Implementation of Planetary Protection at NASA

29 September 2022

ESA Planetary Protection Course

Stuttgart, Germany

Nick Benardini

NASA Planetary Protection Officer

Elaine Seasly

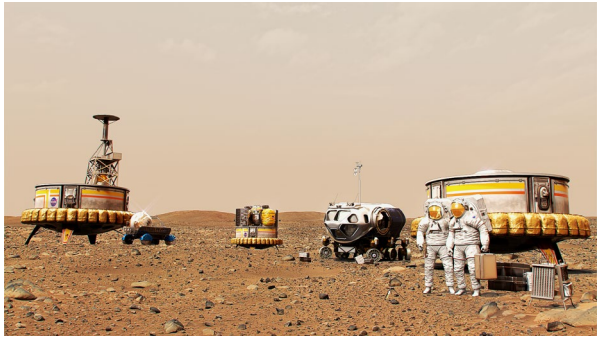
NASA Deputy Planetary Protection Officer

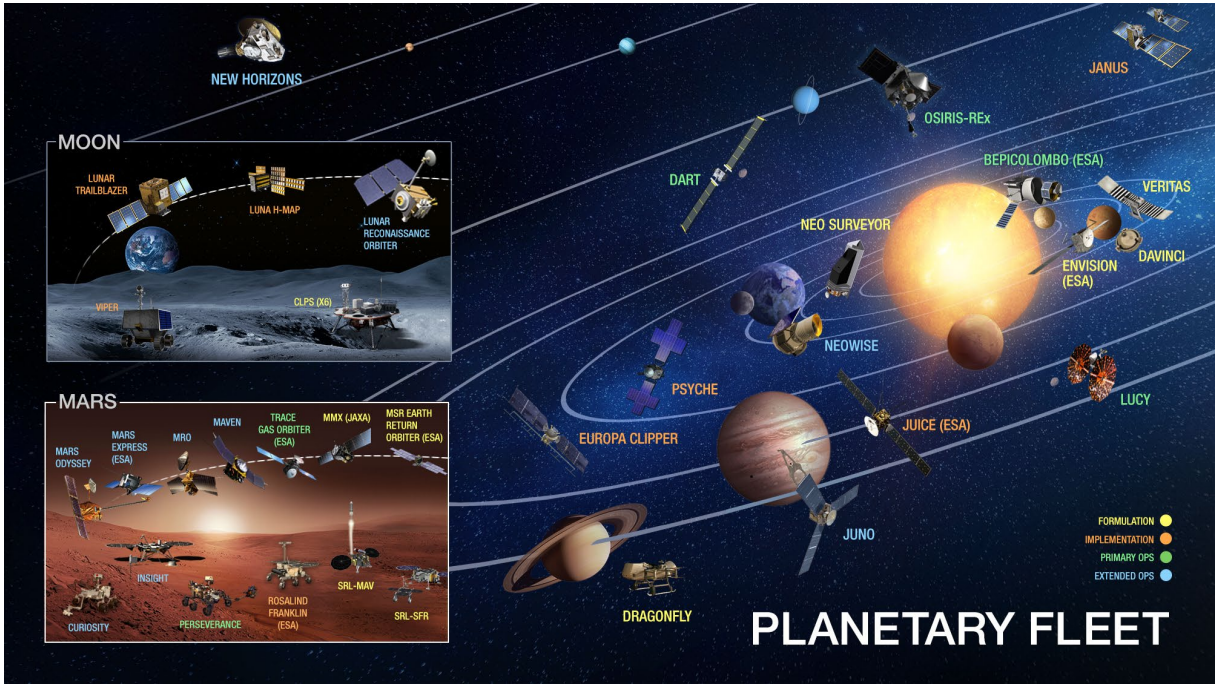
Overview

- Why Planetary Protection?
- Increased need for Planetary Protection
- Organization of Planetary Protection within NASA
- NASA Planetary Protection role with commercial space
- Roadmap and identification of knowledge gaps
- Planetary Protection policy
- Establishment of scientific consensus for Planetary Protection lessons learned

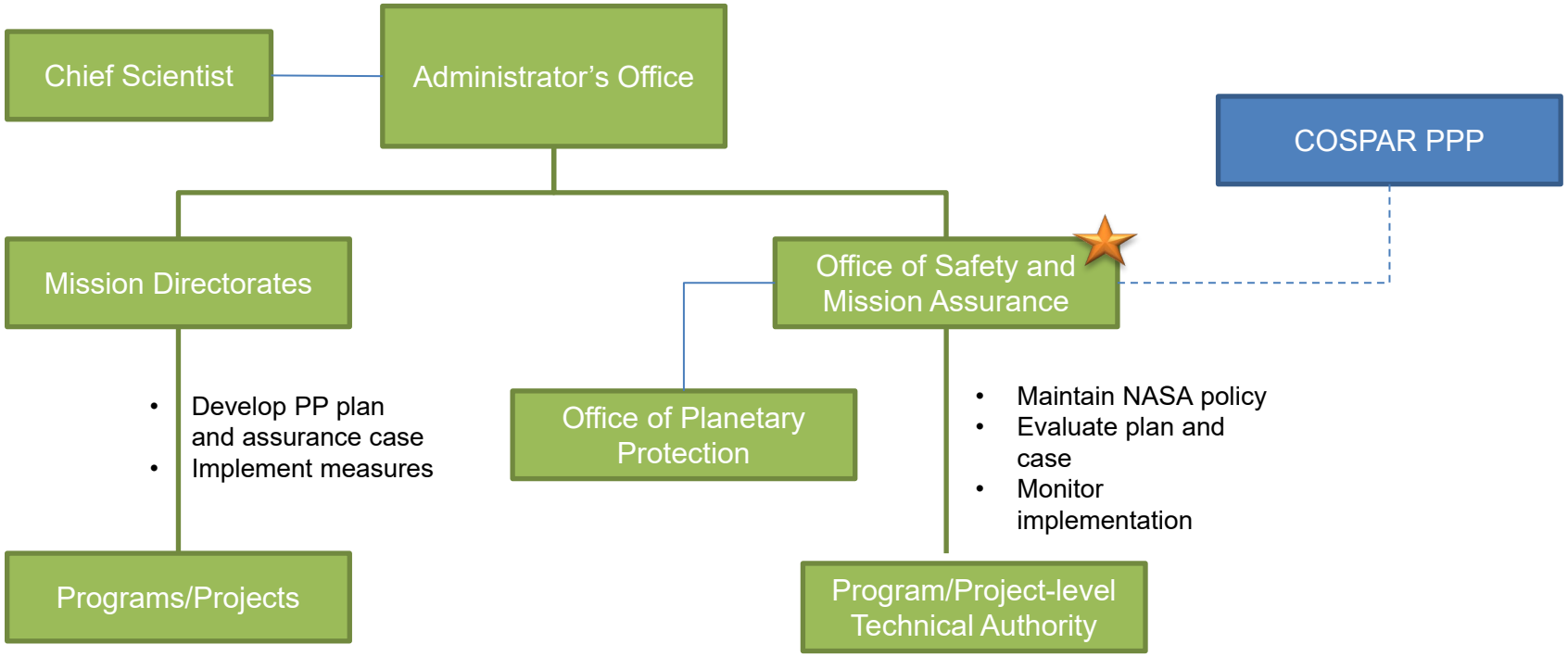
Coordination of Planetary Protection Across Missions

