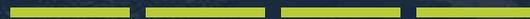# Enabling Mars Exploration Through a Risk Informed Decision Framework

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Background

Problem – The current prescriptive planetary protection technical requirements not sufficient for large robotic (>1500m^2), crewed, or in-situ resource utilization missions.

Solution – A performance-based framework is required for mission design and execution for both forward and backward PP.

Credits: NASA

sma.nasa.gov

OSMA
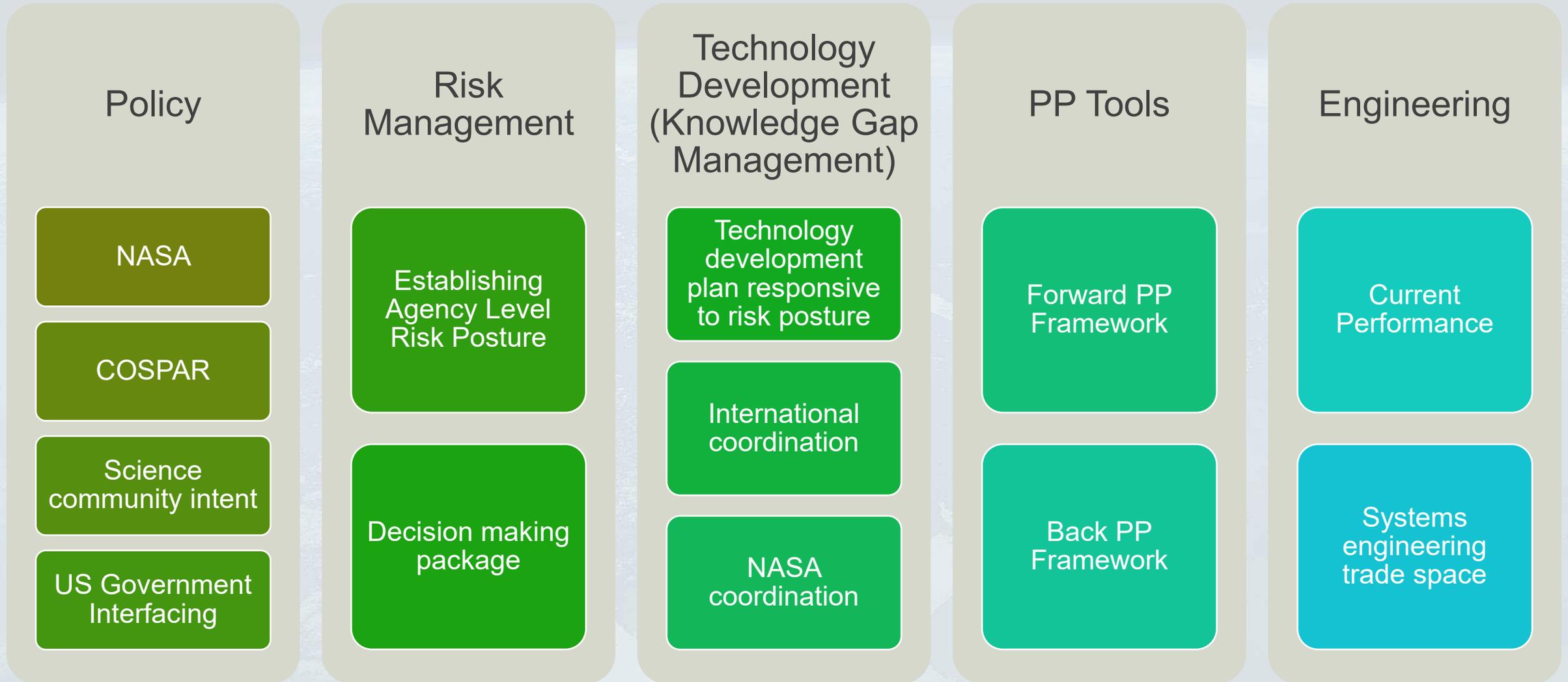
- COSPAR §4.6 "*…Accordingly, planetary protection goals **should not be relaxed** to accommodate a human mission to Mars. Rather, they become even more directly relevant to such missions.*"

Robotic = Crew

▶ **Forward PP Example**

Robotic, Prescriptive

| Policy Objective: control the risk of "harmful contamination" | ? | Guidelines: bioburden constraints for a Category IVa mission | Detailed Guidelines: ≤5×10^5 spores | Implementation: Rover harness needs heat microbial reduction bakeout 150°C, 25 h |

Crew

| Policy Objective: control the risk of "harmful contamination" | Contamination Goal: Pc? | Guidelines: TBD | Detailed Guidelines: TBD | Implementation: TBD |

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■ Probabilistic tools need to be developed to enable Mars exploration.

|	Current	Future Needs

Forward	• Viking Pc analysis (reports)
	• Pc parameter assessment 1990s and special region
	• Europa Clipper model
		• Modernize Mars Pc working model
		   • Updated Mars mathematical framework
		   • Updated biological & environmental parameters

Backward	• Robotic break the chain assurance framework • Sample Safety Assessment	• Crewed break the chain • Crew safety • Biosphere safety

PP Tools

Forward PP Framework

Back PP Framework

Framework needs developed to:
• Harmonize and standardize the PP process.
• Assess the current state of Mars contamination through robotic exploration.
• Inform risk posture trade space.
• Inform technology developments and parameters by assessing modeling sensitivities/uncertainties.
• Support mission planning and execution.

