JPL Biotechnology and Planetary Protection Group Overview

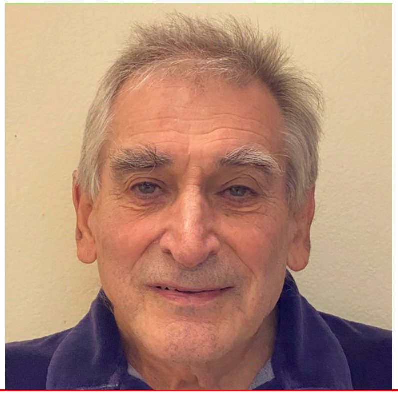
Max Coleman, Ph.D.
Group Supervisor

Moogega Cooper, Ph.D.
Former Group Supervisor

Jet Propulsion Laboratory
California Institute of Technology

Introducing us

Jet Propulsion Laboratory
California Institute of Technology



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2011 - 2024 Astrobiology and Life Detection Instrument Research

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2016 Planetary Protection Lead, Mars 2020 Mission

2020 Planetary Protection Lead, Europa Lander

2021 Group Supervisor, Biotechnology & Planetary Protection Group

2023 Containment Assurance Lead, Mars Sample Return Program

Biotechnology and Planetary Protection Group -1

- **Charter Statement (Objectives, abbreviated)**

  - Preserve the scientific integrity of current and future solar system exploration.
  - Ensure mission compliance with internationally agreed planetary protection requirements.
  - Advocate and educate the scientific, project and programmatic communities regarding the role of planetary protection.
  - Adopt and develop new technologies to improve planetary protection practice.

Biotechnology and Planetary Protection Group - 2

- **Goals (abbreviated)**

  - To enable NASA Planetary Protection (PP) Compliance for future NASA JPL missions
    - Life detection
    - Sample Return
    - Other
    - R&D technology and capabilities to support spacecraft design and implementation
  - Play an integral role in humans to Mars

JPL Flight Project Mission Support*

Project	Category	Launch Yr
Vikings	IV	1975
Galileo	II	1989
Mars Global Surveyor	III	1996
Mars Pathfinder	IV	1996
Cassini	II	1997
Deep Space 1	III	1998
Mars Climate Orbiter	III	1998
Deep Space 2	IVa	1999
Mars Surveyor 98 Lander	IVa	1999
Stardust	II/V	1999
Odyssey	III	2001
Mars Express	III	2003
Mars Exploration Rovers	IVa	2003
Rosetta	II	2004
Deep Impact	II	2005
Mars Recon. Orbiter	III	2005
Dawn	III	2007
Phoenix	IVc	2007

Project	Category	Launch
Juno	II	2011
Mars Science Laboratory	IVc	2011
TGO - Electra Transcievers	III	2016
InSight	IVa	2018
MarCO (Mars Cube One)	III	2018
Mars 2020	IVb, V(r)	2020
Europa Clipper	III	2024
Mars Sample Return (MSR)	III, IVa, V(r)	Planned

*Does not include project support on missions that were cancelled prior to launch (e.g. Europa Lander) or determined to not require PP support (e.g. Kepler)

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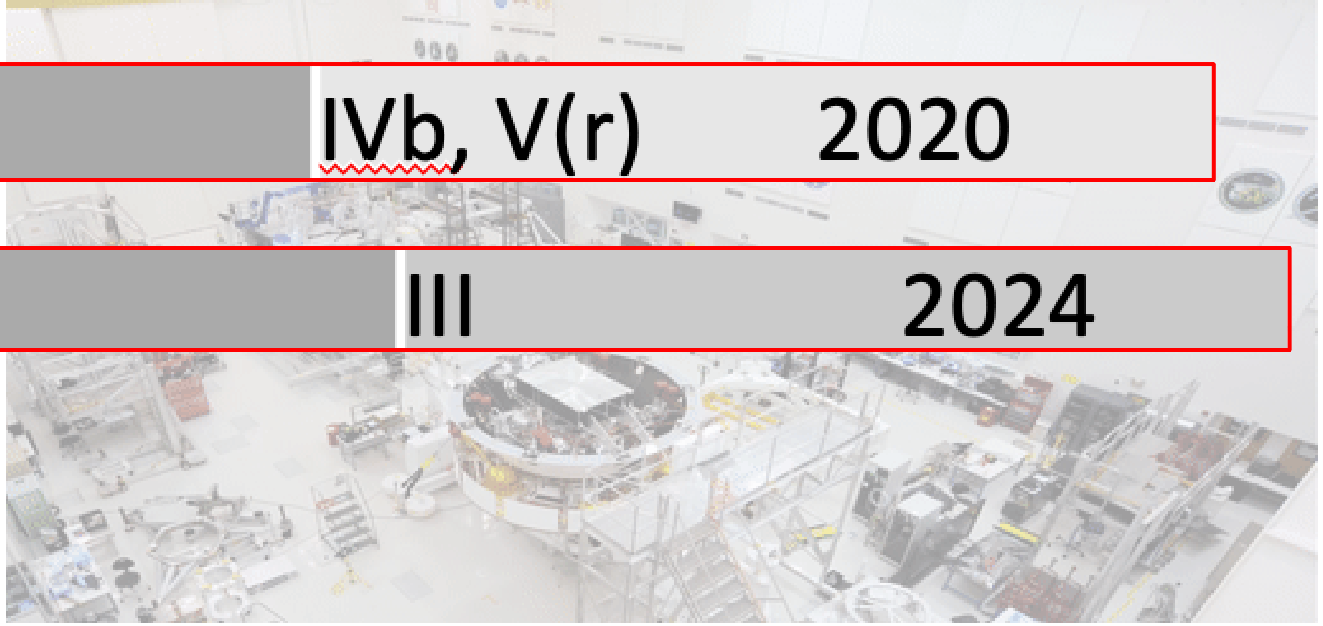

