PP Subcommittee Meeting

NASA HQ

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Towards a Strategic Research & Technology Development Program for Planetary Protection

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Goal Statement and Rationale

State the case for a strategic R&TD program to be funded and directed at the PPO level

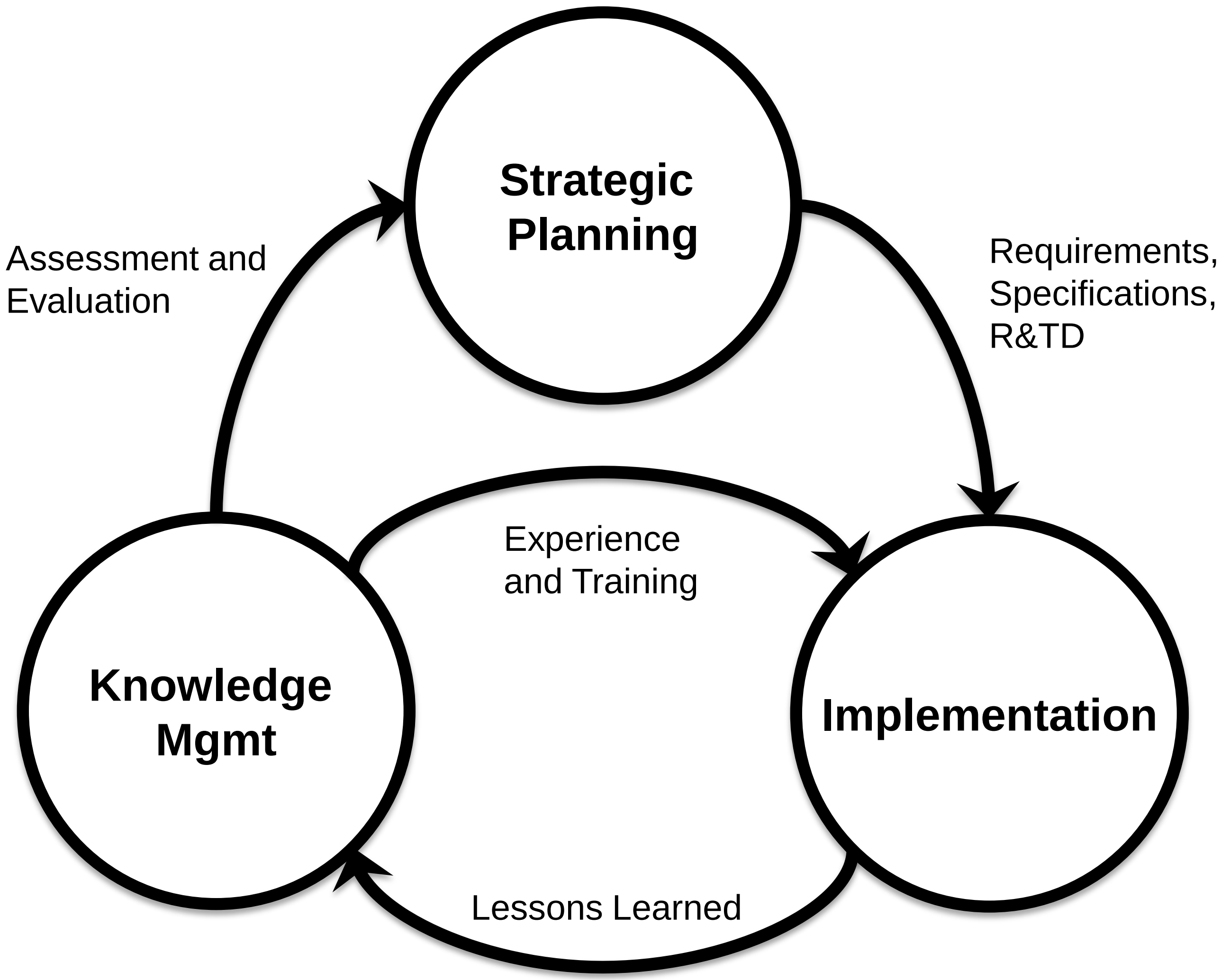
Why?

- Expand **Strategic Planning** horizon beyond the scope, cost, and risk tolerance constraints of the project or program level

- **Facilitate Implementation** by providing tools, drafting standards and specifications, directing supporting research activities, and requirements elicitation

- Enact **Knowledge Management** strategies to guarantee information is accessible and can be shared between stakeholders (NASA Centers, Engineering Teams, Science Teams, Int'l Partners, Contractors, etc.). Provides continuity to sustain PP workforce and expertise

PP R&TD Relationship



Key Benefit: Maintaining Program Continuity and Stability

Current Paradigm

- Most R&TD is funded and conducted at the program level, often for the sole benefit of the program/project
- Select activities are funded by the PPO on an ad-hoc basis
- Focus may change year-to-year; PP workforce unstable based on available missions.

