OFFICE OF THE CHIEF TECHNOLOGIST

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NASA Planetary Protection Technology Development

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Objectives of this presentation

- Provide a brief overview of the Office of the Chief Technologist (OCT)
- Describe OCT technology roadmapping effort and spotlight key relationships to planetary protection (PP) research
- Provide inventory (at overview level-of-detail) of NASA-wide PP research & development (R&D) over last several years
- Describe current focus areas in NASA PP technology development
- Identify key issues and make recommendations to strengthen NASA-wide PP technology development

Overview of OCT

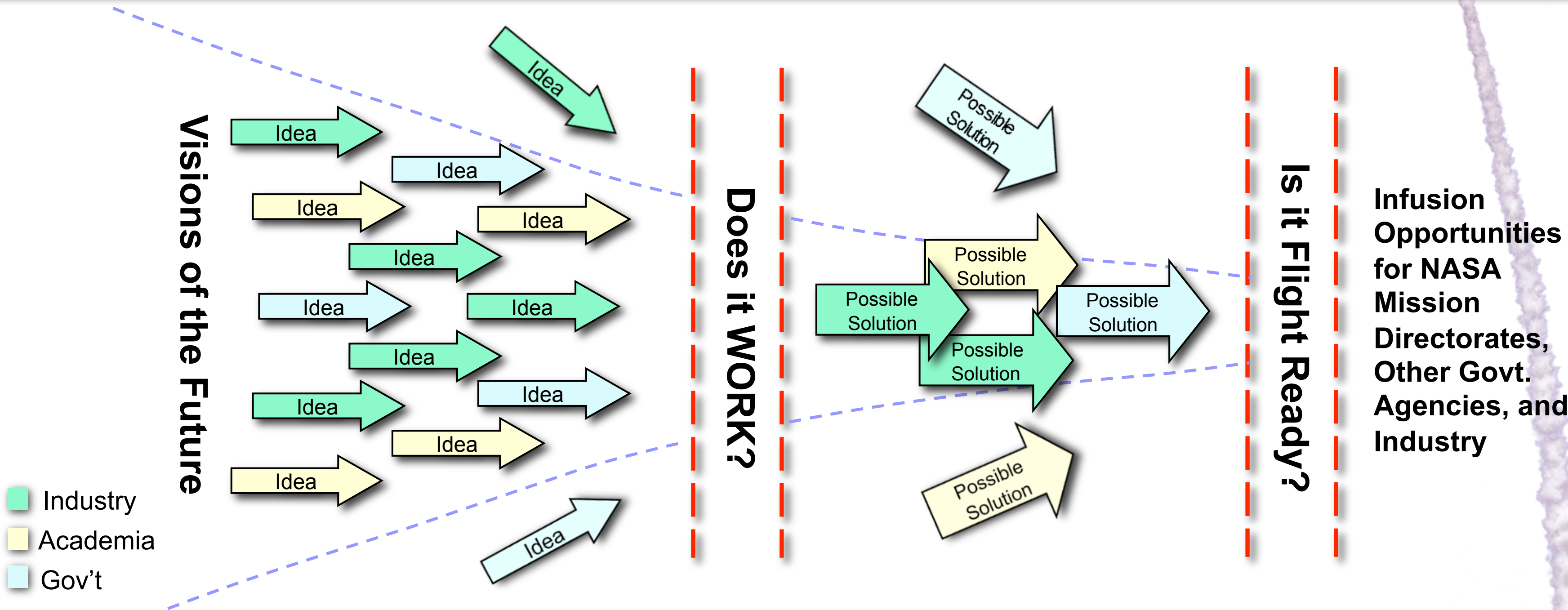
Office of Chief Technologist Roles/Responsibilities

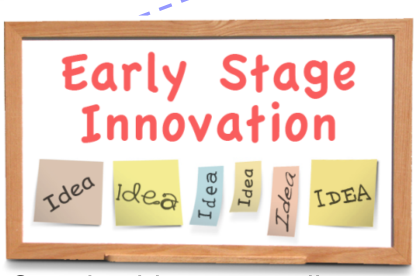
- **OCT established in February 2010**

- **OCT has six main goals and responsibilities:**
  1) Principal NASA advisor and advocate on matters concerning Agency-wide technology policy and programs.
  2) Up and out advocacy for NASA research and technology programs. Communication and integration with other Agency technology efforts.
  3) Direct management of Space Technology Programs.
  4) Coordination of technology investments across the Agency, including the mission-focused investments made by the NASA mission directorates. Perform strategic technology integration.
  5) Change culture towards creativity and innovation at NASA Centers, particularly in regard to workforce development.
  6) Document/demonstrate/communicate societal impact of NASA technology investments. Lead technology transfer and commercialization opportunities across Agency.

- Mission Directorates manage the mission-focused technology programs for directorate missions and future needs
- Beginning in FY 2011, activities associated with the Innovative Partnerships Program are integrated into the Office of the Chief Technologist