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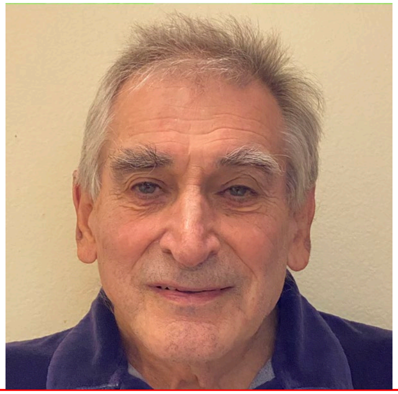
Introducing us



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JPL Planetary Protection Brief History

1959 – Spacecraft Sterilization and Planetary Quarantine Begin at JPL

Richard W. Davies and Marcus G. Comuntzis of JPL gave a joint paper on spacecraft sterilization and in-house biological research begins.

1970s – Spacecraft cleanliness monitoring, sterilization, and environmental controls

Spacecraft prototype cleanliness assessments, cleanroom, and sterilization developments using Viking and Mariner hardware

1975 – Viking Launch

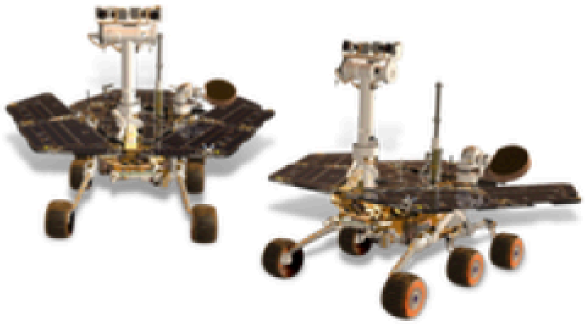
1980-2013 – Heat Microbial Reduction tests and standard development

Utilized microbial isolates collected directly from Viking through MSL to inform the NASA microbial reduction standard.

2000-2005 - Molecular

2000-2005 - Molecular Method Testing and Standard Development

JPL utlizes ongoing flight projects and spacecraft assembly cleanrooms to test and develop ATP and LAL Assay standard protocols for later adoption NASA-wide.



2003 MER launches

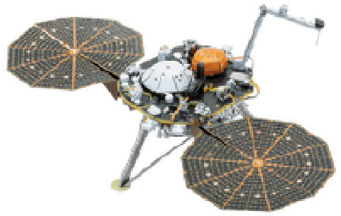
2011 MSL Launch

2001-2012 – Vapor Hydrogen Peroxide Testing and Standard Development

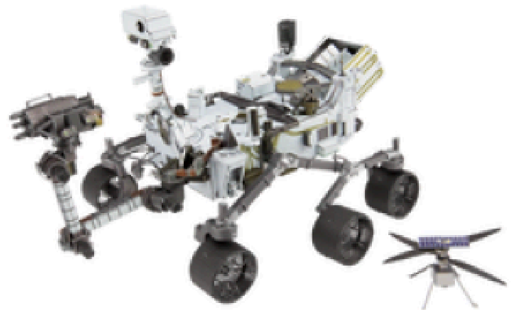
Hydrogen peroxide qualification testing in support of full adoption as a NASA standard sterilization process.

