making leveraged per NPR 8000.4.
 - **Enables** missions in that they can propose a performance or prescriptive approach.
- Adds the ability to leverage NASA, other government agency, and industry consensus standards.
 - **Enables** missions by increasing the potential implementation trade space through adopting or adapting consensus standards of their choice.
- Current scientific consensus used throughout the project life cycle
 - **Enables** missions to propose alternative and analytical approaches that are both responsive to PP requirements and fit within a projects allocated resources.

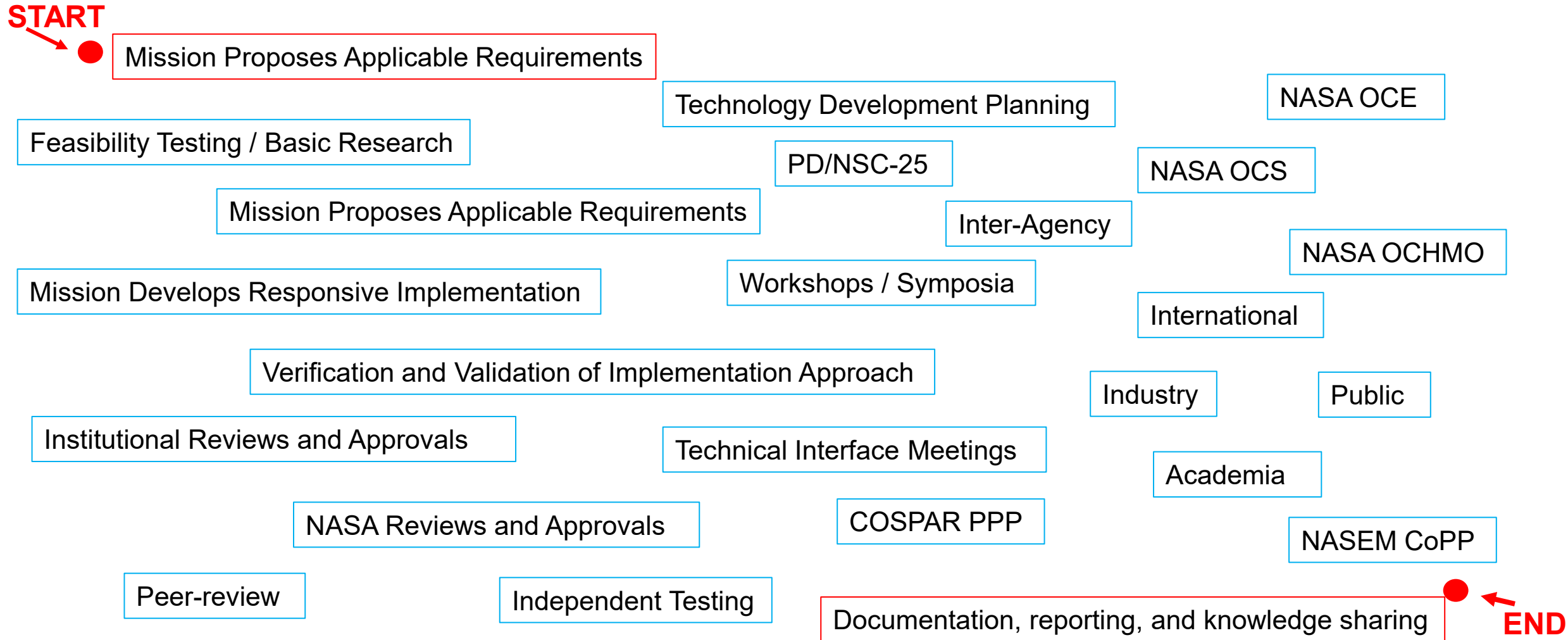
There's no free lunch...

- Sometimes it's easier to take the path well traveled with prescriptive requirements.
 - Easier to do a bioburden approach and collect samples vs. complex PRA's
- Alternative approaches
 - Trade studies to poll and assess knowledge base
 - Lots of information – consideration of international standards or developing new path altogether.
 - Application to mission specific form, fit and function
 - Does it apply?
 - Is the case convincing to external stakeholders?
 - Sound engineering and scientific consensus
 - Are the assumptions scientifically sound?
 - Is the engineering solution robust to peer-review?
 - Additional independent oversight throughout



Credit: NASA

Alternative Approach Process



Strategy for the Moon to Mars Crewed Planetary Protection Policy



2023

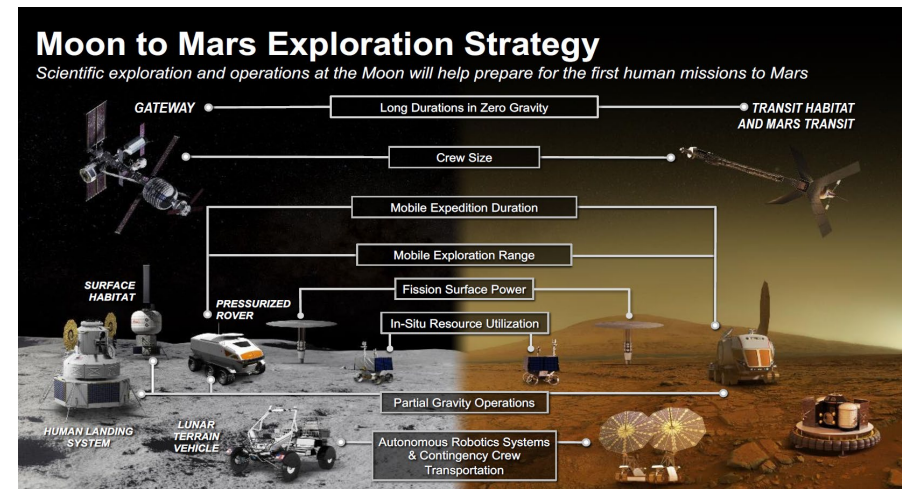
- Completion and documentation of PP crew to Mars knowledge gaps workshops
- Extension of NID 8715.129 to 2025 to align with the update cycle for NPR 8715.24