Space Technology Development Approach



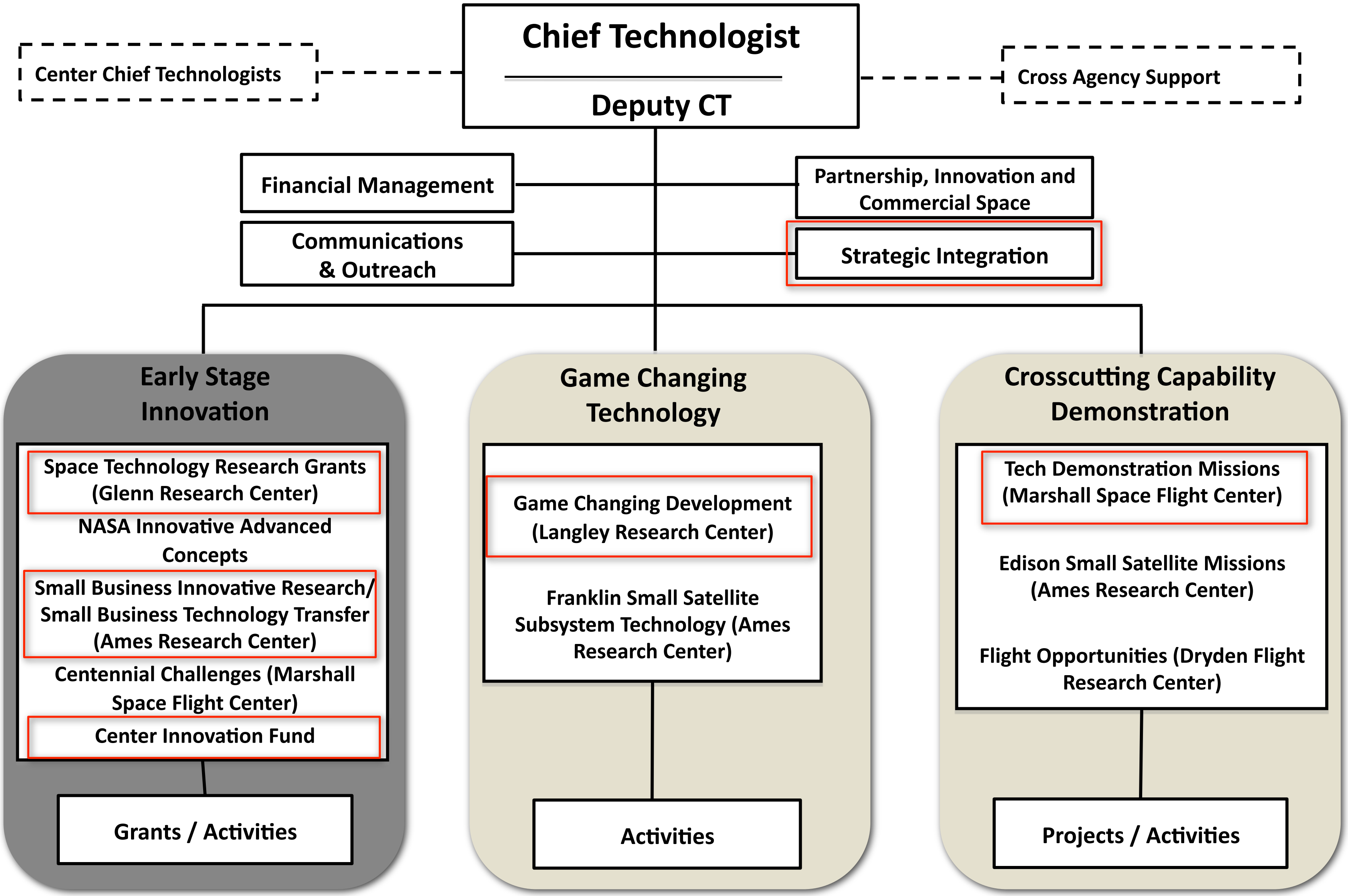


Creative ideas regarding future NASA systems or solutions to national needs.

Prove feasibility of novel, early-stage ideas with potential to revolutionize a future NASA mission and/or fulfill national need.

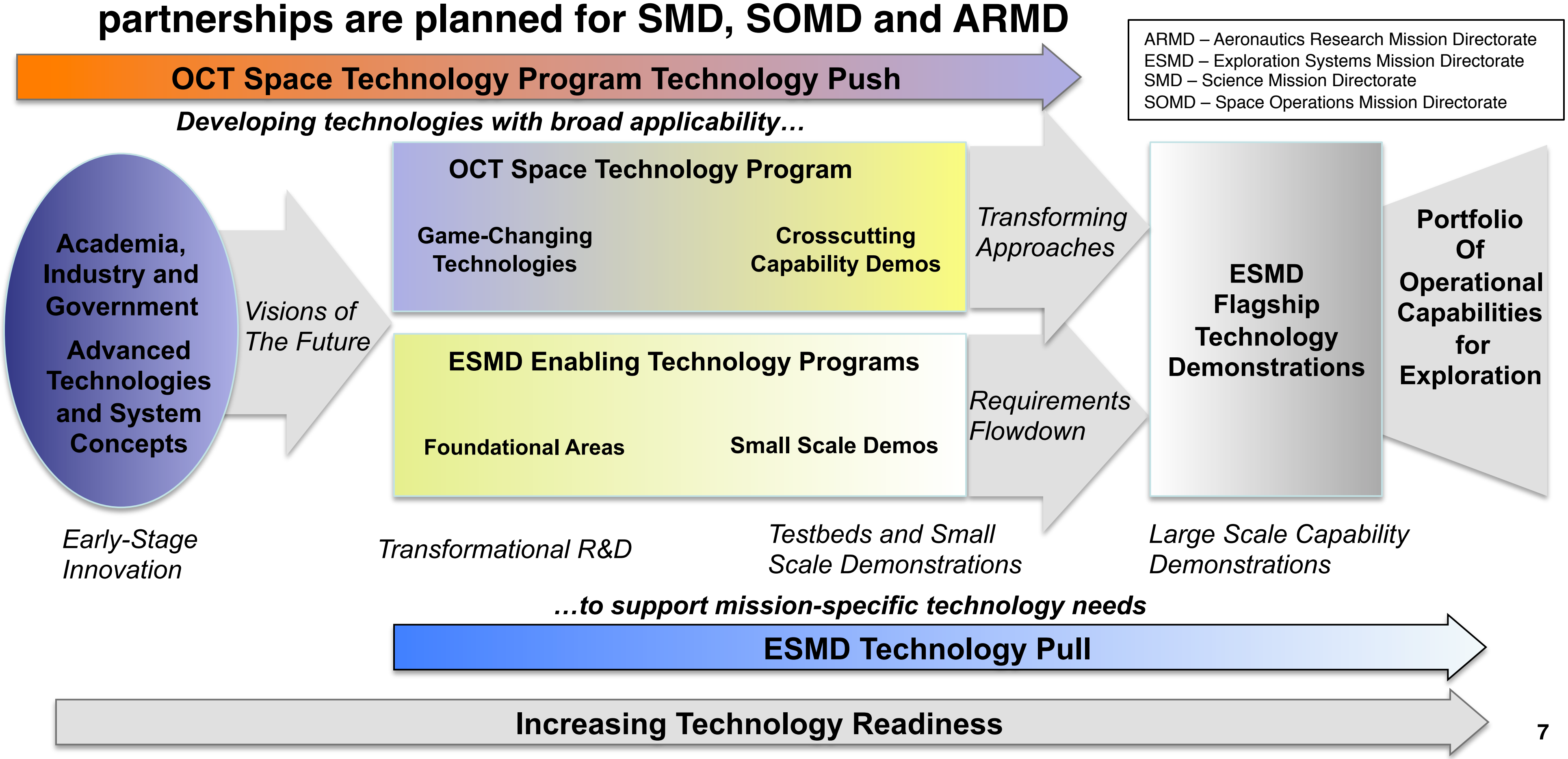
Mature crosscutting capabilities that advance multiple future space missions to flight readiness status