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Modeling the Probability of Contamination for NASA Missions

▶ NASA Handbook SP-20240016475 - Appendix 4

Europa Clipper Contamination Event Tree
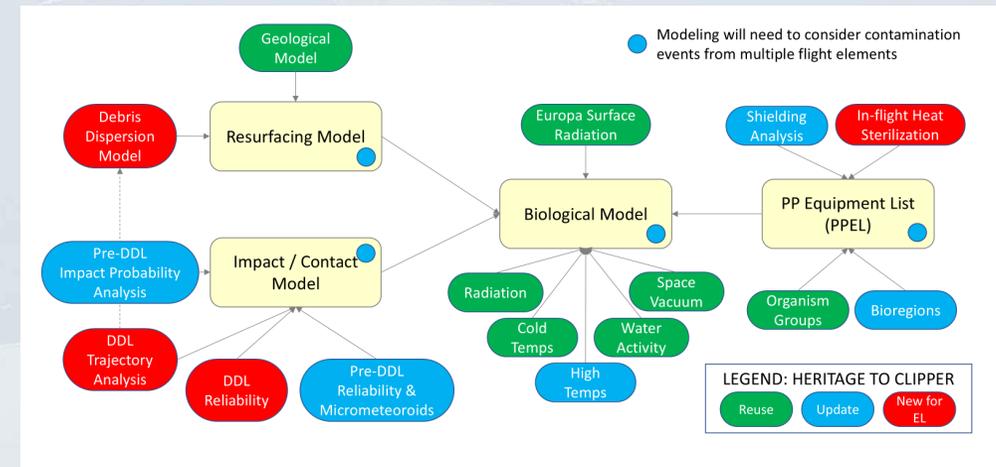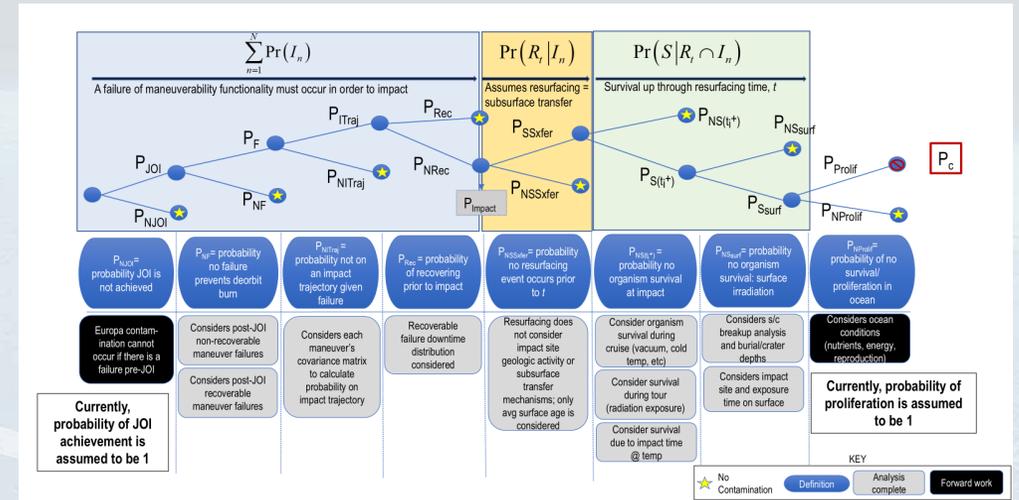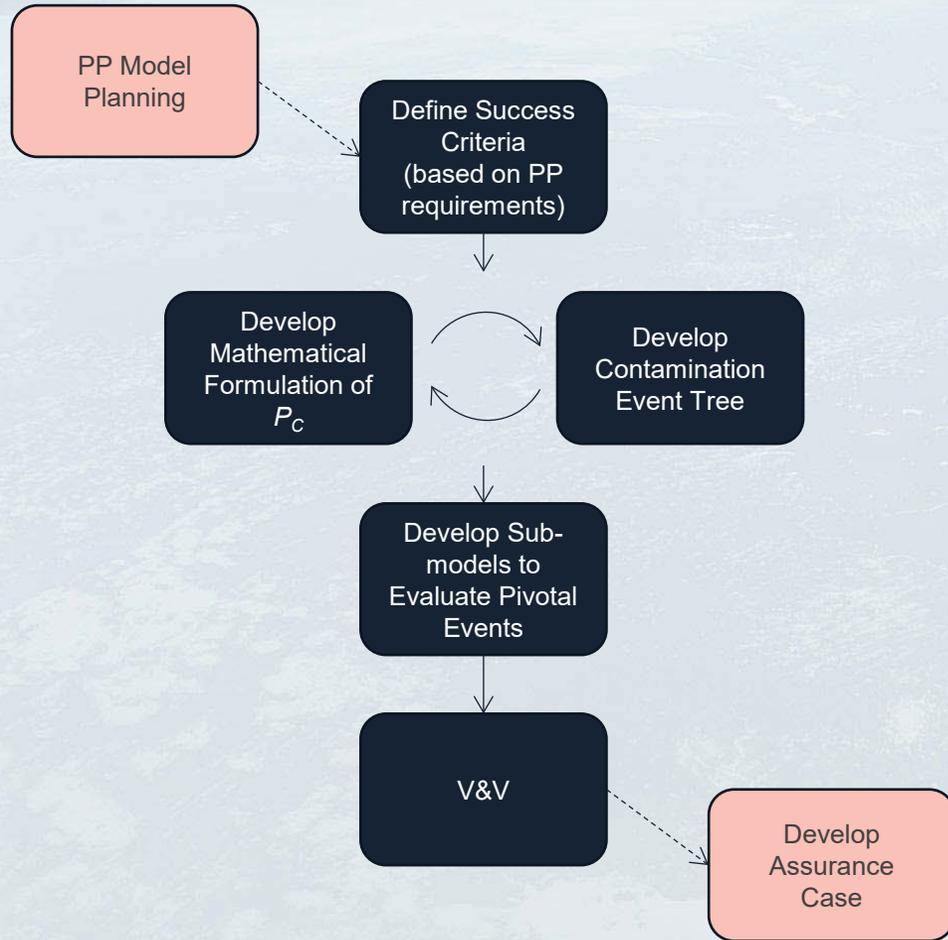
Example of the network of submodels and analysis required for an Icy Worlds probability of contamination model.