- Robotic
- Crewed
- Commercial





Organization of Planetary Protection Within NASA



NASA's Planetary Protection Policy Documents (current)

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

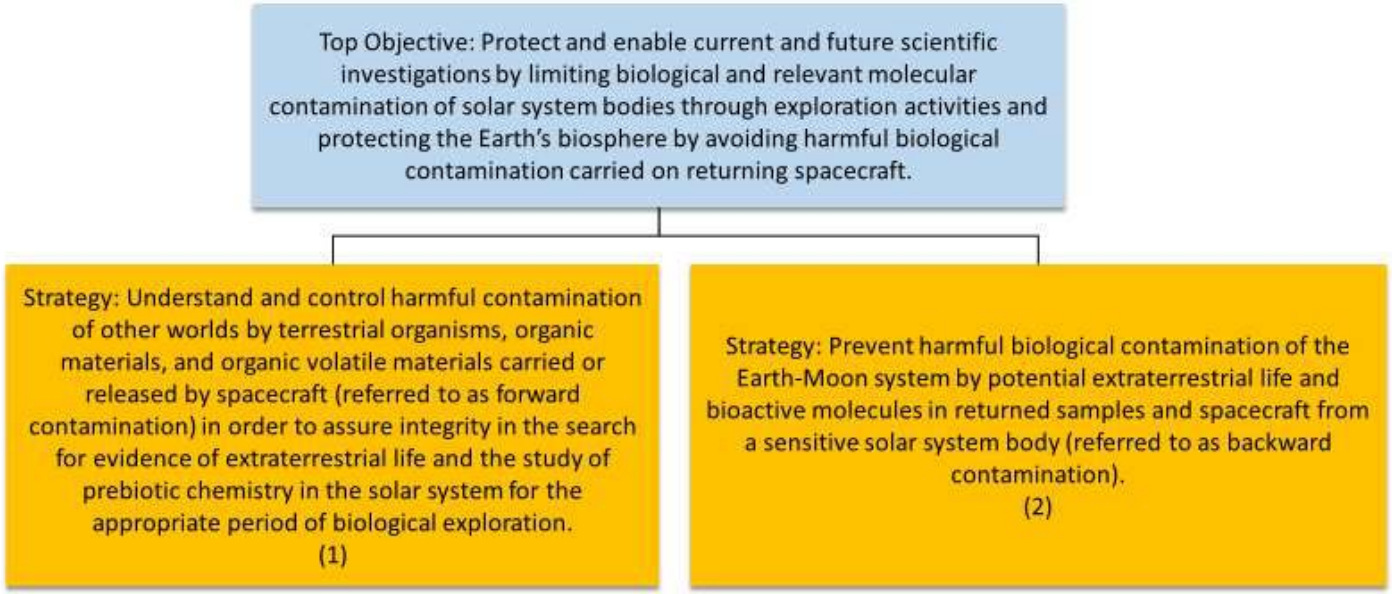
NASA-STD-8719.27
Implementing Planetary Protection Requirements for Space Flight
Effective Date August 30,2022