Favored Paradigm

- Most R&TD activities remain at program level, but integrate with larger strategic goals. PPO coordinates support activities.
- PPO funds both continuing support activities, as well as discrete activities
- Basic R&TD activities continue independently of missions; PP workforce can transition between implementation and R&TD work as "stop-gap" measure to retain expertise

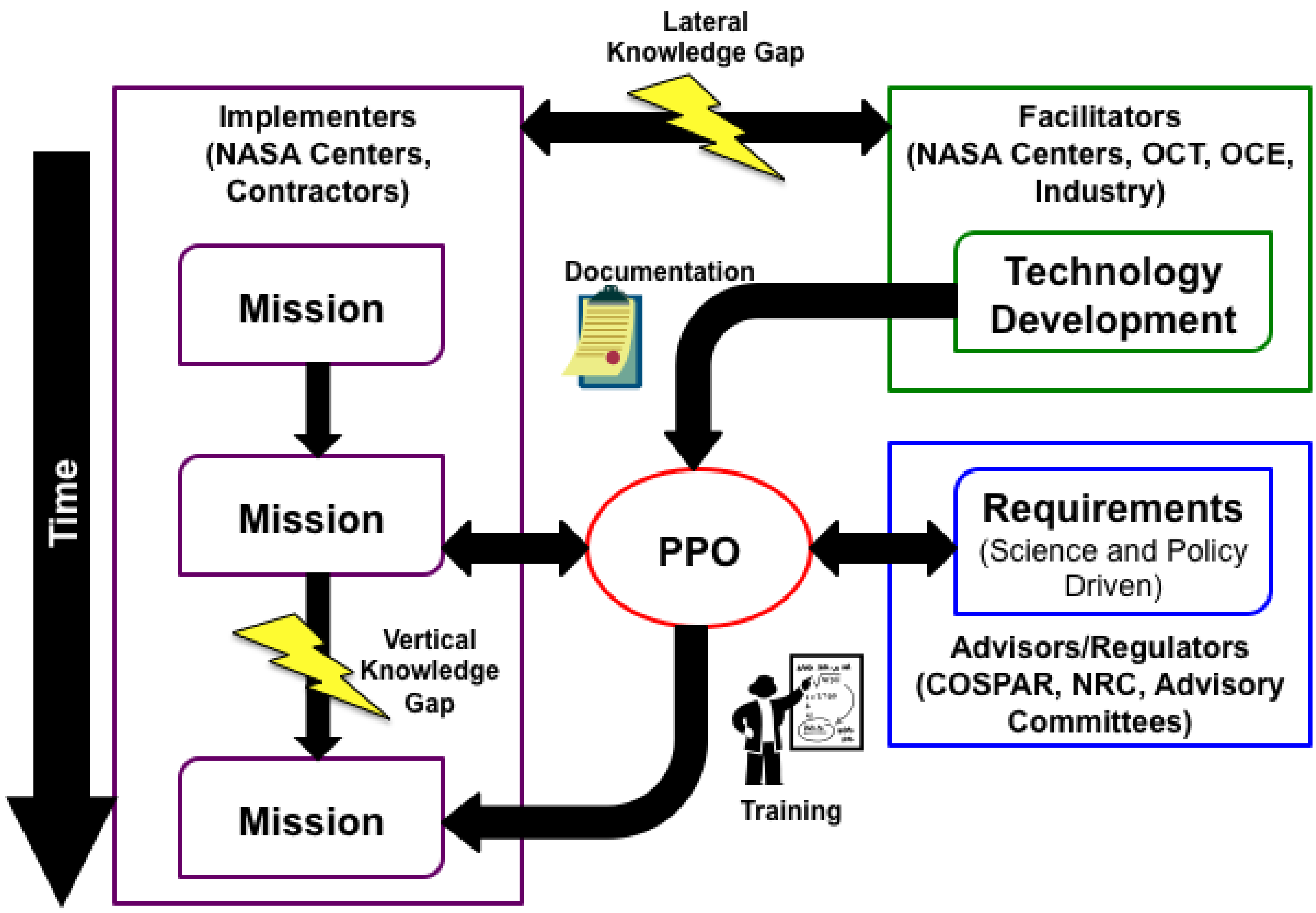
Differentiating between R&TD Philosophies