Office of the Chief Technologist Organization



NASA's Integrated Technology Programs

- **OCT in partnership with the Mission Directorates including ARMD, SMD, SOMD and ESMD will invest in a portfolio of technology investments enabling new approaches to NASA's current mission set, and allowing the Agency to pursue entirely new missions of science and exploration.**
- **The example below shows how OCT will partner with ESMD – similar partnerships are planned for SMD, SOMD and ARMD**



Space Technology: A Different Approach

- **Strategic Guidance**
  - Agency Strategic Plan
  - Grand challenges
  - Technology roadmaps
- **Full spectrum of technology programs that provide an infusion path to advance innovative ideas from concept to flight**
- **Competitive peer-review and selection**
  - Competition of ideas building an open community of innovators for the Nation
- **Projectized approach to technology development**
  - Defined start and end dates
  - Project Managers with full authority and responsibility
  - Project focus in selected set of strategically defined capability areas
- **Overarching goal is to reposition NASA on the cutting-edge**
  - Technical rigor
  - Pushing the boundaries
  - Take informed risk and when we fail, fail fast and learn in the process
  - Seek disruptive innovation such that with success the future will no longer be a straight line
  - Foster an emerging commercial space industry

Space Technology Grand Challenges

Space Technology Grand Challenges

Expand Human Presence in Space

Economical Space Access

Provide economical, reliable and safe access to space, opening the door for robust and frequent space research, exploration and commercialization.

Space Health and Medicine

Eliminate or mitigate the negative effects of the space environments on human physical and behavioral health, optimize human performance in space and expand the scope of space based medical care to match terrestrial care.

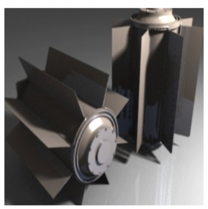
Telepresence in Space

Create seamless user-friendly virtual telepresence environments allowing people to have real-time, remote interactive participation in space research and exploration.

Space Colonization

Create self-sustaining and reliable human environments and habitats that enable the permanent colonization of space and other planetary surfaces.

Manage In-Space Resources

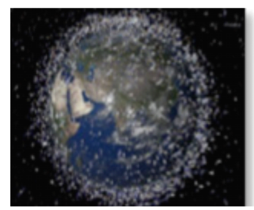


Affordable Abundant Power

Provide abundant, reliable and affordable energy generation, storage and distribution for space exploration and scientific discovery.

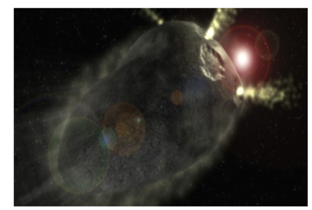
Space Way Station

Develop pre-stationed and in-situ resource capabilities, along with in-space manufacturing, storage and repair to replenish the resources for sustaining life and mobility in space.



Space Debris Hazard Mitigation

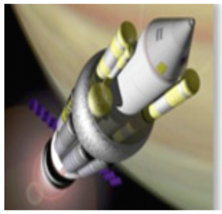
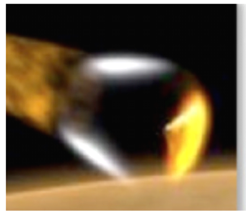
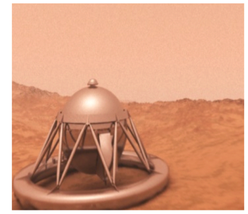
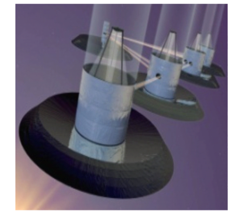
Significantly reduce the threat to spacecraft from natural and human-made space debris.



Near-Earth Object Detection and Mitigation

Develop capabilities to detect and mitigate the risk of space objects that pose a catastrophic threat to Earth.

Space Technology Grand Challenges

Enable Transformational Space Exploration and Scientific Discovery				
				
Efficient In-Space Transportation Develop systems that provide rapid, efficient and affordable transportation to, from and around space destinations.	**High-Mass Planetary Surface Access** Develop entry, descent and landing systems with the ability to deliver large-mass, human and robotic systems, to planetary surfaces.	**All Access Mobility** Create mobility systems that allow humans and robots to travel and explore on, over or under any destination surface.	**Surviving Extreme Space Environments** Enable robotic operations and survival, to conduct science research and exploration in the most extreme environments of our solar system.	**New Tools of Discovery** Develop novel technologies to investigate the origin, phenomena, structures and processes of all elements of the solar system and of the universe.