2024

- Work with ESDMD on developing a framework for PP decision making (external and internal) with Advance Concept Review topic to be addressed in FY24
- Draft proposal for updating COSPAR / NASA policy
- Partnership with Moon to Mars Architecture element leads to further understand hardware capabilities and functional requirements (*e.g.*, establish figures of merit; identify hardware interfaces; identify requirement gaps)

2025+

- Reboot of the Agency PP Research and Technology Steering Group to focus on knowledge gaps and strategic tracking of mitigation paths
- Technology roadmaps update
- Integration with SMD mission datasets
- NASEM CoPP consultation (TBD)
- (2nd) Draft proposal for updating COSPAR / NASA policy



Planetary Protection Crewed Moon to Mars Knowledge Gaps

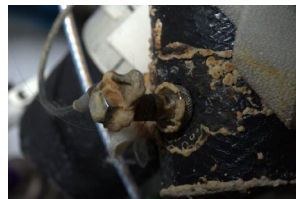
Key technology development areas for planetary protection include:

- 1) microbial and human health monitoring,
- 2) technical and operations needed for contamination control, and
- 3) natural transport of contamination on Mars.

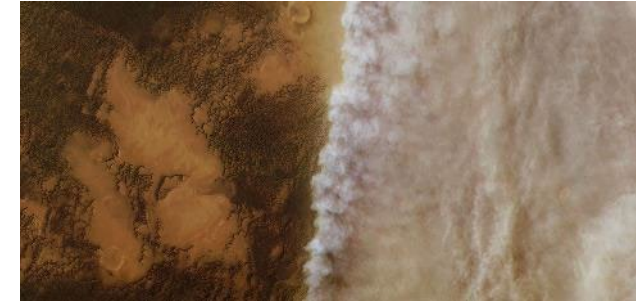


Credit: NASA

Microbial (?) Mysteries on the ISS



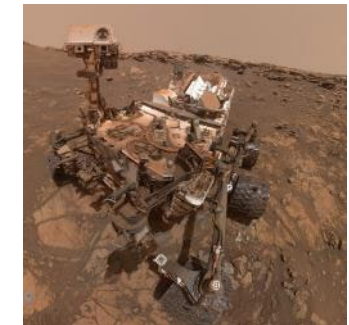
Credit: NASA



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



Credit: NASA/JPL-Caltech



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

“Planetary Protection Knowledge Gap Closure Enabling Crewed Missions to Mars”

- Submitted to Astrobiology for review
- ~50 page 39-author compilation of the 2015-2022 COSPAR, NASA, ESA workshop series capturing international consensus
- Details knowledge gaps, driving assumptions and state-of-the-art in one location

- NASA Handbooks are not contractual!
- Documents guidelines how to approach a topic as opposed to step-by-step protocols
- Provides guidance but is not the only approach.
- Leverages and encourages use of peer-reviewed publications and industrial standard application.
- Intent is to update the handbook on a regular cadence (~year, critical mass) to stay relevant with the community of practice.
- Format
 - Official release PDF + internal SharePoint site for ease of use for NASA and NASA partners.
 - SharePoint site has comments / feedback feature to support next revision.



Sample device preparation.



Membrane filtration setup.

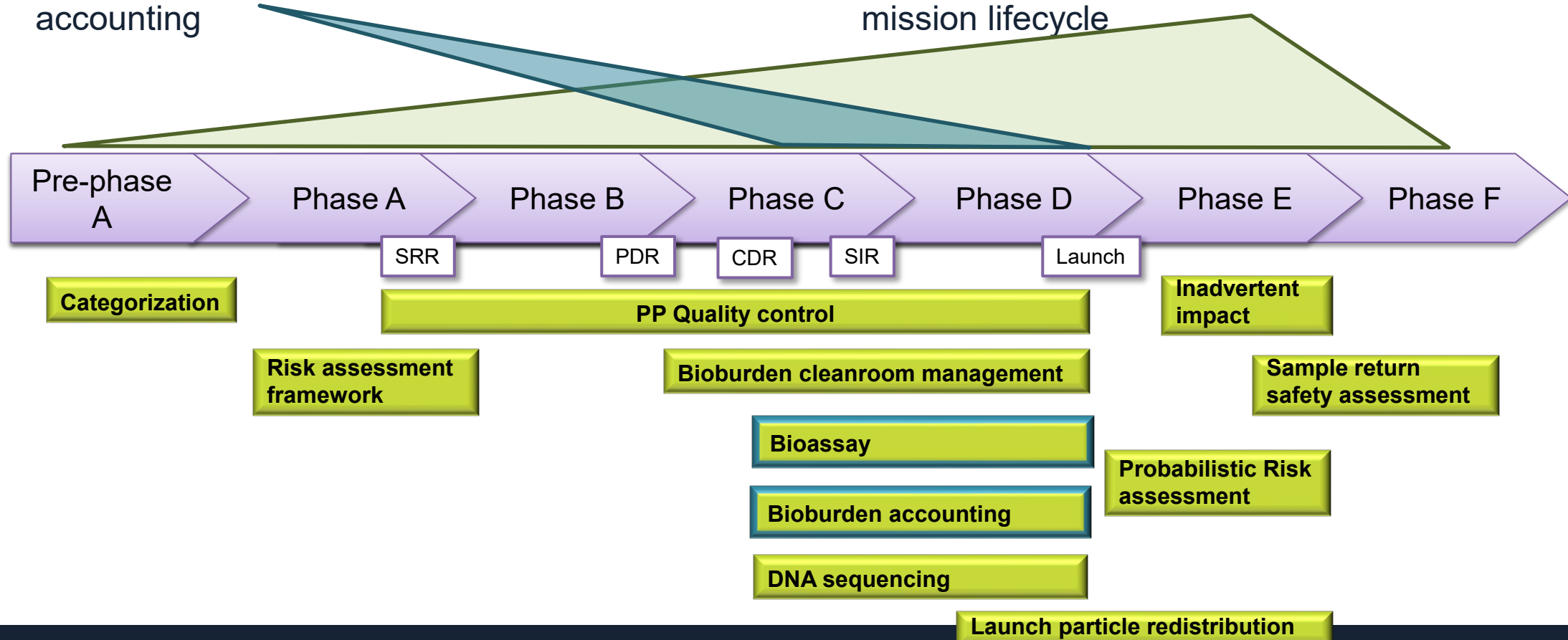
Modernizing a more useful Planetary Protection Handbook