PPO (Capabilities Driven)	Program/Project* (Mission Driven)
•Long-Term Focus	•Mission Focused
•Addresses Low TRL/Feasibility Questions	•Addresses High TRL/Implementation Specific Issues
•Risk/Uncertainty Tolerant	•Low Mission Risk Required
•Generate requirements and specifications	•Generate “Lessons Learned” from implementation
•Communicate issues and knowledge to a variety of stakeholders	•Maintain expertise in-house

*Capabilities-driven and Mission-driven R&TD are **complementing** each other. They are **not** mutually exclusive or competitive!*

** Applies to both contractors and implementation centers*

PPO Role in Knowledge Management

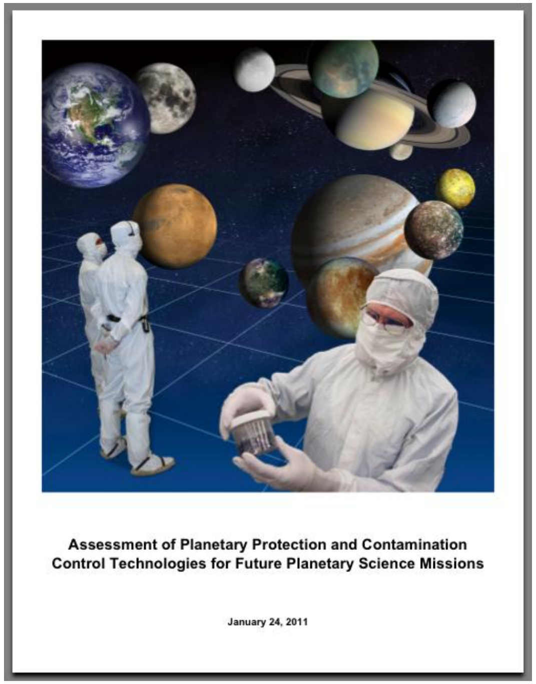


Groundwork

- "***[Assessment of Planetary Protection and Contamination Control Technologies for Future Planetary Science Missions](#)***" (Belz and Beauchamp, 2012) provides overview of current status and recommendations for future implementation.

- Can inform research priorities (to be determined by PPO/committee) for eventual R&TD program

- Overview provided here has slightly different scope and focus
  - Goal to provide comprehensive overview of entire technological and analytical "tool box" with future R&TD potential



Assessment of Planetary Protection and Contamination Control Technologies for Future Planetary Science Missions

January 24, 2011

Overview of PP R&TD Activities

- **Microbial Reduction and Cleaning Methods**
  - Physical Cleaning
  - DHMR
  - Radiation Sterilization
  - VHP
  - SCC
  - EtO
  - Other Methods

- **Recontamination Control and Bio Barriers**
  - Clean Room and Aseptic Assembly/Integration
  - Bio Barriers and HEPA Filters

- **Operational Analysis**
  - Burn Up and Break Up Analysis
  - Trajectory and Impact Analysis
  - In-Space Radiation Environments

- **Cross-Cutting Research and Support Activities**
  - Material/Component Compatibility Studies
  - Biological Assay Methods
  - Resistant Organisms and Genetic Inventory
  - Habitability and Spore Transfer Studies
  - Systems Engineering

- **Restricted Sample Return Handling**
  - Sample Acquisition and Containment
  - Sample Sterilization
  - Clean Sample Handling/Curation
  - Risk Assessment
  - Life Detection

- **Planetary Protection Concepts for Human Exploration**
  - Architecture and Operations
  - Contamination Control for Crewed Missions
  - Crew Health Monitoring