1990s-Present - Nucleic Acid-based testing and standard development

Low-biomass spacecraft and cleanroom samples collected for detailed interrogation using Nucleic-acid-based methods.



2018 Insight Launch



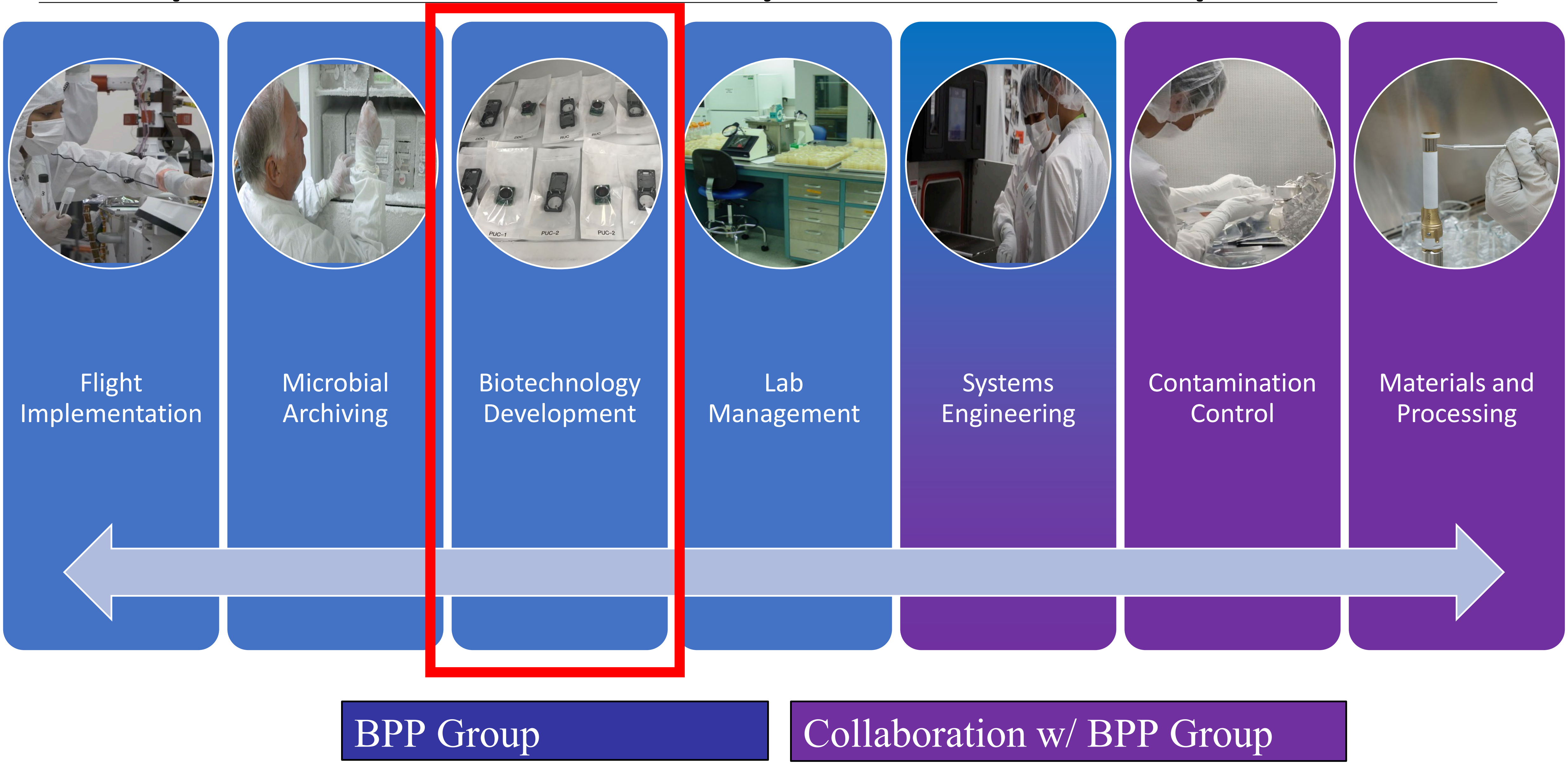
2020 Mars 2020 Launch

Mars Sample Return

Future Technology Development

Technology development in continued support of future planetary protection and life-detection goals.