Old Planetary Protection Handbook

- Bioassay processing and bioburden accounting

New Planetary Protection Handbook

- Details on PP implementation for the full mission lifecycle





Europa Clipper

With Contributions from Ryan Hendrickson, JPL Planetary Protection Lead for Europa Clipper, Jet Propulsion Laboratory, California Institute of Technology

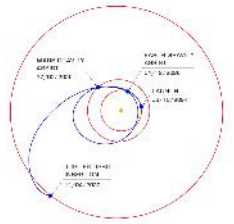
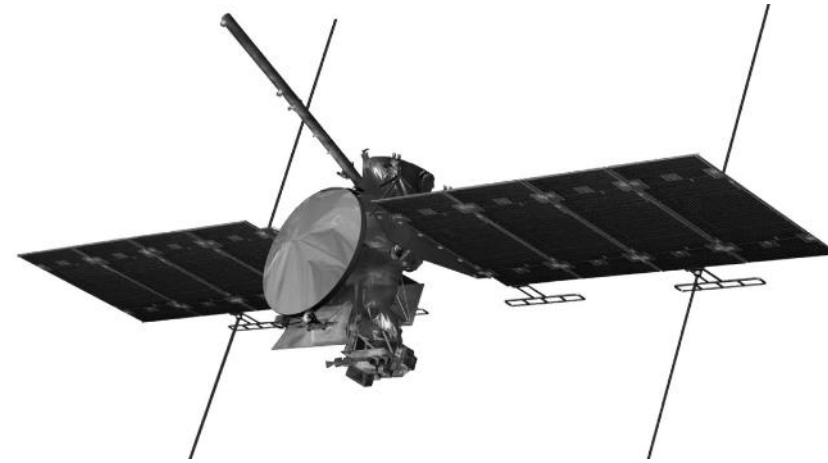


Europa Clipper Mission



Features

- Planetary Protection Category: III
- Nominal Mission includes 45 flybys of Europa at closest-approach altitudes varying from 1700 miles to 16 miles (2700 kilometers to 25 kilometers) above the surface.
- Planned launch in 2024 on a SpaceX Falcon Heavy
- End of mission disposal – Ganymede or Callisto



Science Objectives

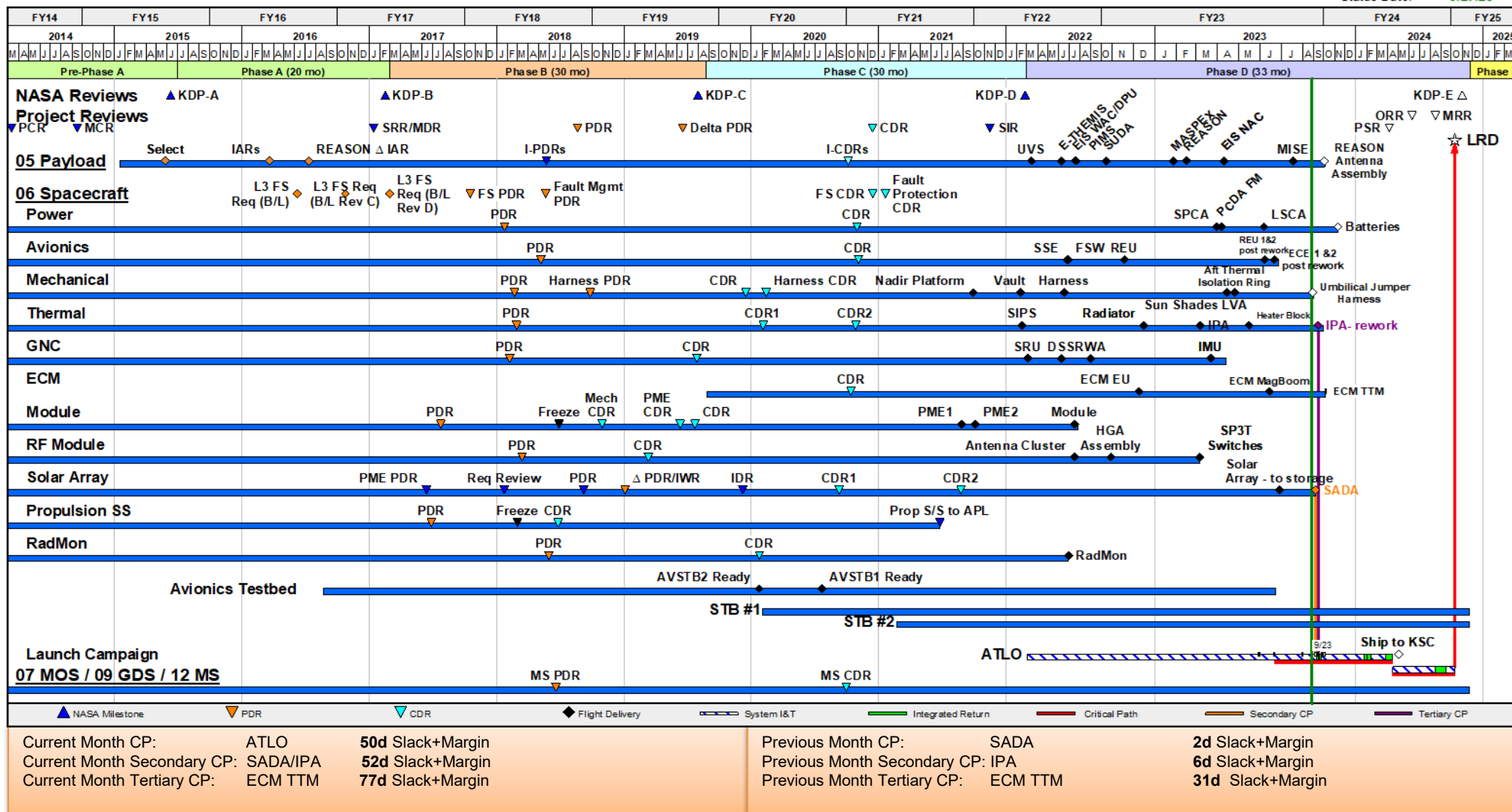
- **Ice shell and ocean:** Scientists aim to determine the thickness of Europa's icy shell — the moon's outer layer that includes its surface. They will discover whether there's water within and beneath the shell. Researchers will estimate the size, saltiness and other qualities of Europa's ocean. They also will determine how the ocean interacts with the surface: Does anything in the ocean rise up through the shell to the top? Does any material from the surface work its way down into the ocean?
- **Composition:** Scientists will investigate the composition and chemistry of Europa's ocean to determine if it has the ingredients to permit and sustain life.
- **Geology:** Scientists will determine how Europa's surface features formed and locate any signs of recent activity such as sliding tectonic plates or plumes that are venting water into space. They will identify key locations on the surface that need more scientific study.

