Backward Planetary Protection Public Safety and Mission Assurance Considerations

Dr. Elaine Seasly

Director, NASA Mission Assurance Standards & Capabilities Division

Dr. J. Nick Benardini

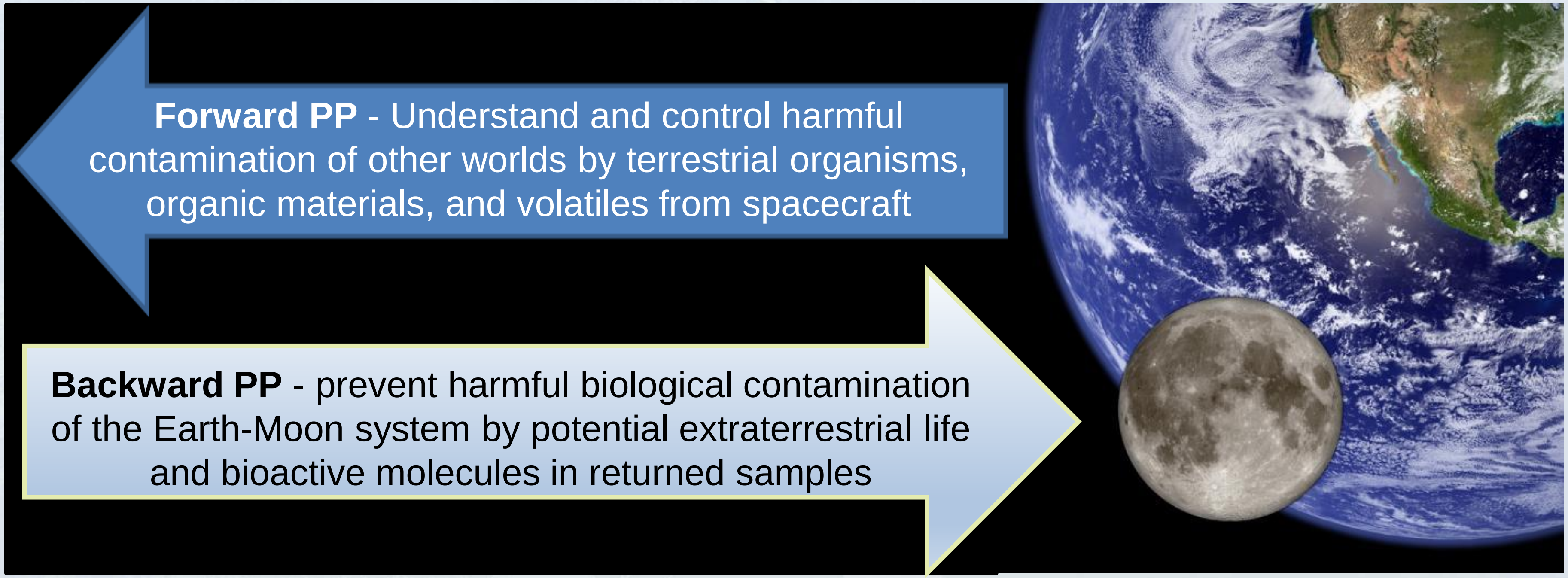
NASA Planetary Protection Officer

TRISMAC 2024

June 25, 2024

Planetary Protection Objective

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.



Backward Planetary Protection: Unrestricted vs. Restricted Earth Return

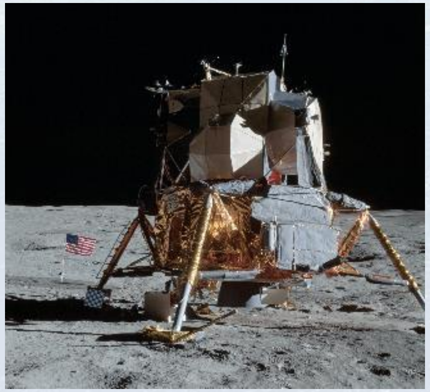
- Backward PP is based on the risk of contamination to the Earth from returning material from the target body.
- **Unrestricted Earth Return Missions**
  - Very low risk of contaminating Earth when returning material from the explored target body
  - No additional PP requirements
  - Examples: Earth’s Moon (after Apollo 14), Venus, most asteroids & comets
- **Restricted Earth Return Missions**
  - Possibility for indigenous life
  - Significant sensitivity to contamination of the target body and the science investigation in understanding the process of chemical evolution or origin of life
  - Required to implement high containment controls to ensure that returned material is not released before sterilization or sample safety assessment
  - Examples: Earth’s Moon (Apollo 11, 12, 14), Mars, Europa, Enceladus