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

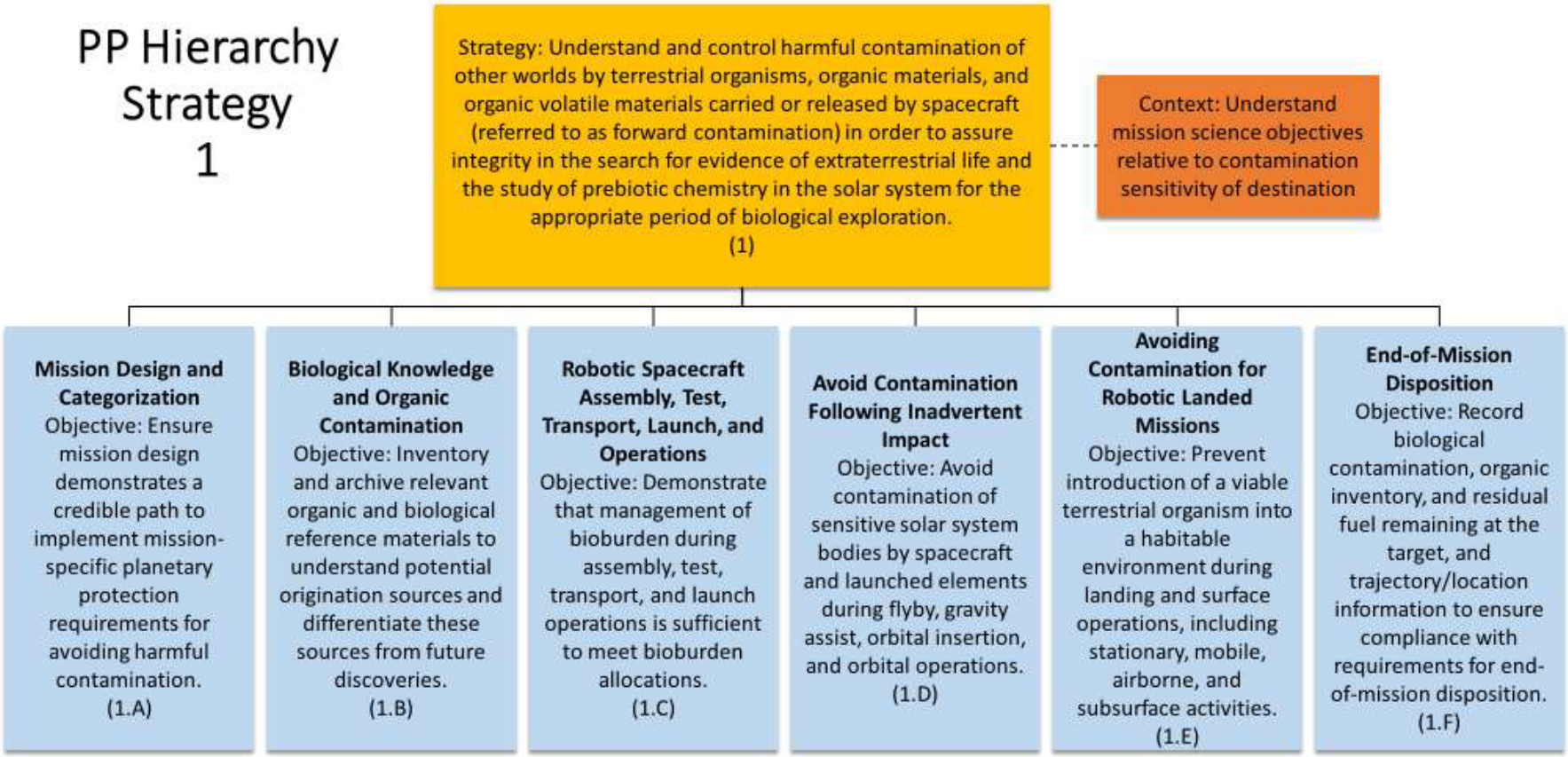
Forward and Back PP Strategy



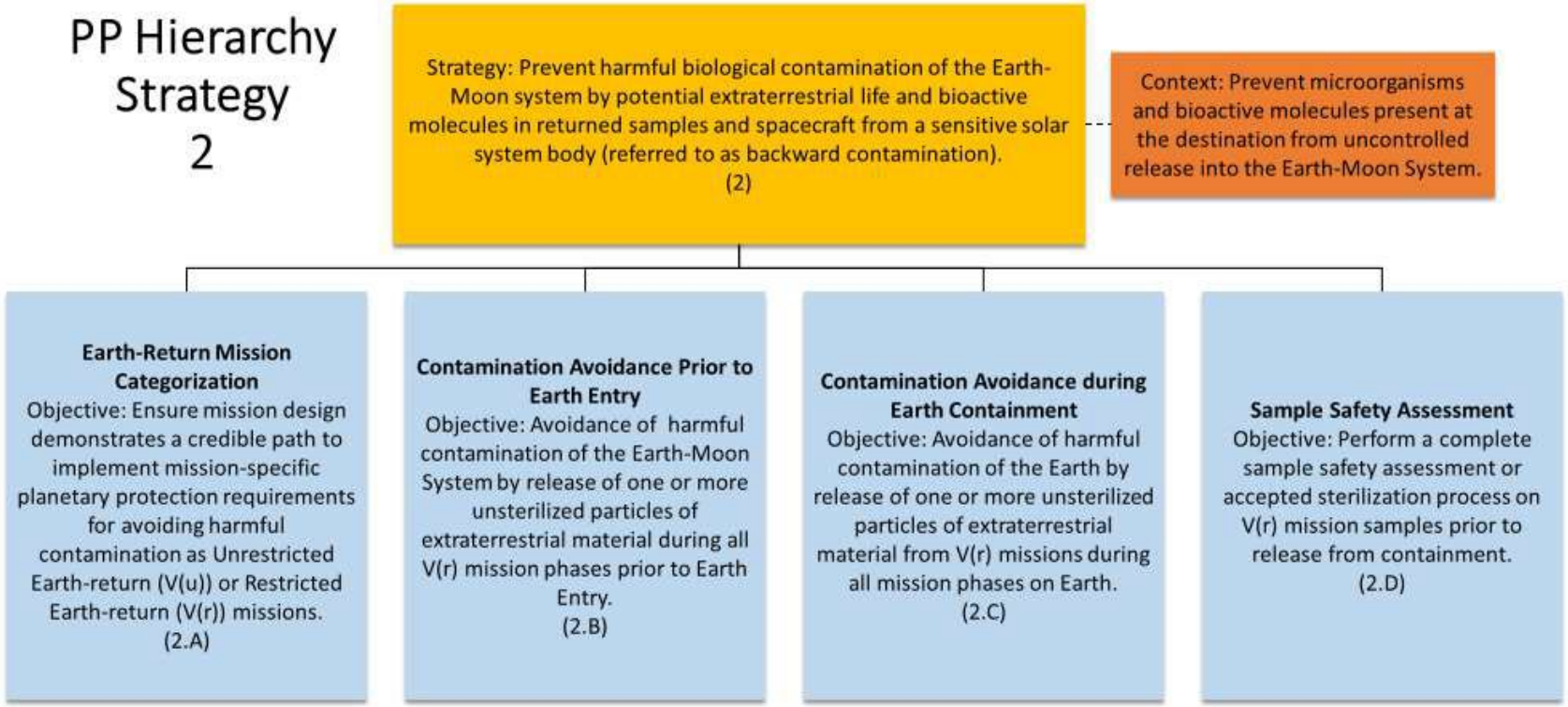
Enabling Objectives

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

Forward Planetary Protection Objectives



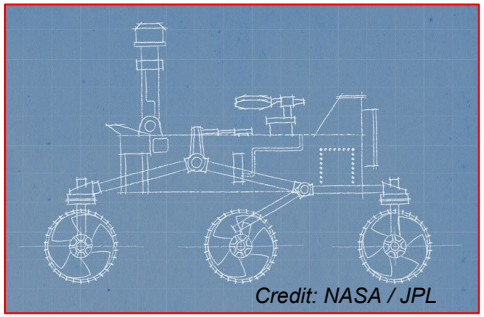
Back Planetary Protection Objectives



Forward Planetary Protection – Category IVa Rover Approach

Hardware Design (Systems Engineering)