NASA Space Technology Roadmaps

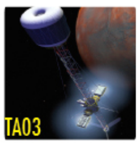
Roadmap Technology Areas (TA)

TA01


- LAUNCH PROPULSION SYSTEMS

TA02


- IN-SPACE PROPULSION TECHNOLOGIES

TA03


- SPACE POWER & ENERGY STORAGE

TA04


- ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS

TA05


- COMMUNICATION & NAVIGATION

TA06

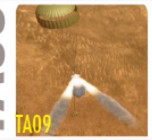

- HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

TA07

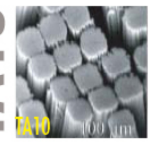

- HUMAN EXPLORATION DESTINA-TION SYSTEMS

TA08


- SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

TA09


- ENTRY, DESCENT & LANDING SYSTEMS

TA10


- NANOTECHNOLOGY

TA11


- MODELING, SIMULATION, INFORMA-TION TECHNOLOGY & PROCESSING

TA12


- MATERIALS, STRUCTURES, MECHAN-ICAL SYSTEMS & MANUFACTURING

TA13


- GROUND & LAUNCH SYSTEMS PROCESSING

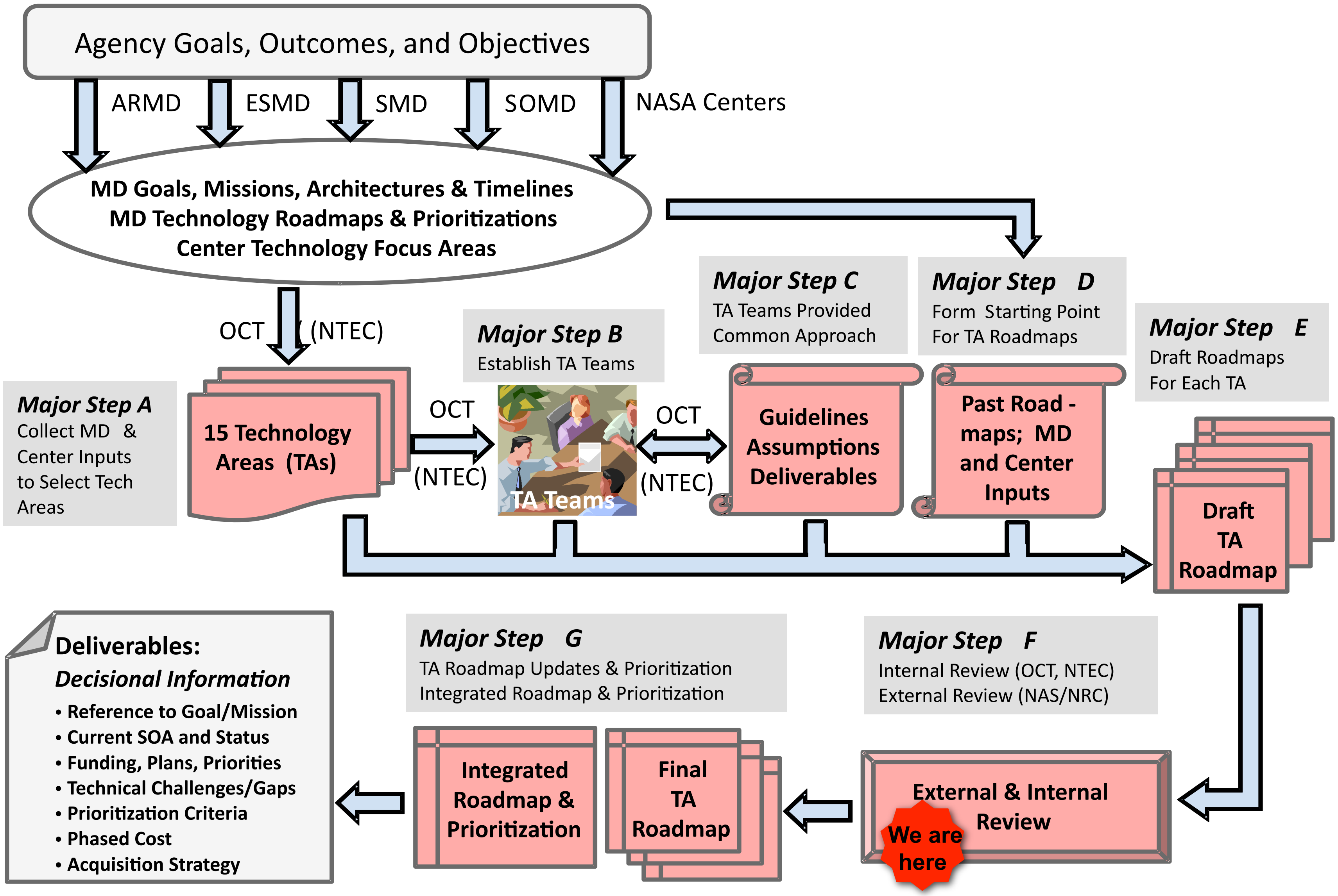
TA14


- THERMAL MANAGEMENT SYSTEMS

Explicit references to PP in draft roadmaps

- **PP substantially addressed**
  - TA06 - Human Health, Life Support and Habitation Systems
    - PP-related drivers for air, water, and waste management subsystems
  - TA07 - Human Exploration Destination Systems
    - Forward and back-PP as key element of Mission Operations & Safety
    - Also mentions planetary defense from NEOs
  - TA08 - Science Instruments, Observatories and Sensor Systems
    - In-situ instruments for bioassay; sterilization techniques
  - TA09 - Entry, Descent and Landing Systems
    - EEV TPS reliability as limiting factor in MSR mission design
- **PP mentioned "in passing"**
  - TA04 - Robotics, Tele-Robotics and Autonomous Systems
    - MSR as driver for remote/autonomous round-trip and back-PP mitigation schemes
  - TA14 - Thermal Management Systems
    - PP requirements for soft-goods used in TPS