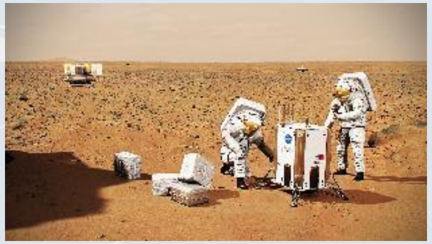
Apollo 14 Crew Quarantine

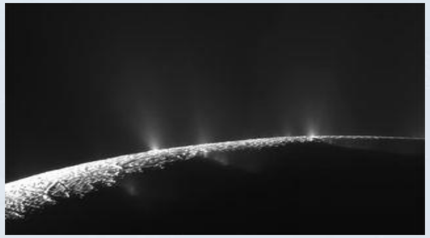
Restricted Earth Return – Then & Now

NOW

THEN





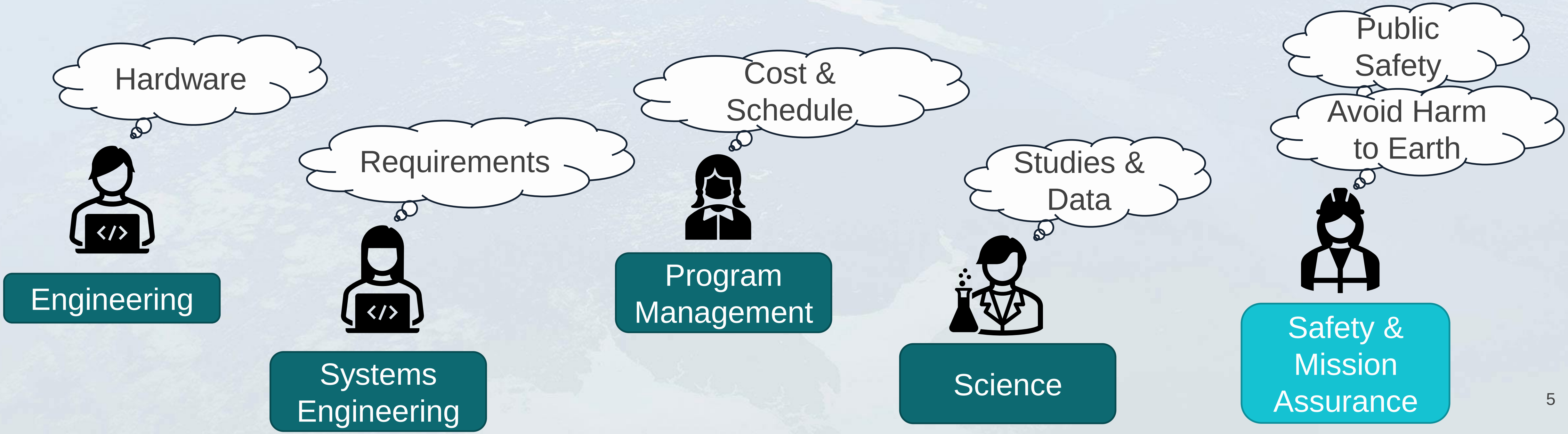


- Apollo 14 was the last restricted Earth return mission with Backward PP requirement
- Mission elements only targeted Earth's Moon
- Mission was US Government only & run by NASA
- Elements part of a single mission focus

- Mars Sample Return and future crewed mission to Mars on the horizon
- Missions planning for sample return from restricted Earth return targets of Mars, Europa, & Enceladus
- International partnerships including both government and commercial partners
- Missions now consider multiple elements phased over time

Safety & Mission Assurance Plays a Key Role in Backward Planetary Protection

- Focus is on public safety & avoiding harm to Earth's environment
- Consults and coordinates processes to assure the safety and containment of Earth-return samples
- Expertise in management of risks that are low-probability & high-impact
- Provides a unique independent perspective from mission project roles



The Objectives-Driven, Risk Informed, and Case Assured Approach

Objectives-Driven

- Objectives are substantiated, monitored, and independently evaluated throughout the lifecycle based on systematic argumentation, explicit assumptions, and objective evidence.