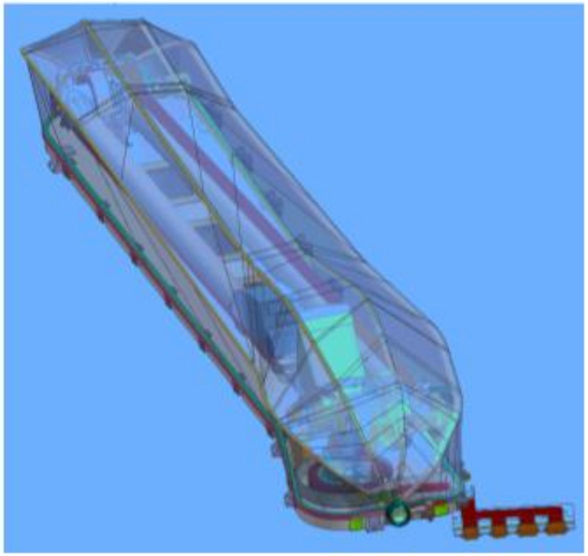
Microbial Reduction/Cleaning Methods

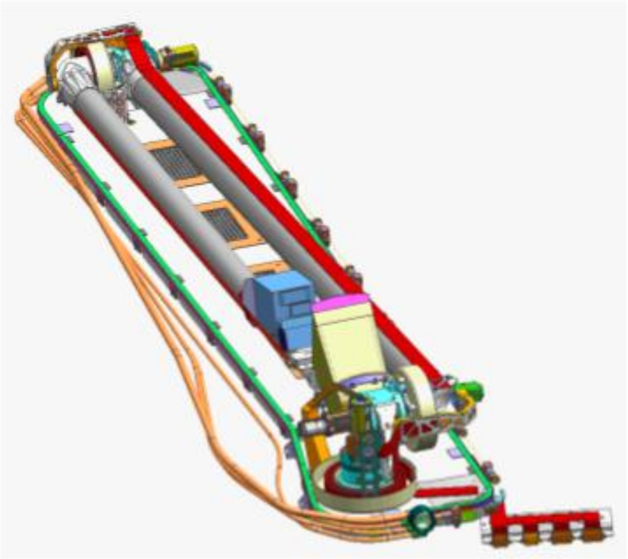
Viking Bake-Out (NASA)

Microbial Reduction/Cleaning Methods

Method	Application	Implementation Status	Associated R&TD
Physical Cleaning/Solvent Wipes	Basic Microbial/Contamination Reduction on Surfaces	Widespread Implementation	Performance on rough/sensitive surfaces; component compatibility; Bio assays
DHMR	Surface or penetrating sterilization on component or full-system level	System-level sterilization with Viking. Standard method on component level. Expanded humidity/temp spec released 2012	Component compatibility; System-level expansion & facility development; Resistant spore research
Radiation (gamma rays or electron beams)	Surface sterilization with some penetration of thin materials (depending on method employed)	Used by Beagle 2 (parachute), and in the food industry. No widespread use for PP	Component compatibility, spore resistance
VHP	Surface sterilization on component or full-system level	Specs released in 2012, pending implementation	Component compatibility, scalability, facility development
SCC	Contamination removal on critical components with potential for microbial reduction	Under study/development	Component compatibility, scalability, potential for microbial reduction
EtO	Surface sterilization of components	Used in medical industry, not yet in PP	System safety, material compatibility, sterilization potential