sma.nasa.gov

OSMA

- The Viking-based contamination equation is:

$$P_c = \Sigma\, N_0\, P_s P_r\, P_g$$

  - *where:*
    - *P_c is the probability of contaminating Mars;*
    - *N_0 is the number of organisms present before sterilization;*
    - *P_s is the probability that a randomly selected organism will survive sterilization;*
    - *P_r is the probability of release, and*
    - *P_g is the probability of growth*

- Partial timeline of probability of contamination and probability of growth workshops, publications, and reports.
  - *1964 – COSPAR establishes 10^{-4}*
  - *1970 – SSB report follow up with 10^{-4} - 10^{-6} values*
  - *1974 – Pc Viking report with Sagan Coleman approach - microbial characteristics, lethality of release / transport mechanisms and the martian environment*
  - *1978 – Pg report recommendation Mars regions (i.e., subsurface, polar ice caps)*
  - *1984 – Pc → Categories and <u>simplification of Pc to spore</u> NASA to COSPAR*
  - *1987 – SSB evaluation of Pc*
  - *1991 – Mars Environmental Survey (MESUR) Mission Mini-Review*
  - *1992 – NCR report, NASA workshop*
  - *2002 – Special regions*
  - *2006 – Special Regions Science Analysis Working Group*
  - *2007 – NASEM recommends non-Mars missions convert to Pc (1e-4) / mission*
  - *2014 – Special Regions Science Analysis Working Group 2*
  - *2021 – NASEM CoPP*

Review publication planned for 2026!

COSPAR: *probability of inadvertent ocean contamination ≤1x10^{-4}…*

10^{-4}

Breakdown of icy body contamination requirement

Pre-impact/ landing: assessed by Project	Project responsibility: risk assessments tied to design or mission features within a Project's control. E.g.:
	• Spacecraft/instrument reliability and design features
	• Trajectory design
	• Manufacturing and processing practices
	• Pre-launch microbial reduction
Post-impact/ landing: requires NASA science input	NASA's science community responsibility: risk assessments tied to geological and biological features outside a Project's control, given flight hardware makes it to icy body surface. E.g.:
	• Icy body subsurface transport processes and geology
	• Microbial survival in icy body environment
	• Terrestrial microbe proliferation in icy body water
	• Defining special regions

- Modernization Mars P_c working model

  - *Mars Planetary Model*
    - Atmospheric
    - Geological
    - Transport (Mars 2020 / MSR foundation)
  - *Biological Model*
    - Mars biocidal factors
    - Space environment
    - Growth and proliferation
    - Organism groups
  - *Hardware model*
    - Material and processes

Example of the network of submodels and analysis required for Mars missions.
Image credit: NASA/JPL Mike DiNicola

- Probability of contamination and probability of growth parameters could benefit from scientific workshops, etc.

  - *Period of biological performance - 50 years from launch?*
  - *Evolving past spores; microbial dark matter etc…*
  - *Do we have technology sweet spots that can generate verifiable requirements? Detection and analysis method must align with the risk.*
  - *Probability of growth? Recommendation of special region parameters to start – temp, availability of water.*

Questions?