STR Process



Agency Goals, Outcomes, and Objectives
ARMD
ESMD
SMD
SOMD
NASA Centers
MD Goals, Missions, Architectures & Timelines
MD Technology Roadmaps & Prioritizations
Center Technology Focus Areas
OCT
(NTEC)
Major Step A
Collect MD & Center Inputs to Select Tech Areas
15 Technology Areas (TAs)
OCT
(NTEC)
Major Step B
Establish TA Teams
TA Teams
OCT
(NTEC)
Major Step C
TA Teams Provided Common Approach
Guidelines Assumptions Deliverables
Major Step D
Form Starting Point For TA Roadmaps
Past Road - maps; MD and Center Inputs
Major Step E
Draft Roadmaps For Each TA
Draft TA Roadmap
Deliverables:
Decisional Information
• Reference to Goal/Mission
• Current SOA and Status
• Funding, Plans, Priorities
• Technical Challenges/Gaps
• Prioritization Criteria
• Phased Cost
• Acquisition Strategy
Major Step G
TA Roadmap Updates & Prioritization
Integrated Roadmap & Prioritization
Integrated Roadmap & Prioritization
Final TA Roadmap
Major Step F
Internal Review (OCT, NTEC)
External Review (NAS/NRC)
External & Internal Review
We are here

STR Schedule

✓ Roadmapping Kickoff meeting with TA chairs	7/28/10
✓ First cut, 1-pg TABS and TASRs provided by each TA	8/13/10
✓ Presentation of Rev 1 Draft Roadmaps for NASA Review	9/15-16/10
✓ Draft Roadmap Review comments due to OCT	9/27/10
✓ TA team disposition of comments and report revisions	10/22/10
✓ OCT approval of final "draft" TA roadmap reports 11/10/10	
✓ Draft NASA Roadmaps sent to NRC & widely distributed	12/2/10
• NRC kick-off meeting	1/25-27/11
• NRC panel meetings and workshops	2-4/11
• NRC Interim Report	8/11
• NRC Final Report	1/12

Inventory of Recent PP Technology Development

NASA PP-related R&D Programs

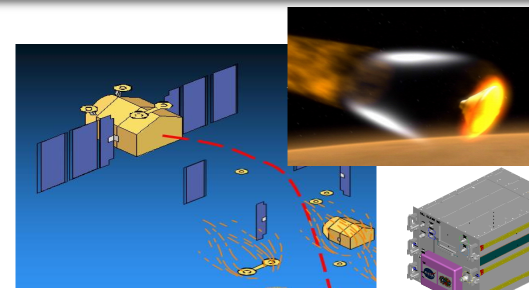
- MEP PP Research & Studies ($1-2M per annum) [Buxbaum]
- ROSES PP Research ($300-500K per annum) [Conley]
  - Focus on limits of life, bioburden detection, and sterilization modalities
- MTP NRA ($2M per annum 2003-2007; none since then) [Lin]
  - Broad portfolio including sterilization, rapid assay, robotic sample handling
- Mission-level PP activities (bridges between R&D and implementation)
  - Phoenix – bio-barrier for manipulator arm and scoop
  - MSL – extensive use of DHMR, new assay methods
  - MSR (including sample handling and containerization for 2018 caching mission)
    - Major driver for back PP and round-trip cleanliness considerations
  - JEO – considering whole-vehicle sterilization (first since Viking in 1976)

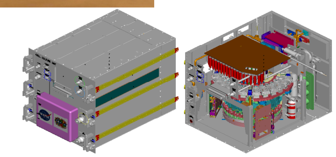
Note: While not explicitly mentioned above, PP implications for a human mission to a NEO or Mars is a major factor in forward planning of agency-wide PP R&D efforts

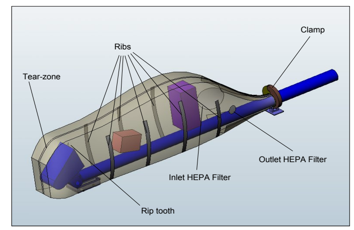
MTP NRA 2003-2007

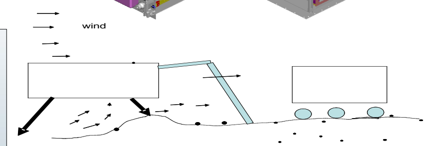
Description

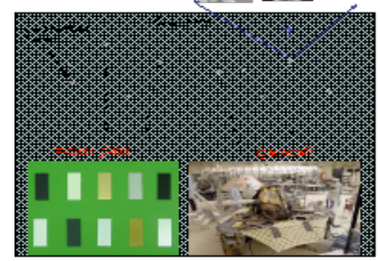
- *To develop technologies needed to meet PP requirements for the next decade missions*
  - Improve cleaning and validation methods
  - Enable cross contamination avoidance and risk prediction capability
  - Develop sample handling system



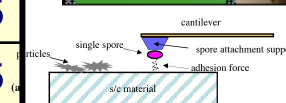


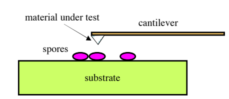


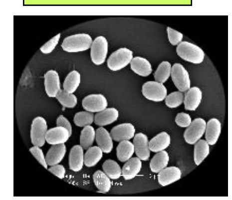


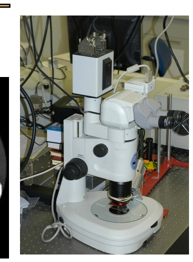


Tasks List & Budget ($K)	Year 1	Year 2	Year 3	Total
Cleaning to Achieve Sterility	278	367	378	1023
A Rapid Single Spore Enumeration Assay	310	308	317	935
Light Weight Biobarrier Technology	308	327	310	945
Spore Adhesion for Contamination Transport Model	295	312	320	927
Near Field and Integrated Particle Transport Model	332	381	291	1004
Mars Orbital Debris Analysis Tool	204	206	0	410
Contained Sample Handling and Analysis System	239	308	352	899
TOTAL	**1966**	**2209**	**1968**	**6143**