Re-Contamination Control and Sample Handling



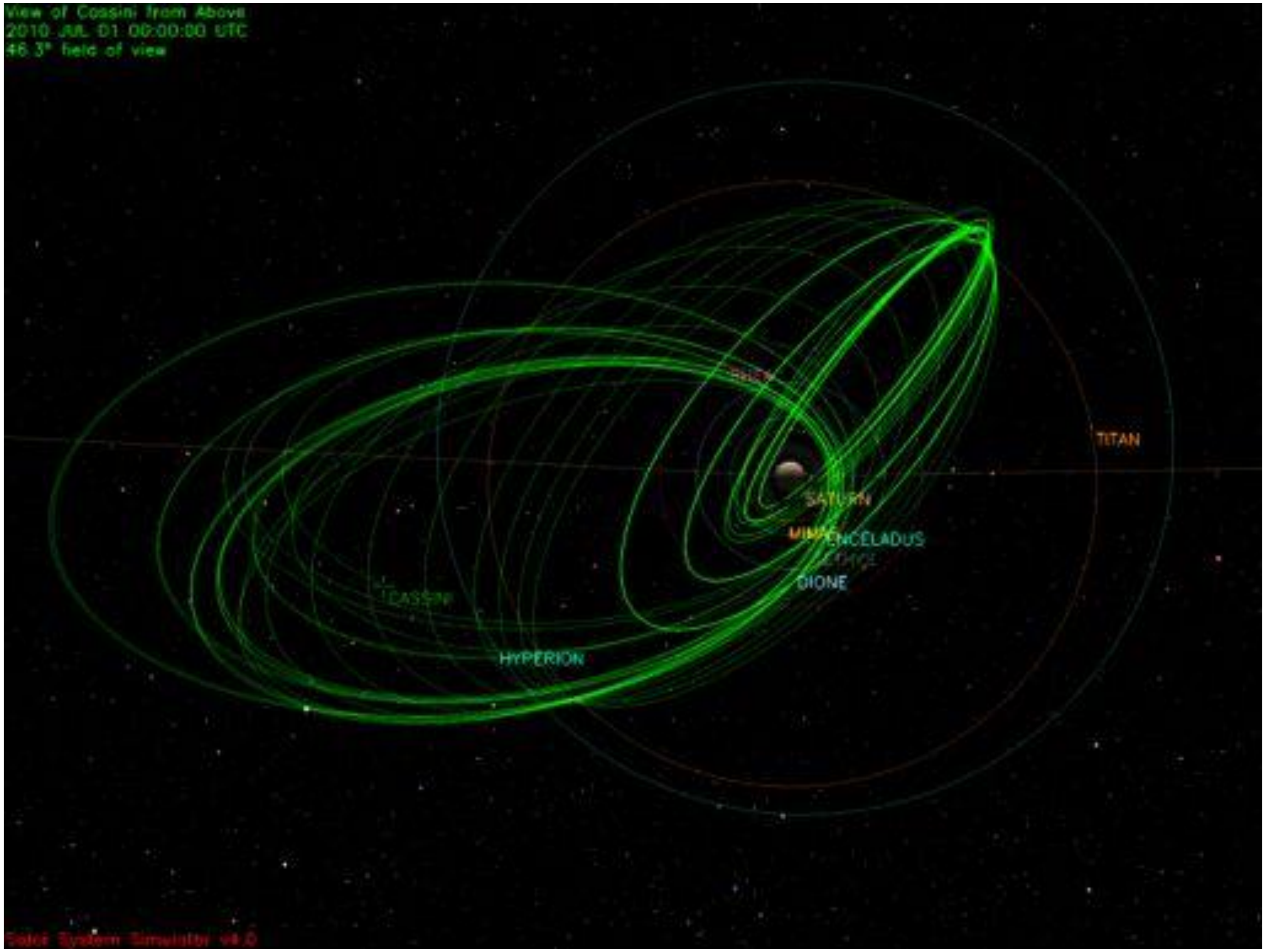


Phoenix Bio Barrier (NASA/JPL)

Re-Contamination Control and Sample Handling

Method	Application	Implementation Status	Associated R&TD
Clean room and aseptic assembly/integration	Passive microbial reduction during ATLO	Pioneered by Beagle 2	Scalability, facility and process development, tele-robotics, systems engineering (for assembly)
Bio Barriers & HEPA Filters	Prevents recontamination of landed hardware or critical (e.g. Category IVc) components during ATLO	Bio-Shield pioneered by Viking. Deployable bio barriers pioneered by Phoenix	Scalability, reliability, compatibility with sterilization processes
Restricted Sample Return Handling and Containment	Isolating sample during acquisition, transport, and evaluation in Sample Handling Facility	Draft protocols exist, but no specifics. Some lessons learned from lunar sample handling and unrestricted sample returns.	Define requirements and characteristics of facilities, systems design for cache/ascent vehicle. Maximize lessons learned from other missions.

Operational Analysis

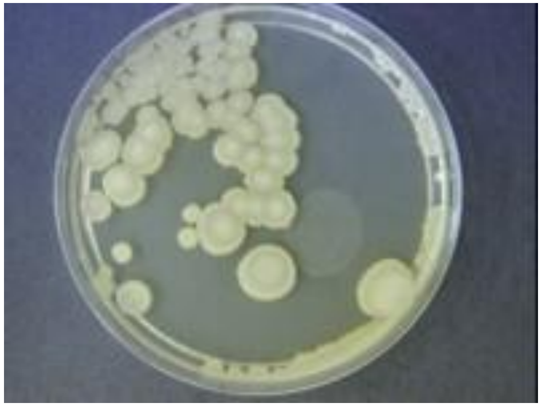


Cassini Mission Extension (NASA/JPL)

Operational Analysis

Method	Application	Implementation Status	Associated R&TD
Burn-Up and Break-Up Analysis	Determine microbial reduction creditable to atmospheric entry	Implemented by MRO, MAVEN. Must be coordinated with PPO on case-by-case basis	Analysis tool development, application to alternative aero shells, spacecraft configurations
Trajectory and Impact Analysis	Avoids impacting potentially habitable bodies, or demonstrated sufficient impact energy for sterilization	Widespread adaptation in trajectory-biasing and mission planning (e.g. MSL upper stage, Juno)	Probabilistic risk assessment tools
Planetary Radiation Environments	Passive sterilization through ionizing radiation exposure in Jupiter's magnetosphere. Limited recontamination control through UV exposure on Mars	Widespread adaptation by Juno. Considered for MSL wheels/drill for recontamination control.	Probabilistic risk assessment tools, modeling, and system design w.r.t. radiation shielded hardware