15

Europa Clipper Schedule



Status Date: 8/21/23



Planetary Protection Requirements

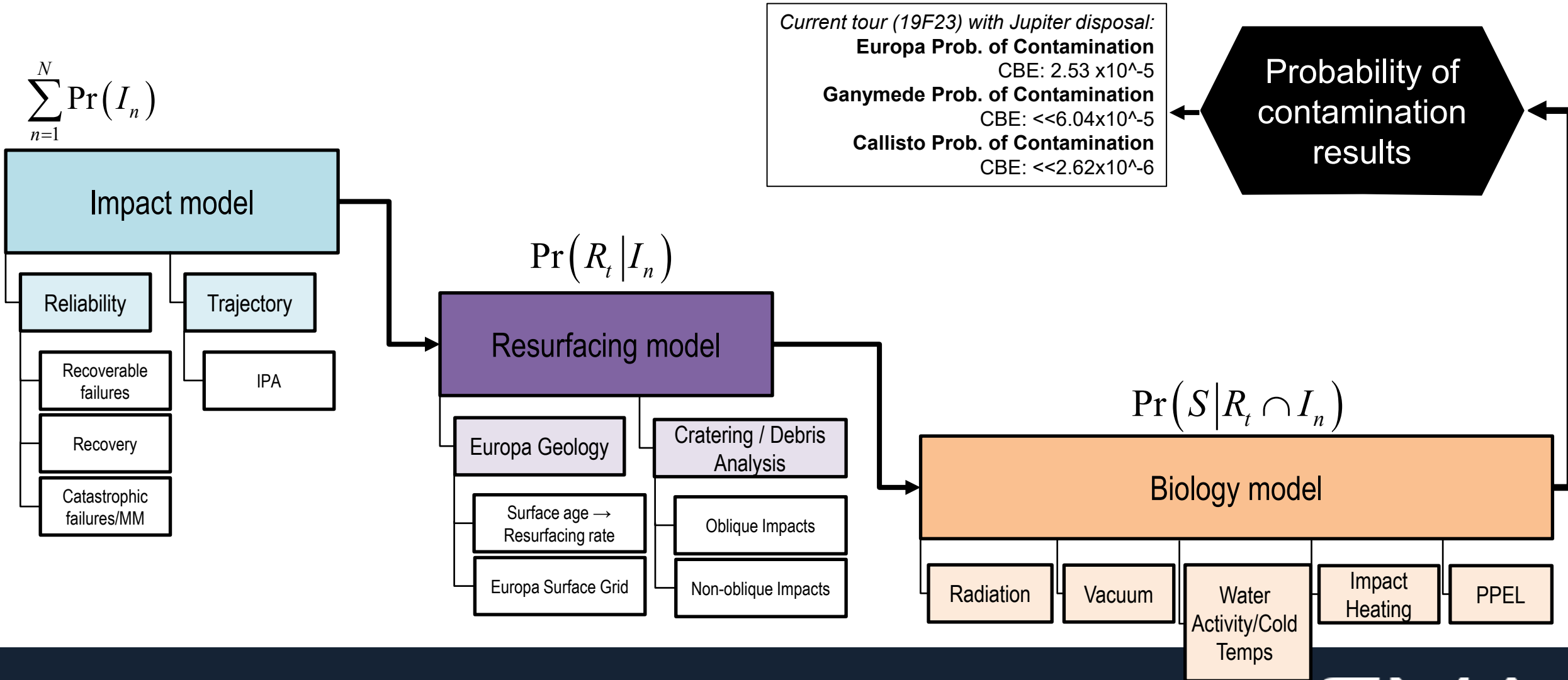
- Probability of Contamination¹ – NPR-STD 8719.27 §4.5.5 “*demonstrate contamination avoidance at a probability of occurrence less than 1.0×10^{-4} for a biological inoculation event into a potentially habitable aqueous environment (e.g., liquid water body, brine) at sensitive solar system bodies in those systems (e.g., Europa and Enceladus) for 1,000 years.*”
- Pre-launch Hardware Bioburden Limits²: hardware, bioregion dependent

Biocidal Parameter	Parameter Achieved	Parameter Not Achieved
>3-log HMR	300 sp/m ²	1,000 sp/m ²
>2.5Mrad by first impact	1,000 sp/m ²	300 sp/m ²
Sterilization by impact heating	1,000 sp/m ²	300 sp/m ²

¹McCoy, K et al. 2021. “Europa Clipper planetary protection probabilistic risk assessment summary”, Planetary and Space Science, Volume 196.

²Smith, A., & Hendrickson, R. (2022). Protecting ocean worlds: Europa Clipper planetary protection inputs to a probabilistic risk-based approach. *International Journal of Astrobiology*, 21(6), 470-483.