PP requirements as applied to MSR

Requirements & Mission Scenarios

"Forward PP" — Outbound to Mars

Any Sample Return — ***"Back PP"***

Avoid contamination of Mars with Earth life
Introduction of viable Earth life into a favorable martian environment is considered harmful contamination by definition

Avoid false positive life detection event
Life detection event in this context is considered to mean detection of contamination that could be confused with extraterrestrial (ET) life

Protect Earth from harmful effects
(biohazards/toxins)

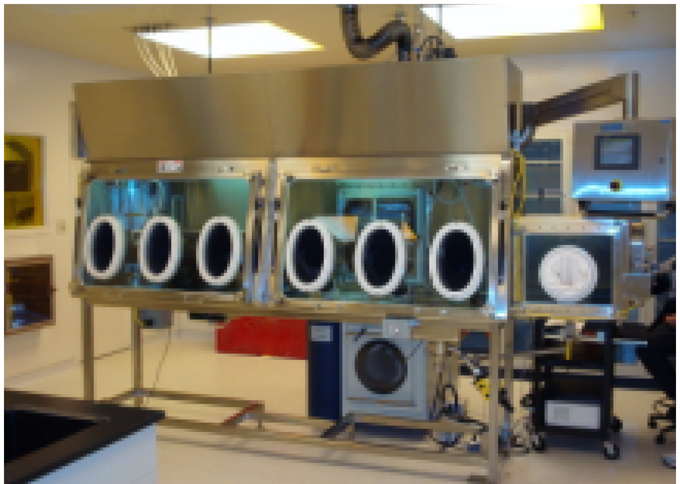
Any MSR mission must comply with these three aspects of international PP policy. Some implementation options overlap, but the requirements each have intent that is distinct.

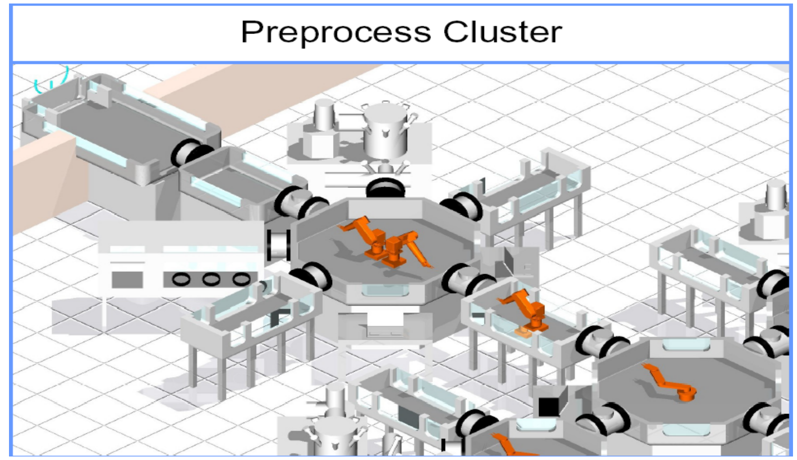
Key Planetary Protection Trades for MSR

Protect Mars	Cat 4A✓	Standard lander bio-loads
	Cat 4C	For special regions. None identified. Would avoid.
Round-trip (Life detection 10^{-2} returned Earth Org)	Cat 4B	Full system sterilization. New facilities and processes – cost $150M
	Cat 4B Subsystem ✓	• Sterilize parts touching sample; isolate by bio-barrier • Main samples taken from outside contaminated landing site; or use clean-sample acquisition techniques
Protect Earth (<10^{-6} release of unsterilized Mars particle <0.2μ)	Cat V ✓	Restricted Earth return
	Sample containment ✓	Reliable sealing including brazing and multiple seals. Direct or inference monitoring.
	Bio-sealing✓ – on-surface ? – in-orbit ?	Current concept establishes containment on surface. Will analyze the adequacy of performing in orbit
	Orbiter disposal ✓	
	Ultra-safe EEV ✓	
	Micro-meteoroid protection✓	Some method(s) needed – imbed EEV or MM-protection material

2003-2004 SRF Concept Studies (1 of 2)

Additional Details on Concept Comparisons





	Teams		
Function	**IDC**	**LAS**	**FLAD**
Sample Handling / Testing / Storage	Controlled Atmosphere Glove boxes	Linked Double Wall Containment Vessels	Linked Double Wall Containment Vessels
Sample Movement	Rapid Transfer Ports	"Common Carriers" moved by robotics	Robotic Operations/ Rapid Transfer Ports
Cleanroom Labs	Separate labs for preliminary characterization, testing, life detection, biohazard testing	Containment vessels in biosafety cleanroom	Separate labs for preliminary characterization, testing, life detection, biohazard testing

2003-2004 SRF Concept Studies (2 of 2)

Significant Findings

- Sample Handling, Testing and Storage
  - Advantages to use of linked, pre-fabricated double-walled containment vessels
    - Improves cleanliness
    - Reduces cost
  - Glove ports will likely be needed for some tasks
- Sample Movement
  - Advantages to robotic movement of common carriers through rapid transfer ports
- Animal and Other Studies
  - Recommend laboratory space separate from physical/chemical processing and life detection testing
- Technology Needs
  - Robotic manipulation of samples
  - Dual-wall processing cabinets
  - Rapid-transfer ports
  - Transfer methods and cold processing
  - Scientific instrumentation (customized for containment environment)
  - Materials that don't contaminate unknown martian samples

MEP PP Application Areas—Progress

- Sterilization
  - Hydrogen peroxide sterilization
    - Research completed and reported to PPO with recommended specification. Currently under evaluation by PPO as formal addition to NASA accepted implementation practice (MPO PP)
    - Materials compatibility under H_2O_2—several rounds of materials testing completed/reported
  - Dry heat time-temperature specifications
    - Research completed and reported to PPO with recommended specifications. Currently under evaluation by PPO as formal expansion of NASA accepted DHMR specifications (MPO PP)
  - Electron-Beam sterilization characterization, incl. materials compatibility (MTP and PP Research)
  - Plasma Sterilization
    - At least two attempts at development, one under SBIR and one under PP Research

MEP PP Application Areas—Progress (cont.)