Cross-Cutting Research and Support Activities

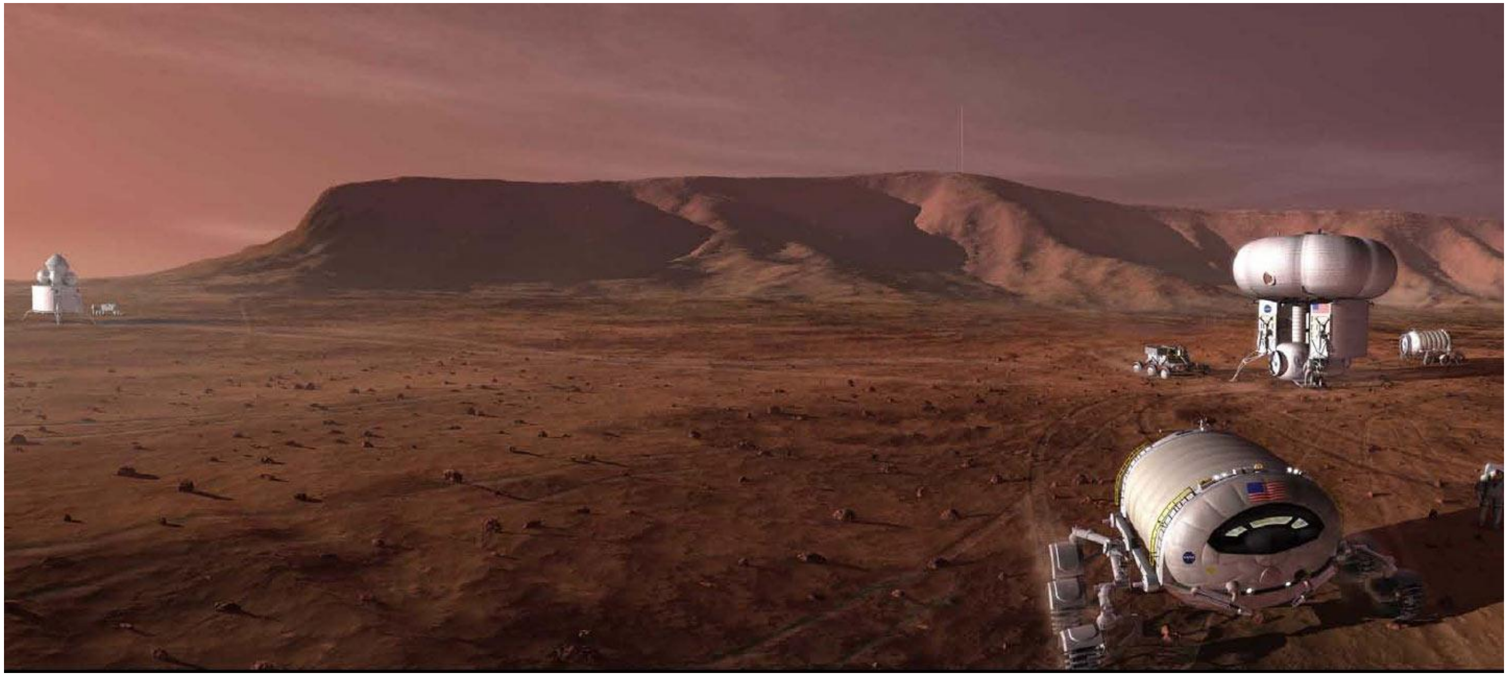


Spore Colonies after Incubation

Cross-Cutting Research and Support Activities

Activity	Status	Associated R&TD
Component and Material Compatibility	Discrete studies exist, but often limited to specific use cases, and not readily accessible	Transform to continues evaluation of common materials and assemblies, accessible through database
Biological Assay Methods	Widespread Implementation of NASA Standard Assay, LAL/ATP used as criteria for cleaning	Expanded use of LAL/ATP as quantitative equivalence to the NASA Std Assay is further studied and specified
Resistant Spores and Genetic Inventory	Resistant strains have been isolated in spacecraft assembly facilities. Astrobiology research informs on existence of new extremophiles. First phase of Genetic Inventory complete	Continue coordination with astrobiology research, further characterization of genetic inventory. Continuous monitoring of facility cleanliness and fall-out
Habitable Planetary Environments and Spore Transfer	Conservative view of "special regions" given available data. Case-by-case studies of inducing habitability (via perennial heat source or impacts). Initial studies on environmental transfer between surface/subsurface of Europa, and between Mars and Phobos/Deimos	Modeling of planetary environments and habitability measurements; Systems engineering and risk assessment for individual missions
Systems engineering/Operations Research	PP not fully integrated with requirements tracking and early mission development	Embed PP in requirements tracking process. Assign staff as PP-liaison for systems engineering during early