- Establish Driving Requirements
  - 5 x 10^5 spores total
  - 3 x 10^5 spores landed
  - 300 spores / m^2
- Bioburden Allocation
- Organic Inventory
- Implementation Planning



Planetary Protection starts in early mission phases

Hardware Implementation (Clean)

- Microbial Reduction (e.g., heat microbial reduction, etc.)
- Verification of cleanliness (e.g., NASA Standard Assay for spores)



Verification – Swab of the ExoMars camera

Recontamination Prevention (Keeping it Clean)

- Cleanroom assembly and test
- Hardware cleaning and covering
- Late critical system installation
- Launch environment cleanliness
- Pre-launch report
  - Bioburden, organic reporting



Credit: NASA / JPL

Late integration of the Mars 2020 Sample Tubes

Backward Planetary Protection Elements

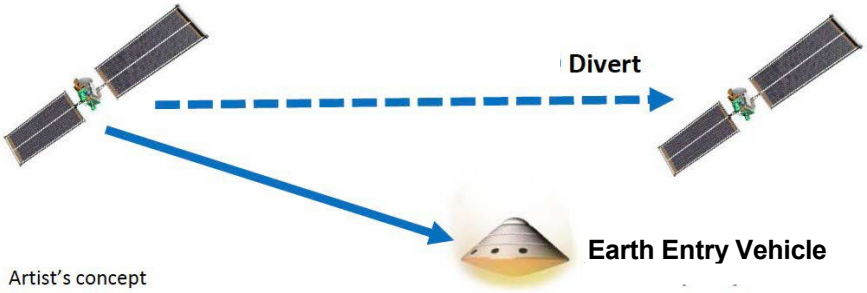
Notional Mission Phases

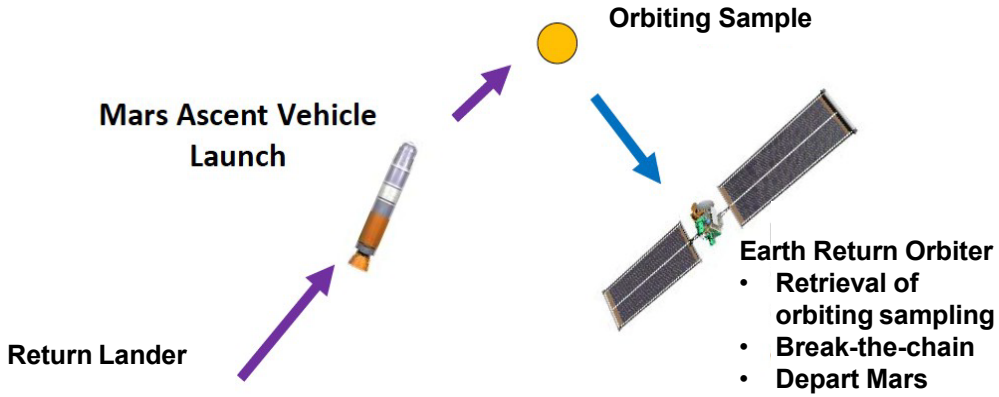
Mars Surface Operations	Sample Rendezvous in Mars Orbit	Earth Return Transit	Earth Arrival

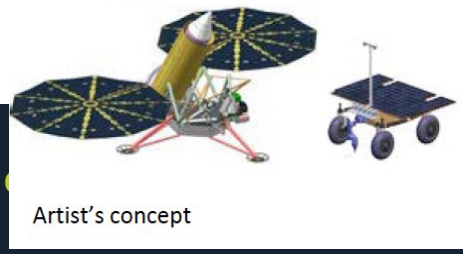
Backward PP Elements

Containerization, break-the-chain

- Redundant robust containers
- Hardware design and/or sterilization are several options being considered







Inadvertent Earth Avoidance

- Orbiter off-Earth bias until shortly before sample release
- Redundant navigation and avionics systems for Earth Entry and Earth diversion of orbiter upon Earth Entry Vehicle release.

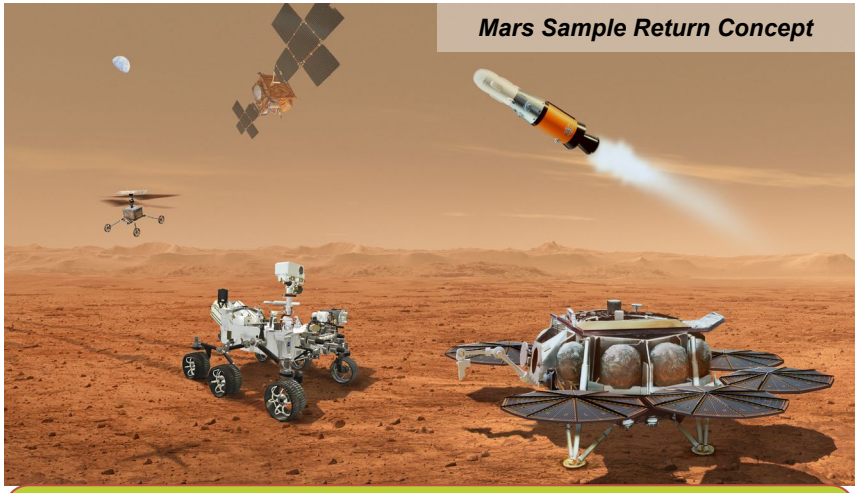
Mars Dust and Potential Mars Biological Management