- Validation of cleanliness
  - Alternative bio-assaying and detection technologies
    - LAL and Total-ATP molecular assays validated and approved for NASA PP use as supplement to NASA Standard Assay (MPO PP funded)
    - Several efforts to develop/assess new detection methods (e.g., Ponce, Bhartia/Hug, Lin/Anderson, mainly through PP Research)
  - NASA Standard Assaying
    - Faster but equivalent “Rapid Spore Assay” characterized and reported to PPO. Currently under evaluation by PPO as acceptable option to traditional method. (Initially MTP Focus Technology then MPO PP funded)

- Cleaning
  - Evaluation of “cleanability” of spacecraft materials
  - Evaluation of precision cleaning methods, seeking approach to “cleaning to sterility”
  - Alternative cleaning methods studied, e.g., supercritical CO_2
  - Survey paper to be written on past decade’s cleaning studies (2011 MPO PP funding)

MEP PP Application Areas—Progress (cont.)

- Contamination related
  - Transport and modeling
    - Incremental progress through multiple rounds of contamination transport modeling efforts (MTP)
  - Cross contamination and contamination-free sampling
    - Test-bed study of cont. transfer from s/c to planet caused by engine plumes (Marshall & Mancinelli funded by MPO PP)
    - Minimal other new work except some conceptual analysis of operational scenarios (MTP)
  - Planning to invest based on PPO guidance on "round trip PP"

- Microbial Characterization in Assembly Facilities
  - On-going microbial diversity assessments in the context of missions (PP Research)
  - Microbial hardiness/survival research for PP (mainly PP Research)
  - Genetic Inventory (MPO PP)
    - Multi-year task to develop vetted method for DNA collection and processing for "passenger list"
    - Eventual DNA assessment method TBD by PPO, but testing with state of art methods

Assessment of
Current PP Technology Focus Areas

Emerging PP technologies – Forward PP

- Microbial reduction technologies
  - Dry heat microbial reduction – component-level, new materials, new processes
  - Vapor phase hydrogen peroxide
  - Radiation (gamma ray, electron beam) sterilization
  - Super-critical CO_2 cleaning
- Rapid detection techniques for bioburden assessment
  - LAL/ATP
  - Rapid spore assay
  - PCR/Q-PCR
  - DPA
- Cross-contamination avoidance
  - Biobarriers
  - Aseptic assembly

Emerging PP technologies – Back PP

- Breaking the chain of contact
  - Remote container sealing (and monitoring)
  - Surface sterilization of MSR Orbiting Sample Container
- Safe return of Mars sample
  - EEV TPS design (avoid parachute)
- Returned sample handling
  - Double-walled processing cabinets (gloveboxes)
  - Robotic manipulation of samples
  - Rapid-transfer ports
  - Transfer methods and cold processing
  - Common carriers
  - Scientific instrumentation customized for containment environment