Probability of Contamination



PP Sampling Status



Requirement	CBE Spore Bioburden Density at launch	Margin %
<300 spores/m2	58 spores/m2	~80%
<1000 spores/m2	49 spores/m2	~95%

- Remaining Hardware Sampling:
 - Instruments: Europa Imaging System, Rader for Europa Assessment and Sounding, Europa Thermal Emission Imaging System
 - Engineering Subsystems: Telecom Module, Thermal, Propulsion Module, Harnessing, Solar Arrays
 - Launch Vehicle Hardware: Payload Fairing, Multilayer insulation, Payload Adapter Fitting
- 642 sampling events completed (as of 10/9/23)
- ~50 sampling events remaining



APL and JPL Planetary Protection Team

- Remaining PP Gate Products:
 - Reviews: PP Pre-Ship Review (~3/2024), PP Pre-Launch Review (~9/2024)
 - Reports: PP Pre-Launch Report (~7/2024), PP Post-Launch Report (~12/2024), PP Extended Mission Report (if applicable, TBD), PP End-of-Mission Report (TBD)
- Remaining Activities
 - Continued interface with new planetary launch provider – SpaceX
 - Environmental testing
 - Solar Assay delivery to KSC
 - Set up KSC PP Lab
 - Move and transport to Cape (via plane)
 - Launch site support and processing



PP Sampling of Propulsion Module August 2021
Credit: Johns Hopkins APL/Ed Whitman

NASA Independent Verification and Assurance Paradigm Shift (1 of 2)

- NPR 8715.24 §2.4 “*h. Oversees the project’s execution of the planned planetary protection implementation, by timely communication and coordination with the NASA Project Manager, to verify compliance with identified Agency planetary protection requirements throughout the project life cycle by defining and **conducting independent verification and assurance activities (technical authority audits)***”
- Office of Planetary Protection partnered with the NASA Safety Center’s Assessments and Investigations Office to perform an assessment of the PP processes being used for Europa Clipper.
- Allows PP to streamline independent assessments as the Safety Center’s Assessments and Investigations Office has an established prowess within the NASA engineering community.
- Office of Planetary Protection has conducted independent audits on past projects (e.g., MER, MSL, InSight, Mars 2020) that have typically involved direct hardware swab and wipe sampling by NASA HQ personnel.
 - These audits have focused on temporal, single point cleanliness, involving multiple visits (>15/project).
 - Coordination for these events are time consuming particularly during critical path spacecraft assembly.
- This paradigm shift helps to build confidence in the entire end to end process as opposed to single point cleanliness assessments. Also serves to provide a process feedback loop for the entire discipline - the implementing organization, assessment team members and NASA HQ).

NASA Independent Verification and Assurance Paradigm Shift (2 of 2)

- Purpose
 - Conduct an assessment of Planetary Protection for Europa Clipper process at JPL and KSC to ensure effectiveness of biological contamination control and data generated to support planetary protection biological cleanliness assessments.
- Scope
 - Evaluate processes, procedures, analyses, laboratory methods and materials, and facilities in use to implement PP.
- Assessment
 - Review of documentation required to implement PP (~50 documents).
 - Virtual interview sessions to inquire about process flow and seek clarity.
 - On-site visit to observe PP sampling, processing, and sampling receiving.
 - On-site interviews with key stakeholders in project – cleanroom management, contamination control, analytical chemistry laboratory, and hardware quality assurance.
- Report out to the Office of Planetary Protection, SMA senior leadership at each NASA Center, and project management.
- Findings from report
 - Updates and suggested clarity to NASA STD and Handbook policy.
 - Process improvement areas for NASA standard assay in membrane filtration, lab quality control and assurance practices, and suggested updates to best practices in the lab.

Europa Clipper Cleanroom Operations Live!



Live From the Clean Room - Build: X Live From the Clean Room - Build: X +

youtube.com/watch?v=yk0X3Sh2gIE

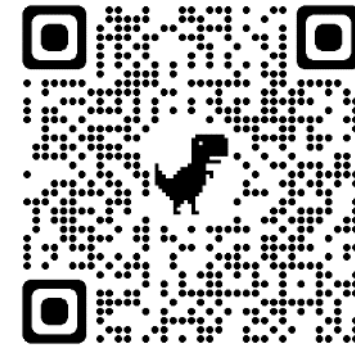
YouTube Search



Live From the Clean Room - Building Europa Clipper

NASA Jet Propulsion Laboratory 1.17M subscribers Subscribe

0 Share Save



<https://www.youtube.com/watch?v=yk0X3Sh2gIE>

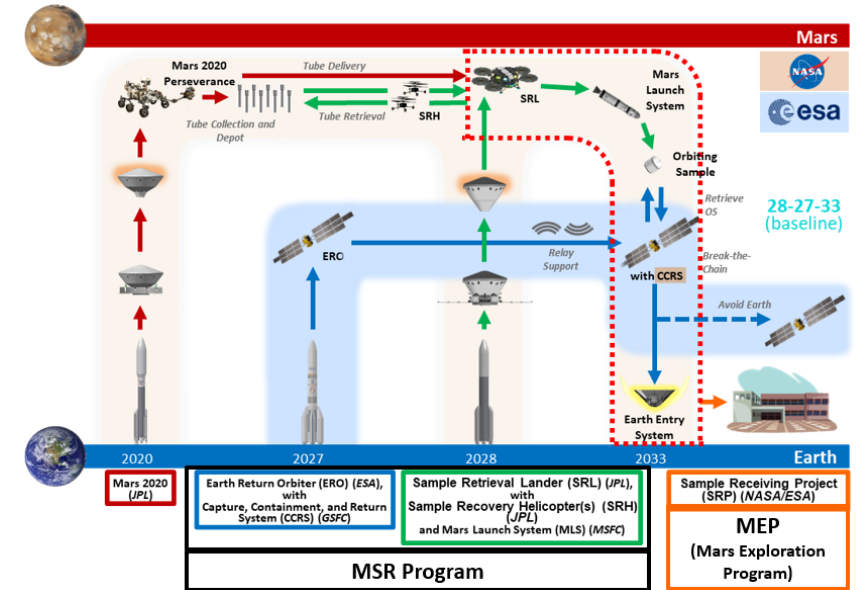


Mars Sample Return

Mars Sample Return Campaign



- Mars Sample Return Campaign notified OSMA/OPP in February 2023 that it was going “to proceed on risk” with a UV break-the-chain approach as an alternative to the high heat brazing.
- Given the alternative approach, Office of Planetary Protection requested that NASA Office of Chief Scientist conduct an independent review of the campaign’s biological assumptions and planned use of an active ultraviolet (UV) approach for BPP.
- NASA Office of Chief Scientist assembled a study team of US Government and invited experts. The Study Team provided a series of recommendations for the team to consider during design, validation and verification testing, and operations. Currently under consideration with the Campaign.
- Publication report entitled, “Biological Assumptions and Planned Ultraviolet Treatment for Mars Sample Return Backward Planetary Protection - An Independent Scientific Review” has been prepared with plans on submitting draft to Astrobiology in Nov 2023.