- Dust avoidance hardware design and operations
- Potential use of active and/or passive sterilization measures

Shifting the Approach to Requirements Development



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

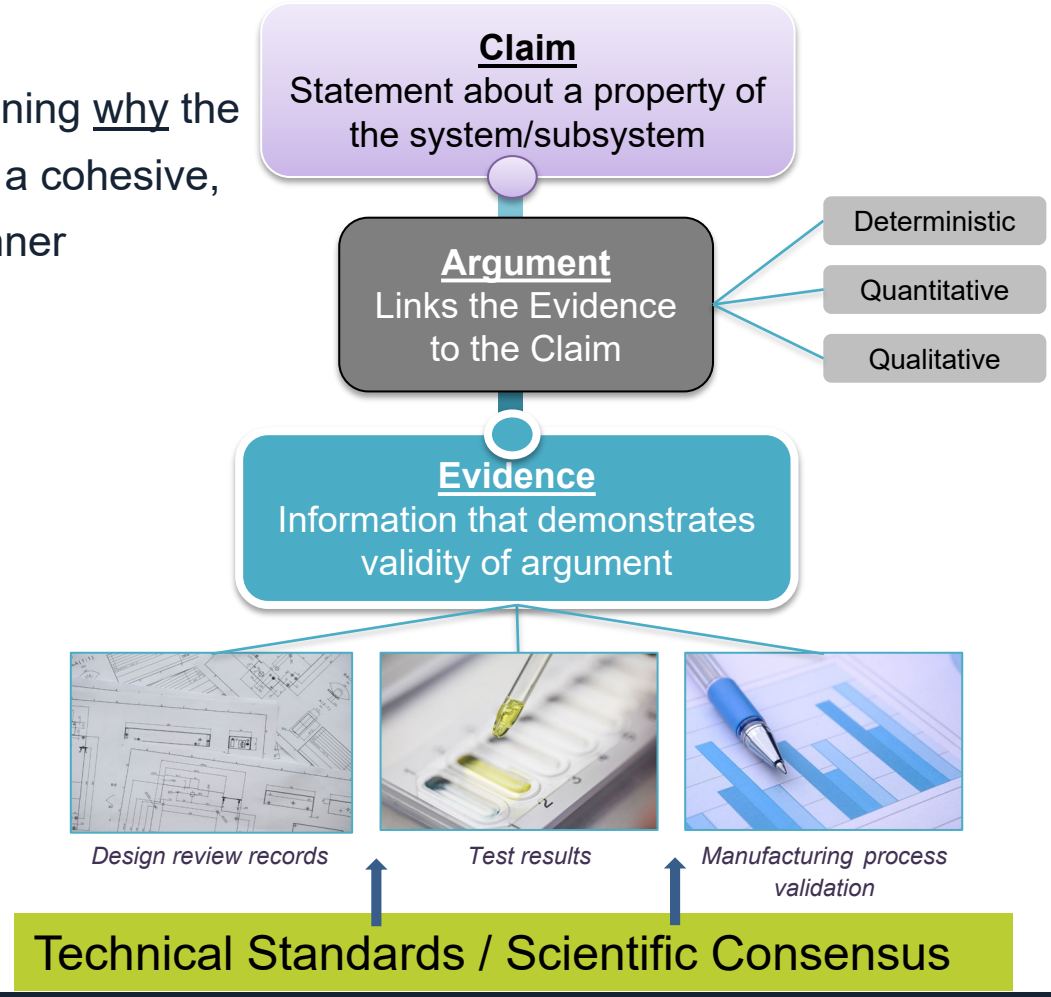


Performance-based Requirements:
Specifying "What to do" but not "How to do it"

- 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 **NOT** a relaxation of requirements or a "get out of jail free card"

The Assurance Case Approach

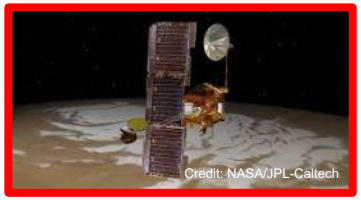
- Allows for a combination use of prescriptive and performance-based requirements
- Brings forth the entire story and reasoning why the system is safe or will be successful in a cohesive, comprehensible, and transparent manner



Notional Forward PP Mars Exploration Trade Space

REQUIREMENTS

Prescriptive



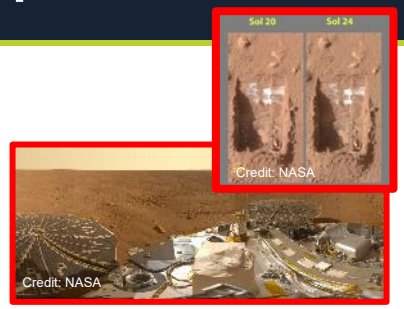
Robotic - Mars Orbiter
PP Category III – Orbital Lifetime
Mars Odyssey



Robotic - Mars Orbiter
PP Category III – Bioburden
MAVEN mission



Robotic - Mars Lander / Rover
PP Category IVa
Mars Science Laboratory – Curiosity



Robotic - Mars Lander / Rover
PP Category IVc – Mars Special Region
Phoenix Lander

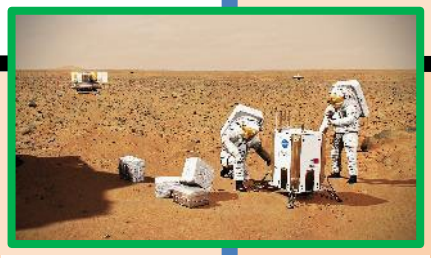


Robotic - Mars Lander
PP Category IVb –
Life Detection
Viking Lander

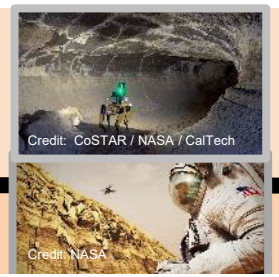
Knowledge Gaps

IMPLEMENTATION

Easier ← → **Challenging**



Crewed – Habitat / Close EVA Study



Crewed + Robotic -
Special Region Exploration



Crewed – Habitat / Far
(kilometers?) EVA Study



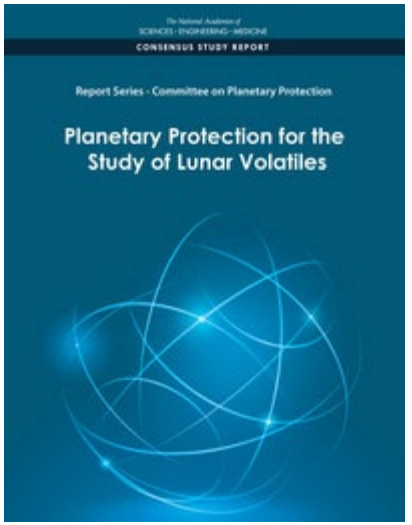
Crewed Special Region/Sampling for
life detection/In-situ life detection