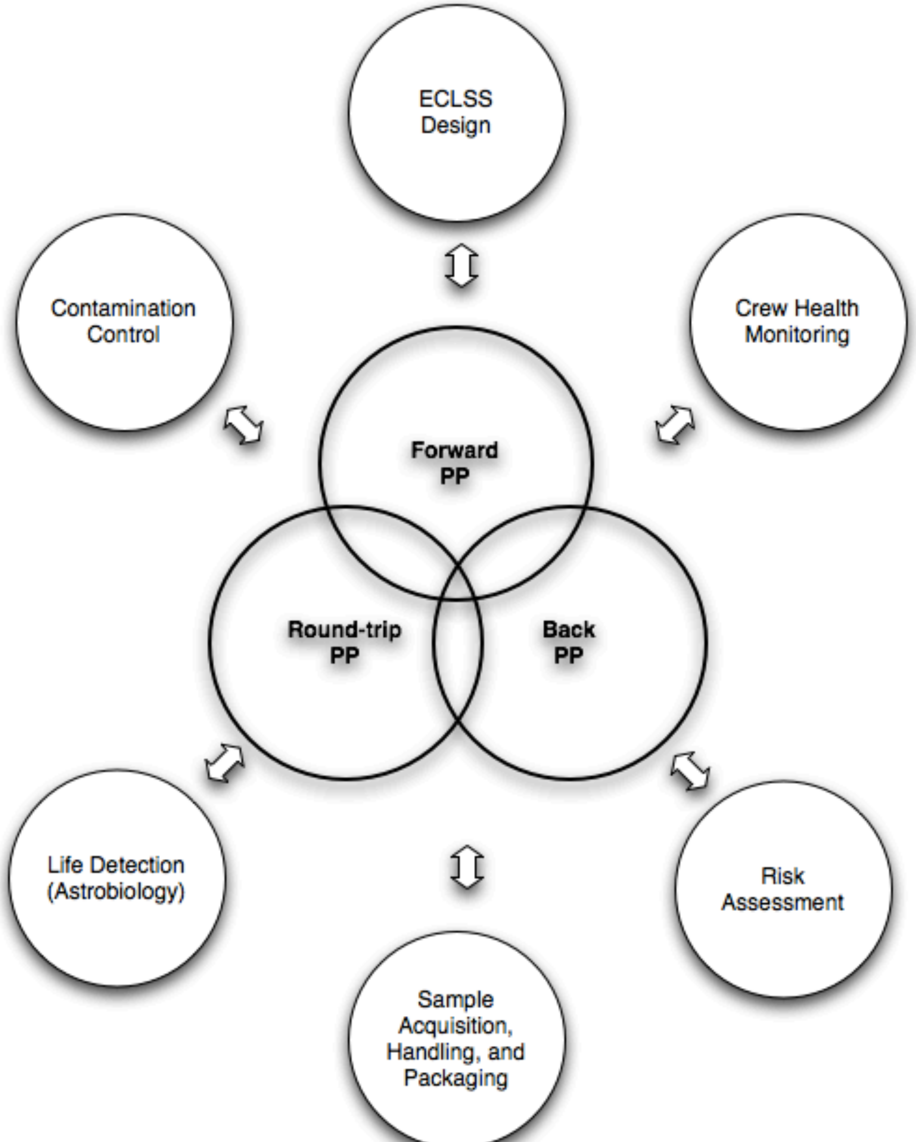
Summary assessment of PP technologies

Topical area	MD Applicability SMD	ESMD	SOMD	ARMD	Funding (past five years)	Funding outlook
Forward PP						
Limits of life	x				$	$
Bioburden reduction (sterilization)	x	x	x		$$	$$$
Bioburden reduction (cleaning)	x	x	x		$$	$
Rapid assay	x	x	x		$$	$
Cross-contamination control	x	x			$	$$
Aseptic assembly	x				$	$
ECLSS system design/monitoring		x	x		$	$$
Back PP (crew health/isolation)						
EVA suit design		x			$$	$
Crew decontamination/quarantine		x			$	$
Round-trip/Back PP (sample acquisition/transfer)						
Sample acquisition, handling, and containerization	x	x			$$	$$$
Exploration operations planning	x	x			$	$
Back PP (Earth return)						
Sample container sealing and leak monitoring	x				$	$$
Container surface cleaning/sterilization	x				$	$$
TPS design for EEV	x	x			$$	$$
Back PP (returned sample handling)						
Double-walled processing cabinets (gloveboxes)	x				$	$$
Robotic manipulation of samples	x				$	$$
Rapid-transfer ports	x				$	$$
Transfer methods and cold processing	x				$	$$
Common carriers	x				$	$$
SRF-custom scientific instrumentation	x				$	$$

Note: Does not include studies or tool development

Key
$ - hundreds of $K
$$ - single-digit $M
$$$ - double-digit $M

PP Inter-relationships



Key Issues and Recommendations

Issue: PP Technology Development mid-TRL Gap

- PPS noted correctly during its Aug 2010 meeting that there is no comprehensive program to develop and mature critical PP technologies for the benefit of the Agency as a whole
  - Planetary Protection Officer has a small ($0.xM) budget for PP research under the NASA ROSES call
  - Mars Exploration Program and Outer Planets Program offices at NASA HQ and JPL fund some cross-cutting technology development efforts ($0.xM-$xM)
    - Amount rises and falls with strength of overall technology program
  - $xM-$xxM investments made by mission project offices to solve specific mission needs (e.g., Phoenix manipulator arm/scoop biobarrier, JEO whole-spacecraft sterilization)
  - ESMD PP-related needs are in flux as the focus shifts from Mars to Moon to NEOs

- This leaves a gap between: (1) the early-stage developments under ROSES and Program Office base technology funding and (2) the highly specific developments for focused mission technologies
  - To bridge this gap, the PPS may choose to recommend a program focusing on the maturation of promising cross-cutting PP technologies

Issue: Inconsistent Level of PP-related R&D across Mission Directorates

- SMD mission suite (and PP needs) is fairly well-understood
  - Clear that MSR will drive many aspects of PP R&D over the next decade
    - Round-trip PP
    - Returned sample handling (Category V mission)
  - Implications of Earth-origin biomass contact with Europa (also applicable to Titan and Enceladus) are driving system-level architecture decisions for future OP missions

- ESMD mission suite (and PP needs) less well-understood
  - Transition of emphasis Mars -> Moon -> NEO invokes a widely-varying need posture
  - Some initial efforts (workshops, RFI responses) have been made, but there is no focused PP-related R&D in ESMD at this time

- The PPS may choose to recommend an integrating function/organization that would clarify the R&D implications for a suite of candidate missions, enabling a more stable approach to PP-related R&D

ACRONYMS

•ATP	Adenosine Triphosphate
•ARMD	Aeronautics Research Mission Directorate
•CT	Chief Technologist
•DNA	Deoxyribonucleic Acid
•DPA	Dipicolinic Acid
•DHMR	Dry Heat microbial Reduction
•EEV	Earth Entry Vehicle
•EDL	Entry, Descent, Landing
•ECLSS	Environmental Control & Life Support System
•ESMD	Exploration Systems Mission Directorate
•ET	Extraterrestrial
•EVA	Extravehicular Activity
•FLAD	Flad & Associates
•IDC	Industrial Design and Construction
•JEO	Jupiter Europa Oribter
•LAL	Limulus Amebocyte Lysate
•LAS	Lord, Aeck, Sargent
•MD	Mars Directorate
•MEP	Mars Exploration Program
•MPO	Mars Program Office
•MSR	Mars Sample Return
•MSL	Mars Science Laboratory
•MTP	Mars Technology Program
•NRA	NASA Research Announcement
•NTEC	NASA Technology Executive Council

ACRONYMS

•NAS	National Academy of Sciences
•NASA	National Aeronautics and Space Administration
•NASA HQ	National Aeronautics and Space Administration Headquarter
•NRC	National Research Council
•NEO	Near-Earth Objects
•OCT	Office of the Chief Technologist
•OP	Outer Planet
•PP	Planetary Protection
•PPO	Planetary Protection Officer
•PPS	Planetary Protection Subcommittee
•PCR	Polymerase Chain Reaction
•Q-PCR	Quantitative Polymerase Chain Reaction
•R & D	Research & Development
•ROSES	Research Opportunities in Space and Earth Sciences
•SRF	Sample Receiving Facility
•SMD	Science Mission Directorate
•SBIR	Small Business Innovation Research
•SOMD	Space Operations Mission Directorate
•STR	Space Technology Roadmap
•SOA	State of the Art
•TABS	Technology Area Breakdown Structure
•TASR	Technology Area Strategic Roadmap
•TA	Technology Areas
•TPS	Thermal Protection System
•TBD	To Be Determined