OPP Research and Technology Updates

Research and Technology Updates



- Coordination of activities include:
 - SMD's **Research Opportunities in Space and Earth Science Planetary Protection Research (ROSES-PPR) program** David Smith, Acting ROSES-PPR Manager)
 - STMD's **Small Business Innovative Research (SBIR) program** Sub-topic 13.04 Contamination Control and Planetary Protection (JPL/GSFC sub-topic technical managers)
 - FY23 Phase 1 – 3 awards selected; cleaning/microbial control with polymerics, antimicrobial coatings, and nucleic acid sampling and processing
 - STEM Engagement's **Established Program to Stimulate Competitive Research (EPSCoR) program** (OSMA/PPO technical manager)
 - Research Infrastructure Improvement (RII) Track 4: EPSCoR Research Fellows Program - planetary protection added
 - Rapid, Response Research (R3) FY23 – 2 awards selected; cleanroom microbial detection (ID) and UCV assessments (NV)
 - Rapid, Response Research (R3) FY24 – Announcement of Opportunity active on Nov. 13 (can view on NSPIRES now though)



NASA Image: JSC2023E026248 - NASA astronaut Victor Glover tests hardware for the ISS External Microorganisms investigation at the Neutral Buoyancy Laboratory at NASA's Johnson Space Center in Houston.



Commercial Engagement

Commercial Engagement



- FAA Payload Review Consultations
 - CLPS managed under FAA Payload Review process
- “Explore Mars – The 2023 Human to Mars Summit” was held in DC, May 16-18, 2023.
- “Achieving Consensus on GUV in Public Spaces” was held in Atlanta, June 6-8, 2023.
 - Greatest concentration of GUV expertise in the world
 - 69 in-person and 50+ virtual attendees from 13 countries.
 - 70 companies, 7 government agencies, 17 universities and 3 nonprofits.
- NASA 2023 Contamination, Coatings, Materials and Planetary Protection Workshop was held at GSFC, September 12-14, 2023.
 - ~200 in-person and 157 virtual attendees
 - 61 Non-US Institutions, 296 US Institutions



Explore Mars – The 2023 Human to Mars Summit



NASA 2023 Contamination, Coatings, Materials and Planetary Protection Workshop



PP Resources



- Mission peer-reviewed PP reports now captured on Office of PP website, as available
- Increases transparency of NASA activities - 27 reports linked to-date!

Missions

Planetary Protection requirements are specific to the type of mission and explored planetary bodies. Accordingly, NASA assigns each mission a **Planetary Protection Category** based on the type of planned encounter (e.g., flyby, orbiter or lander) and the type of planetary bodies that are encountered and explored during the mission (e.g., planet, moon, comet or asteroid). In general, the Planetary Protection Categories (Categories I-V) are organized to reflect the **degree a target (or encountered) planetary body may provide clues regarding life or prebiotic chemical evolution** and can be further refined through **planetary target and type of mission**. When exploring a target body that may provide clues to the process of chemical evolution and/or the origin of life, spacecraft will have a higher level of cleanliness, with the mission providing detailed operating procedures. When exploring a target body that potentially supports Earth life, spacecraft will undergo stringent cleaning and sterilization processes and may be subject to certain operating restrictions. Planetary Protection requirements and mission categories are based on the scientific advice of the Space Studies Board and on NASA or international policy guidelines.

Category ^	Planetary Body ^	Mission ^	PP Report Available ^	Mission Status ^
I	Sun	Ulysses		Completed
II	Moon	Explorer	Yes	Completed
II	Moon	Apollo 6	Yes	Completed
II	Sun	Solar Orbiter Collaboration*		Planning Phase
II	Jupiter	Galileo		Completed
II	Jupiter	Juno	Yes (1) (2)	Ongoing
II	Jupiter/Saturn	Pioneer 10 and 11		Completed

APPLIED MICROBIOLOGY, Sept 1967, p. 1045-1048
Copyright © 1967 American Society for Microbiology

Vol. 15, No. 5
Printed in U.S.A.

Microbiological Burden on the Surfaces of Explorer XXXIII Spacecraft¹

EDMUND M. POWERS

Planetary and Space Science 196 (2021) 105139



Contents lists available at ScienceDirect

Planetary and Space Science

journal homepage: www.elsevier.com/locate/pss



Europa Clipper planetary protection probabilistic risk assessment summary[☆]

Kelli J. McCoy^{*}, Michael DiNicola, Chester Everline, Hayden Burgoyne, Kirk Reinholdt, Brian Clement

^{*}Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, USA



Astrobiology > VOL. 23, NO. 8 |

Special Collection: MARS 2020 Planetary Protection and Contamination Knowledge Investigations

normal

Planetary Protection Implementation and Verification Approach for the Mars 2020 Mission

Moogega Cooper[✉], Fei Chen, Lisa Guan, Akemi A. Hinzer, Gayane Kazarians, Cynthia Ly, Timothy B. Shirey, and Kristina Stott

Published Online: 14 Aug 2023 | <https://doi.org/10.1089/ast.2022.0046>

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](#)



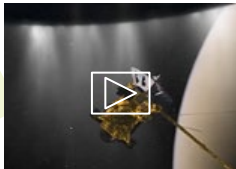
[Protecting the Planet: Planetary Protection vs. Planetary Defense](#)

NEW

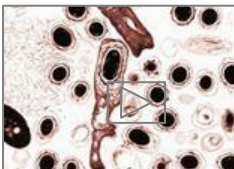


[OSIRIS REx Sample Return Doesn't Pose a Risk to Earth's Biosphere](#)

Videos



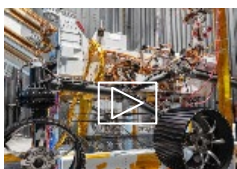
[Planetary Protection: An Introduction](#)



[Just How Small is a Spore?](#)



[Forward and Backward PP Overview](#)



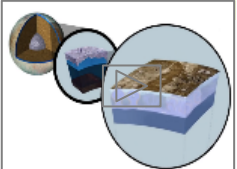
[Behind the Spacecraft Perseverance](#)



[Mission Design and PP Categorization](#)



[Probability of Impact](#)



[Ocean Worlds](#)



[End of Mission Disposition](#)



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



Questions?