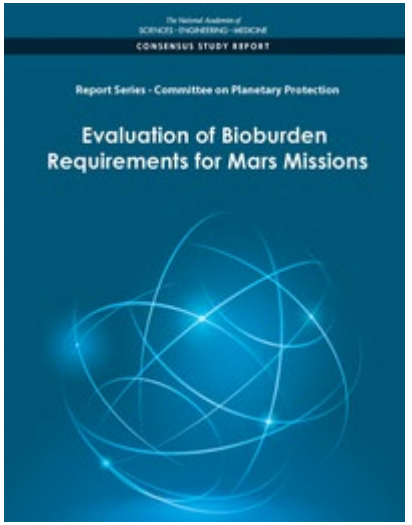
Key
Robotic
Robotic + Crewed
Crewed

Performance Based

Scientific Consensus

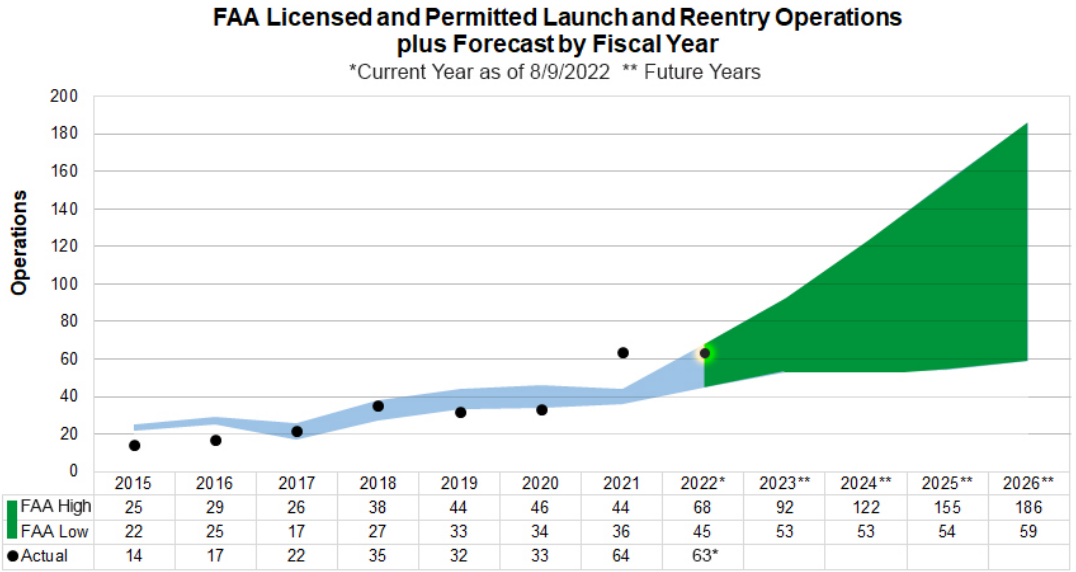
- Utilization of current scientific consensus throughout the project life cycle is important to ensure that missions maintain an acceptable approach for demonstrating compliance with the Outer Space Treaty.
- Scientific consensus implies that a majority of international scientists should accept a current scientific discovery.
- It should **NOT** be reactive towards a new scientific findings, but represent a widespread viewpoint allowing time for peer-reviewed debate and discussion.
- Strategy
  - Multidisciplinary/large scale topics this may require scientific organizations such as the National Academies of Science Engineering and Medicines (NASEM) Committee on Planetary Protection or a mission-by-mission tailoring process initiated by The Committee of Space Research (COSPAR) Policy on Planetary Protection.
  - Focused topics such as categorization or implementation topics an independent science review board or the peer-reviewed journal community with mission report out during the COSPAR PPP meeting.





NASA's PP Role with Commercial Space

- NASA is not a regulatory agency and has no authority over non-NASA launches from US territory or non-US launches by other US entities.
- NASA currently consults with the Federal Aviation Administration (FAA) when asked by the FAA to review a commercial provider's voluntary launch license.
- Technical consultation includes
  - a description of the propulsion systems,
  - a description of the trajectory,
  - an assessment of biological contamination risk and associated mitigation strategy, and
  - reporting spacecraft organics for the Moon.



	2015	2016	2017	2018	2019	2020	2021	2022*	2023**	2024**	2025**	2026**
FAA High	25	29	26	38	44	46	44	68	92	122	155	186
FAA Low	22	25	17	27	33	34	36	45	53	53	54	59
Actual	14	17	22	35	32	33	64	63*				

https://www.faa.gov/space/licenses

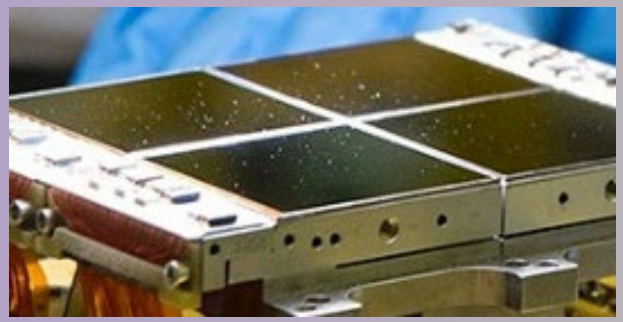
Planetary Protection Lessons Learned

Close Connection Between the Contamination Control and Planetary Protection Disciplines