Risk Informed

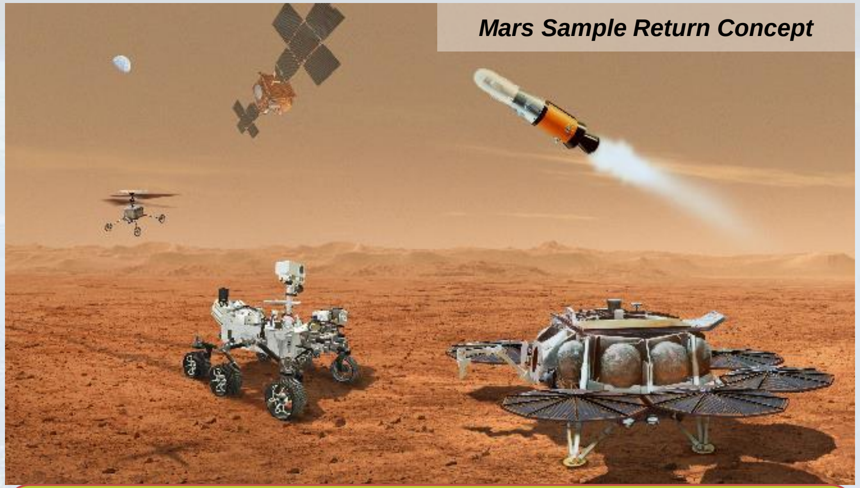
- Risks are understood, documented, and consistent with the established risk posture.
- Consider the potential benefits and strategic importance of the mission(s) and consequences of failure, to inform decisions regarding:
  - Formulation
  - Implementation
  - Assurance of the mission.

Case Assured

- Comprehensive and logical claims made with sufficient argument(s) & objective evidence.

Objectives-Based Performance Requirements

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



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

- **SMA helps to determine:**
  - *Are the objectives clearly defined?*
  - *Can non-experts understand the objectives?*
  - *Can the objectives be feasibly achieved?*

- Shifting from prescriptive to performance-based requirements:
  - 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"

Utilizing Trade Space & Analysis of Alternatives

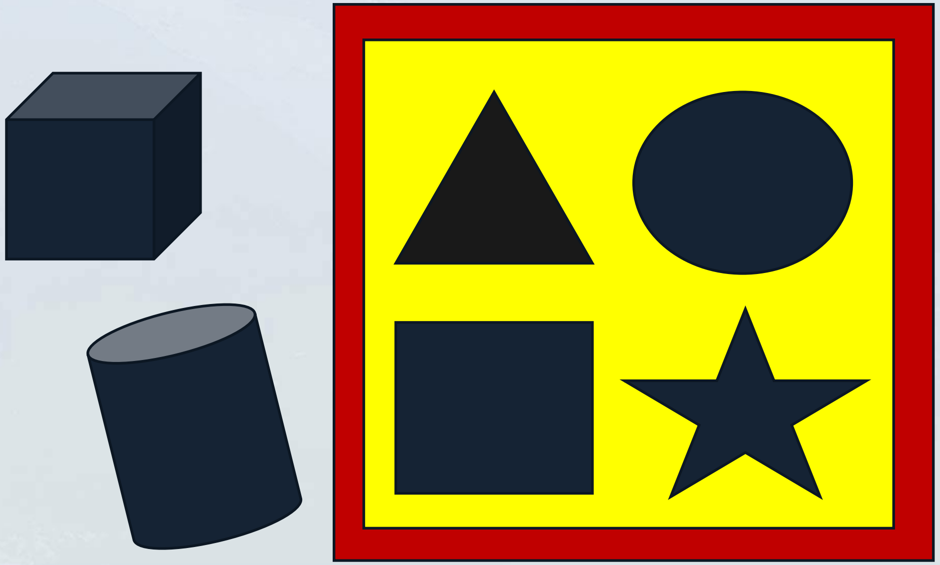
Previous Approach:

- “Design heritage” results from decades of iterations into high fidelity engineering designs and operational concept of a point solution
  - *Example: Mars Sample Return has design elements unchanged from the 1990s*
- PP requirements were then developed in response to these hardware designs and operational concepts resulting in a one-size prescriptive approach
  - *Requirements reactive to hardware designs instead of hardware designed to meet requirements*

- **SMA oversight of design trades and analysis of alternatives:**
  - *Broader identification of risks and consideration of what “could be” for the system*
  - *Independent check for appropriate use of performance-based and prescriptive requirements*

New Approach:

- Taking the Objectives-Driven, Risk Informed, Case Assured approach for PP enables the ability to think creatively about the design and performance of the future state of the system
  - *Allows for use of both performance-based and prescriptive requirements at appropriate levels of the architecture*
  - *Allows for PP requirements to be flexible and adaptive to accommodate and enable engineering trades and analysis of alternatives*



Restricted Earth Return approval requires a formal and well-defined decision-making process.

- Define the approval process, engagement plan, and communication strategy early in the mission lifecycle.
- This risk posture and responsive technical science and engineering decision making approach and implementation should be understood by all stakeholders within the agency.
- SMA community should be in regular communication between partners.
  - *Should track with the project systems engineering schedule and agency level key decision points*
- Broadscale impacts to the Earth's biosphere require high level governmental decision making.
  - *For example, NASA is required to engage the President of the US for approval.*

SMA helps to coordinate and champion the approval process

Agency approval process?

SMA approval?

Scientific consensus?

Partner approval?

Regulatory / Intra-gov approval?

Public perception and approval?

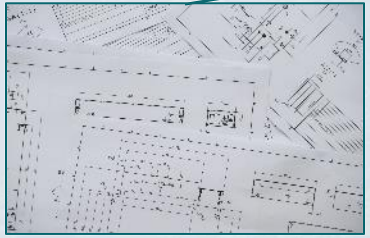
Coordination of the End-to-End Assurance Case Process

Claim
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

- **SMA coordinates between multi-mission elements & partners:**
- Establishing the Use Case
  - *Is the approach applicable?*
- Scientific Consensus
  - *Does the use case make technical sense?*
  - *Would most of the international scientific community agree with this approach?*
- Technology Matured to Implement
  - *Other industries or academic uses matured?*
  - *Technology demonstrated in relevant environment?*
- *Is the current policy and standards agile enough to accommodate approach?*
- *Does it align to the safety / risk posture?*

Thank You!

Ensuring public safety and mission assurance for a restricted Earth return mission will require an objectives-driven, risk informed and case assured approach to address backward planetary protection compliance. The safety and mission assurance stakeholders play a key role in this process by consulting and coordinating processes to assure the safety and containment of Earth-return samples and the public.

Abstract

- Apollo 14 was the last restricted Earth return mission that implemented backward planetary protection requirements where preventing harmful contamination of the Earth's biosphere is the highest priority. Over the past 50 years, engineering and science technology advancements have been made to manage, sterilize, contain and assure safety of particles and biological contamination that provide a robust trade space for enabling and implementing a sample return mission. As missions start to plan sample return from restricted Earth return targets (e.g., Mars, Europa or Enceladus) considerations should also be made to understand the complexities of campaign architectures with multi-mission elements, regulatory and external governmental decision makers, and multiple international partners.
- Ensuring public safety and mission assurance for a restricted Earth return mission will require an objective driven, risk-informed and case assured approach to address backward planetary protection compliance. The safety and mission assurance stakeholders play a key role in this process by consulting and coordinating processes to assure the safety and containment of Earth-return samples and the public. Throughout the life cycle of the mission planning consulting and coordination should consider the following: A. how modern advancements play a role in trade space where heritage design and prescriptive approaches can overshadow early formulation, B. establishment of technical roles and responsibilities and interface controls between agencies and partners within established legal frameworks, C. coordination of the end to end assurance case between multi-mission elements and partners, and D. development of objective-base, performance requirements for managing backward planetary protection. Fostering continued awareness and openness of these considerations will continue the dialogue, a critical step on the path, to enable sample return from restricted Earth return targets from a backward planetary protection perspective.