Backup

- PD/NSC-25
- Alternative Approach Example
- Life Detection and PP as a stakeholder balance
- Scientific Consensus Trade Space
- Category II Mission Requirements Overview



UNCLASSIFIED
CONFIDENTIAL

THE WHITE HOUSE
WASHINGTON
December 14, 1977

PRESIDENTIAL DIRECTIVE/NSC-25

SUBJECT: Scientific or Technological Experiments with Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems into Space

Two earlier Presidential memoranda dealt with the conduct of scientific or technological experiments that might have large-scale or protracted effects on the physical or biological environment (NSAM 235 of April 17, 1963) and the launching into space of systems involving nuclear power (NSAM 50 (revised) of April 10, 1963). These two NSAMs are hereby rescinded. The general purpose, however, behind these two directives--to give the President the opportunity to consider all factors before any such experiment is carried out--remains valid. The President has approved the policy and procedures below to accomplish that purpose.

It should be understood that experiments which by their nature could reasonably be expected to result in domestic or foreign allegations that they might have major and protracted effects on the physical or biological environment, or other areas of public or private interest, are to be included under this policy even though the sponsoring agency feels confident that such allegations would in fact prove to be unfounded.

Where such experiments constitute major action either licensed or funded by Federal Agencies that significantly affect the quality of the human environment, an environmental impact statement will be prepared. The data from such statement may be used in complying with the following procedures which do not affect the requirement to comply with the provisions of the National Environmental Policy Act:

1. The head of any agency that proposes to undertake a large-scale scientific or technological experiment that might have major and protracted effects on the physical or biological environment, or on other areas of public or private interest, will call such proposals to the attention of the Director of the Office of Science and Technology Policy (hereafter the Director). The Director will consult with the Chairman of the Council on Environmental Quality (hereafter, the Chairman). Notification of such experiments will be given sufficiently in advance that they may be modified, postponed, or cancelled, if such action is judged necessary in the national interest.

2. In support of proposals for such experiments, the sponsoring agency will prepare for the Director a detailed evaluation of the importance of the particular experiment and the possible direct or indirect environmental effects that might be associated with it. The data from an environmental impact statement may be used in complying with this procedure.

3. The Director in consultation with the Chairman will review the proposals and supporting materials presented by the sponsoring agency in order to assure that the need for the experiment has been properly weighed against possible adverse effects.

4. On the basis of this review, the Director in consultation with the Chairman will recommend to the President what action should be taken on the proposed experiment. If the Director, in consultation with the Chairman, judges that inadequate information is available on which to make a judgment, the Director may request that additional studies be undertaken by the sponsoring agency or may undertake an independent study of the problem. Agencies will be notified if an extended delay is anticipated in approval.

5. In the case of experiments that have major national security implications, the head of the sponsoring agency will notify me so that I may determine on an individual basis the procedure to be followed in reviewing these experiments.

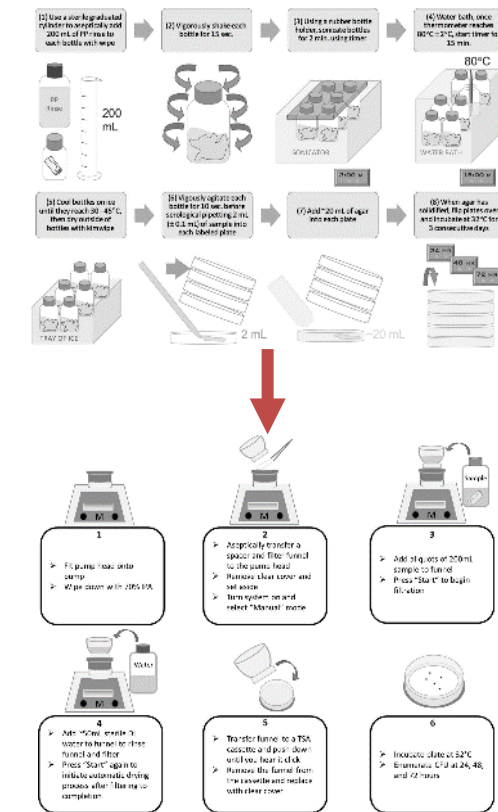
6. While the final decision to conduct such experiments must continue to reside with the government, the National Academy of Sciences and, where appropriate, international scientific bodies or intergovernmental organizations may be consulted in the case of those experiments that might have adverse effects beyond the US. When experiments are expected to have such impacts in foreign countries the Secretary of State will be notified. In arriving at decisions on specific projects, foreign policy considerations should be taken into account. Recommendation on the advisability of the courses of action will be made by the Director in consultation with the Chairman and with the sponsoring agency and the State Department as appropriate.

7. Any large scale scientific or technological experiment that may involve particularly serious or protracted adverse effects will not be conducted without the President's approval. Any experiment that may involve serious or protracted adverse effects will not be conducted without the approval of the head of the department or agency involved, with, in appropriate cases, the advice of other concerned agencies.

8. To the extent that it is consistent with national security, and subsequent to approval of the experiment, there should be early and widespread dissemination of public information explaining the purpose, benefits, and assessments of impacts.