Contamination Control (CC)

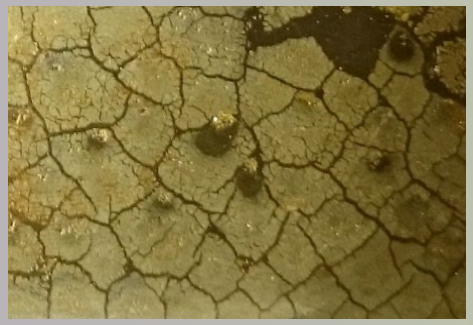
Planetary Protection (PP)

Particulate Contamination



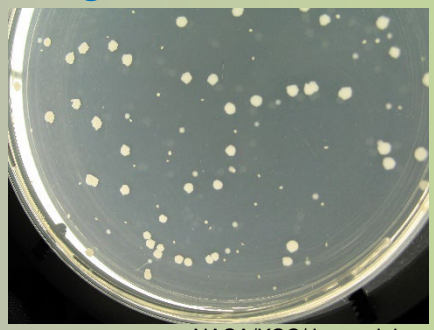
NASA/Goddard/Chris Gunn

Molecular Contamination



NASA/Langley/Elaine Seasly

Biological Contamination

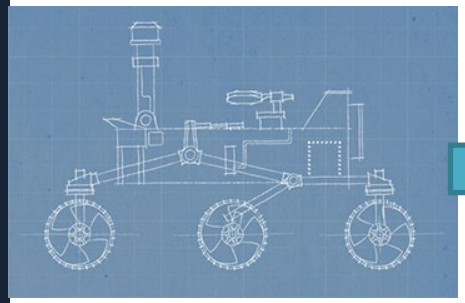


NASA/KSC/Jason Johns

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

End-to-End Consideration of Planetary Protection

- Most primarily think of implementation, but Planetary Protection spans the entire mission lifecycle
- Planetary Protection involves communicating with various audiences: scientific, engineering, policy, political, media & communications, etc.