PP Considerations for Human Exploration



Mars DRA 5.0 (NASA)

PP Considerations for Human Exploration

Category	R&TD Implications
Mission Architecture and Operations Concepts	Formalize precursor measurement requirements, operation concepts for Zones of Minimum Biological Risk (ZBRs), human-robotic interfaces and protocols, local contaminant transfer, traverse restrictions and boundaries, landing site selection.
Contamination Control Methods of Human Missions	Risk analysis of contaminant release of life support systems, EVA suites, large-scale bioshields for landed hardware, in-situ sterilization of robotics/tools
Crew Health Monitoring	ISS research of symptoms in zero gravity. On-board diagnostic tools, e.g. Flow Cytometers

PP Activities Timeline

2012 – VHP, Extended DHMR Spec's released. Genetic Inventory Task Complete

2013 MAVEN Launch (ISRO MOM Launch?)

2014 Hayabusa-2 Launch

2016 InSight Launch

2018 Phobos Grunt-2 Launch?

2020 Rover Mission. Life Detection? Sample Caching? Hayabusa-2 Return

2022 JUICE Launch

Osiris-REx Return (Sample Handling Analog)

2025-2030? Mars Sample Return?

PP R&TD must stay ahead of mission development and take advantage of learning opportunities.

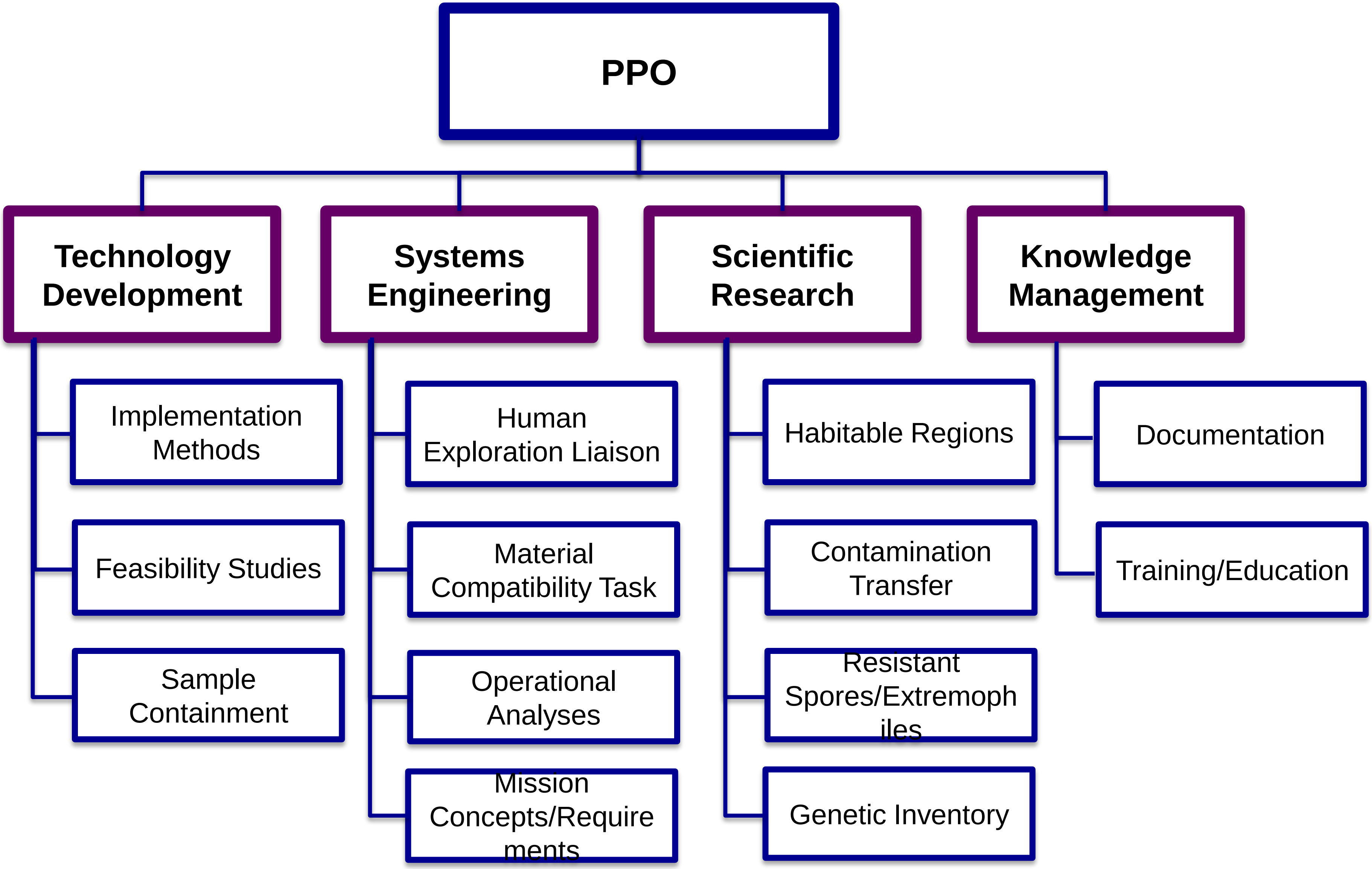
2040's? – Human Mars Exploration?