Alternative Approaches Examples

- Alternative approaches that align with scientific consensus should be proposed by the project.
- Project should evaluate and proposal project specific use case. As needed, this may require additional comparative analyses, test plan verification and validation to demonstrate fit and form, acceptance testing, etc.
- **Some of the examples from projects to-date**
 - Membrane filtration
 - Inadvertent contamination of Mars or Moon
 - Do what is needed for your project!
 - Statistically intense mission design approach involving launch dispersions, 100,000 monte carlo runs, b-plane keyhole analysis, etc.
 - Not in the neighborhood and don't have the energy capable of getting us there.



Pour plating vs. membrane filtration from Stott et. al 2022.

Welcome scientifically sound alternatives approaches to PP!

Life Detection Science and Planetary Protection Cleanliness for IVb Missions

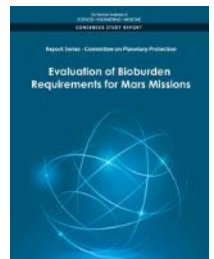
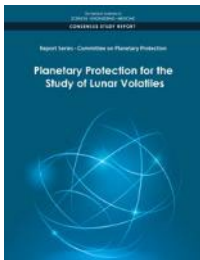
- PP is a **stakeholder** in the outcome of the scientific consensus of results, but **should NOT define “how-to” or prescriptive parameters.**
- NPD 8700.1F – protecting planetary environments and public safety
- Life detection owned by mission directorate / science but need requirement to link PP as a stakeholder. Without a requirement **reporting is optional or may be considered out of scope.**
- Forward PP Objectives may be needed to drive hardware cleanliness to avoid contamination and cleanliness leading up to false positive science results (as opposed to PP driving science requirements). Category IVb implementation technical requirements has 3 options
 1. the prescriptive Viking route,
 2. a bioburden approach driven by the nature and sensitivity of the life detection instrument route (Mars 2020), or
 3. an analytical route that demonstrates that the life detection experiment is preserved (expanded approach).

Scientific Consensus in Practice

- Scientific consensus mentioned throughout NPR 8715.24 and NASA-STD 8719.27, but what does this mean in practice?
- Need to establish a process in which missions can leverage scientific consensus throughout the project life cycle and/or the discipline can update policy and broad scale approaches.

	Small	Medium	Large
Engineering	Table top review	Tiger Team	Standing Review Board
OSMA / OPP	Subject Matter Experts	Non-advocate review board	CoPP

- Subject Matter Expert
 - Peer-reviewed manuscript – adoption of membrane filtration to assess bioburden on spacecraft surfaces
- Non-Advocate Review Board (ad hoc)
 - NASA Office of Chief Scientist independent review / study – Ganymede Utilization for End of Mission Disposal (2021), Updated Review of Titan Science (2022) and Feasibility of leveraging ultraviolet radiation as an alternative approach to bioburden control and management for PP sensitive missions (Present topic)
- CoPP – Study of Lunar Volatiles, Evaluation of Bioburden Requirements for Mars Missions
- What happens in the end?
 - Planetary Protection’s role is to advise on whether scientific consensus has been achieved.
 - Decision authority resides with the Mission Directorate Associate Administrator, Administrator, or OSTP/President.





Planetary Protection Category II Missions Requirements

Mission	Target Bodies	Planetary Protection Requirements	Engineering and Science Requirements (contamination control)
Deep Impact/EPOXI	Comets Tempel 1 & Hartley 2	Impact Avoidance + Documentation	Cleanroom Processing; Foreign Object Debris (FOD) Driver ^{1, 2}
New Horizons	Pluto/Charon	Impact Avoidance + Documentation	Cleanroom Processing; Payload driver ³
OSIRIS-REx	Comets Wild 2 & Tempel 1	Impact Avoidance + Documentation	Cleanroom Processing; Science Sample Return driver ⁴
Lucy	Eight asteroids, including one from the Main Belt and seven from the Trojan asteroids	Impact Avoidance + Documentation	Cleanroom Processing: Payload driver ⁵

¹<https://deepimpact.astro.umd.edu/faq2.html>. Note: "Deep Impact is being assembled and tested in a Class 100,000 cleanroom.... The clothing requirements are in place to prevent contamination of the flight hardware from foreign object debris (FOD)"

²KSC Press Release, Dec 22, 2004. <http://www.spaceref.com/news/viewpr.html?pid=15761>, Note: "For the media event, procedures for optically sensitive spacecraft must be followed by individuals entering the cleanroom where the spacecraft is being processed."

³McNutt et. al. 2007. The Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI) on the New Horizons Mission. Note: "class 10,000 or better clean room...instrument was kept under purge at all times"

⁴Dworkin, J P et al. "OSIRIS-REx Contamination Control Strategy and Implementation." *Space science reviews* vol. 214,1 (2018): 19. doi:10.1007/s11214-017-0439-4. NOTE: "To return a pristine sample"

⁵<https://www.nasa.gov/feature/goddard/2021/nasa-s-lucy-in-the-cleanroom> Note: "L'Ralph camera sits atop the spacecraft's Instrument Pointing Platform (IPP) that's used to aim Lucy's instruments in a specific direction - seen here in the clean room"

NASA missions typically require cleanroom processing to support engineering and science cleanliness requirements, irrespective of PP requirements.

Contamination Control Driving Cleanroom Processing is Beneficial for Preventing Harmful Contamination for DAWN and JUNO



Mission	Target Bodies	Planetary Protection Requirements	Engineering and Science Requirements (contamination control)
DAWN	Asteroids Vesta & Ceres Cat III due to Mars flyby	Impact Avoidance + Documentation + Cleanroom + Organic inventory	Cleanroom Processing; FOD / Payload Driver
Psyche	Asteroid Psyche Cat III due to Mars flyby	Impact Avoidance + Documentation + Cleanroom + Organic inventory	Cleanroom Processing; FOD / Payload Driver
JUNO	- Cat II – Jupiter Extended Mission Cat III – Europa, Ganymede and Io	Impact Avoidance ¹ + Probability of Europa Contamination + Documentation + Cleanroom + Organic inventory	Cleanroom Processing; Payload driver

¹Lam et al. 2008. Planetary protection trajectory analysis for the JUNO mission. AIAA/AAS Astrodynamics Specialist Conference Hawaii August 18-21, 2008.