Mission Design & Categorization



Hardware Assembly, Test, Transport, & Launch

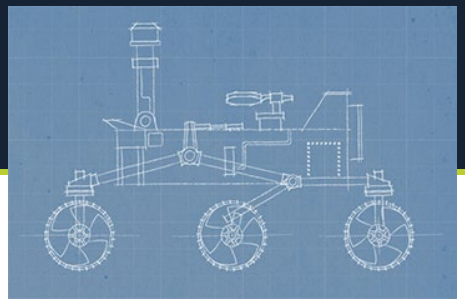


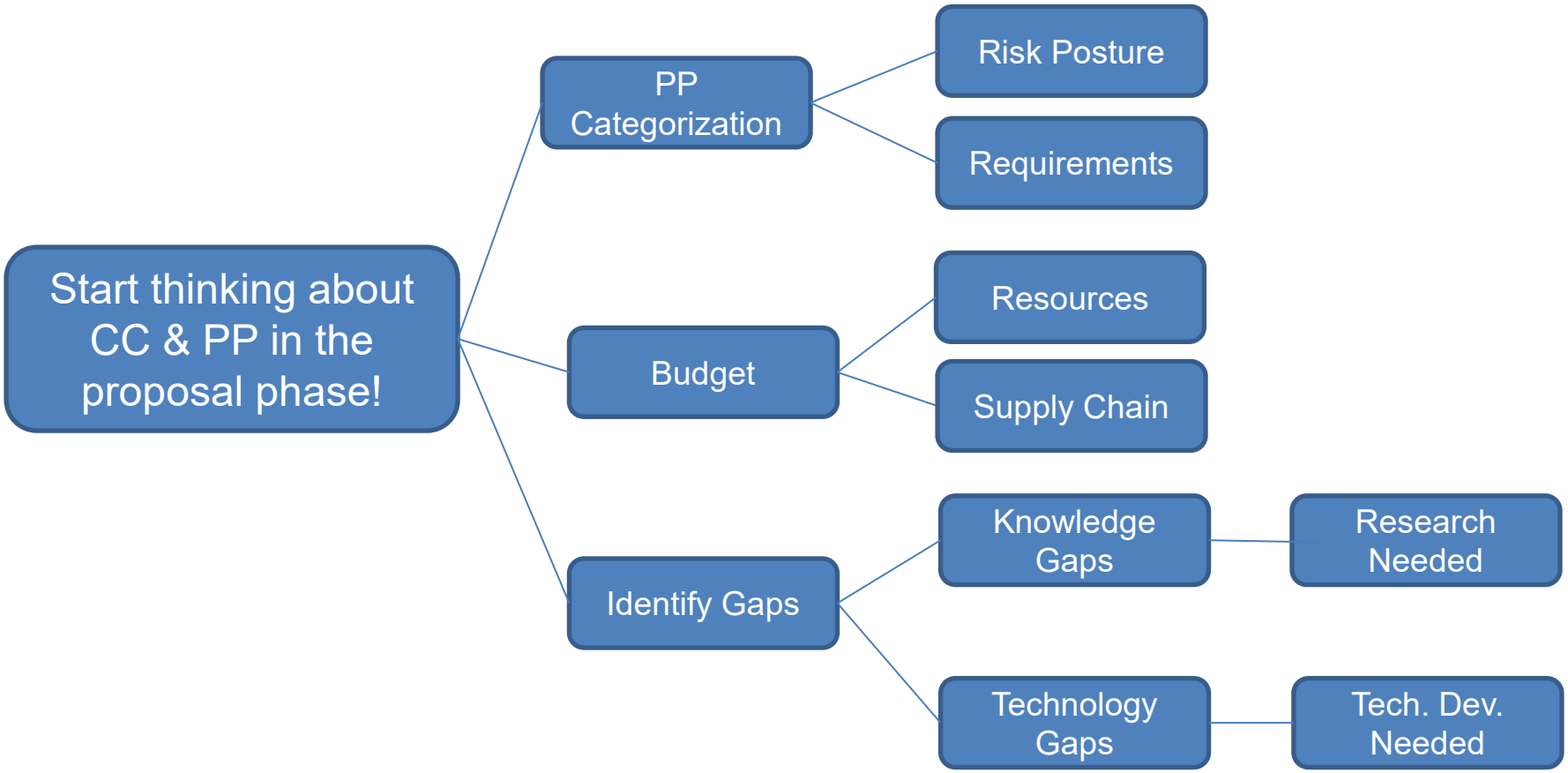
Mission Operations



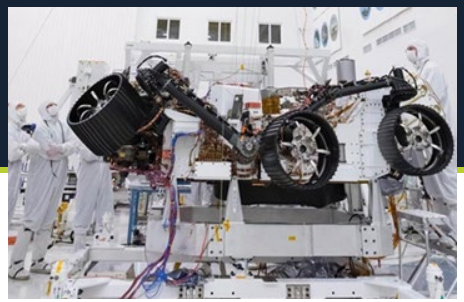
Extended Mission & End of Mission Disposition

Mission Design & Categorization Phase





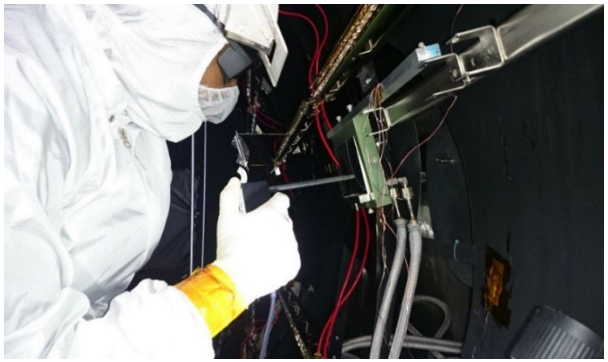
Hardware Assembly, Test, Transport & Launch Phases











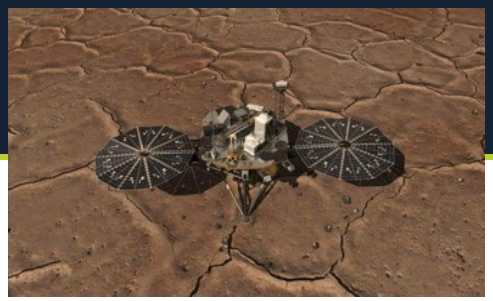
Managing Clean Areas:
- Training personnel
- Monitoring behavior
- Environmental monitoring

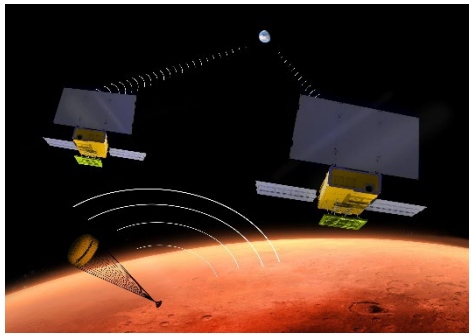
Quantification of Contamination:
- When to clean/sample
- Accounting for processing time
- Compatibility of materials
- Bioburden accounting

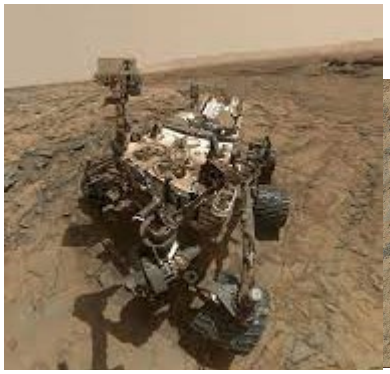
Responding to Contamination Events:
- Incident notification & response plan
- Data collection and analysis
- Reporting results and decision making
- Recontamination prevention

Mission Operations Phase











Inadvertent Impact Avoidance:

- Analysis includes all launched elements
- Consider all secondary and auxiliary payloads
- Can drive PP categorization

Mission Operations:

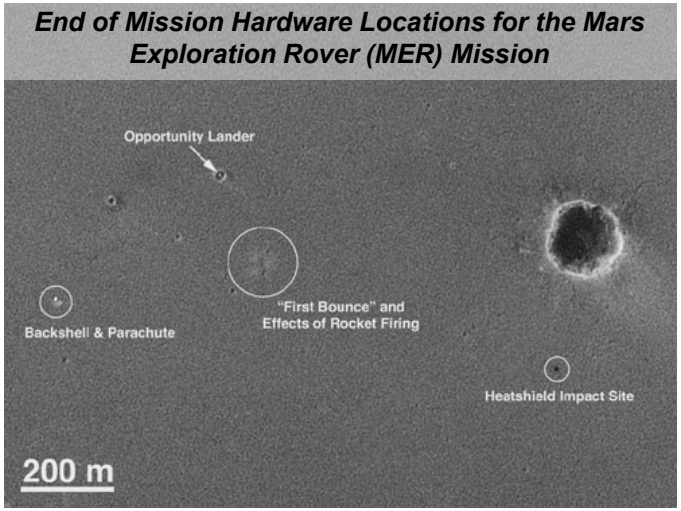
- Consider interactions with target body and contamination potential
  - Roving, flying, digging, drilling

Extended Mission & End of Mission Disposition





Curiosity Rover Wheel on Mars



Extended Missions:

- Consider if a mission can be extended much longer than originally anticipated!
- Potential to access sensitive areas over time

End of Mission Disposition:

- Documentation of final hardware location and residual materials
- Consider contamination potential over time
  - Orbiters need to consider inadvertent impact

Collaboration, Coordination, and Sharing

- Opportunities exist to collaborate, share knowledge and lessons learned, and encourage support amongst contamination control and Planetary Protection practitioners.
- Plan for documentation and telling the story to capture knowledge and pass on to future practitioners.
- Consider the “Yes, If…” approach to challenges
  - When asked, “Is this possible?” our response should be, “Yes, if…” instead of “No, because….”



Together we can ensure the ability to learn from space exploration is preserved for current and future generations.