Preliminary Cost Estimates for Restricted Sample Return R&TD

- System Sterilization – 1M to 2M per year (3-6 yrs)
  - Integrated Material and Component compatibility study on system level (interaction of materials and accessibility), systems engineering synergisms with aseptic integration, DHMR/VHP facility design
- PP for Restricted Earth Return – 500k to 1M per year (5-7 yrs)
  - Bio barriers, sample collection/isolation (multiple layers), risk assessment, verification and monitoring of containment, contingency and failsafe measures (sample sterilization or trajectory biasing)
- Returned Sample Containment & Handing – 1-2M per year (5-10 yrs)
  - BSL-4-equivalent facility requirements and logistics, site selection, aseptic sample transfer and analysis, robotics and microminiaturized equipment, redundancies and contingency plans, biohazard suits, rapid transfer port, glove port, materials.
- Life Detection and Biohazard Analysis – 500k to 1M per year (5-10 yrs)
  - Life detection instrumentation (incl. non-destructive) and tests, biohazard analysis for small samples, biostatistics, development of release protocols, inter-agency collaboration.

Estimates are preliminary and for planning/discussion purposes only. Estimates are for long-lead times for restricted earth return missions.

Proposed PP R&TD Framework



Proposed Strategic R&TD Priorities

- **Full-System Sterilization to enable life detection missions**
  - Supported by comprehensive component compatibility task, and aseptic integration techniques (allow limited post-sterilization access/integration for complex systems), and early systems engineering of mission concepts for PP compliance.

- **MSR Sample Containment and Analysis**
  - Develop sealing requirements, verification methodologies and instrumentation, and aseptic transfer capability. Expand on draft protocol, conduct inquiries and trade-off studies for sample handling facilities on an international basis with comprehensive cost and risk assessment

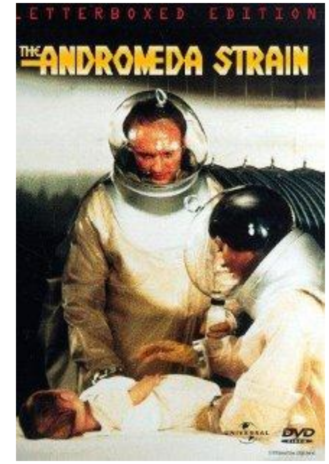
- **Coordination with Human Exploration Architecture Groups**
  - Formalize interactions by assigning liaisons, conduct joint activities, and support early development of crew health monitoring and in-situ sterilization methods

- **Continue genetic inventory characterization, development of assay methods and microbial reduction techniques**

Ignoring Stratgic R&TD for PP risks Programmatic Failures!

War of the Worlds* (1953)

Star Trek Original Series (1967)



The Andromeda Strain (1971)

2010: Odyssey Two (1984)

Red Planet (2000)

Prometheus (2012)

Backup Slides

Proposed Delphi Activity

- **Create Panel of Experts**
  - ***Multi-Disciplinary and Cross-Agency***
- **Define Evaluation Criteria**
  - ***Significance (Positive Weighting)***
  - ***Urgency (Positive Weighting)***
  - ***Cost and Effort Requirement (Negative Weighting)***
  - ***Risk and Uncertainties (Negative Weighting)***
- **Perform iterative scoring of research activities**