JPL Spectrum of Planetary Protection Expertise



Excised (and updated) from:

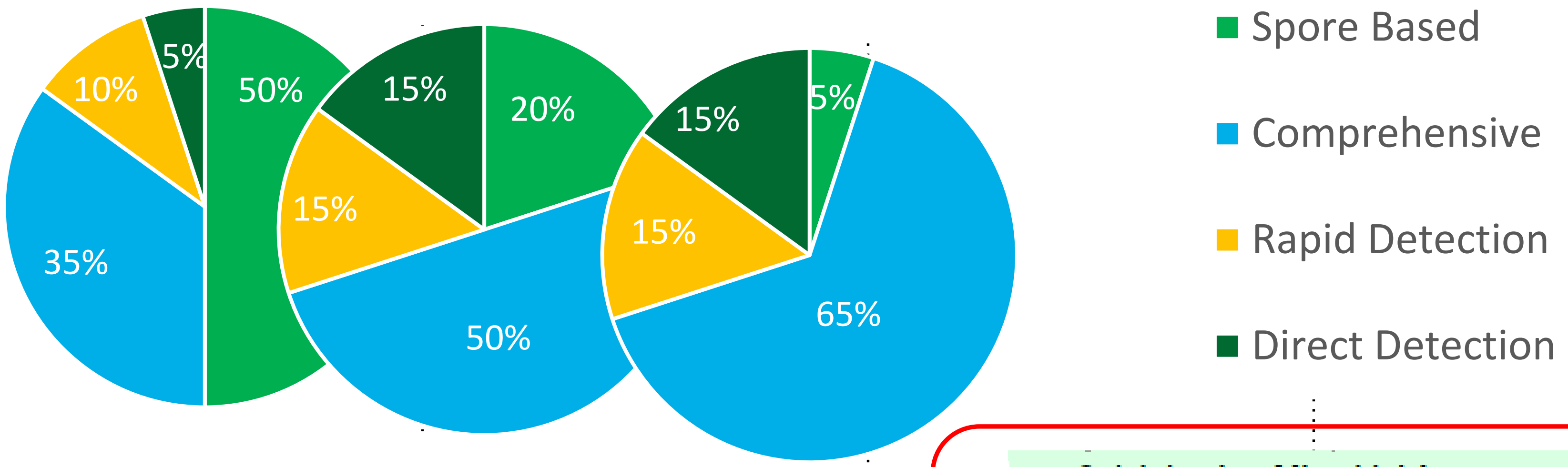
DRAFT TECHNOLOGY ROADMAP 2019: PLANETARY PROTECTION ROADMAP

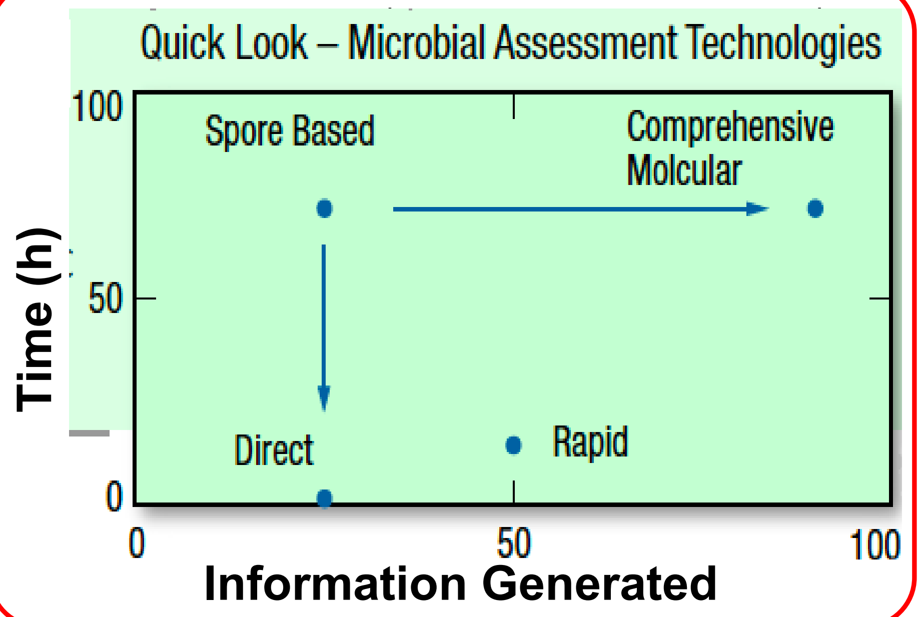
National Aeronautics and Space Administration

2020 | 2025 | 2030 | 2035 | 2050

Target

Biological Assessment Approaches





Flight Project Needs

DIGITAL PCR (dPCR)

METAGENOMICS

DETECTION

- Low-biomass hardware requires sensitive contamination detection methods.
- Limit of detection and thresholds for cleanliness need to be defined.

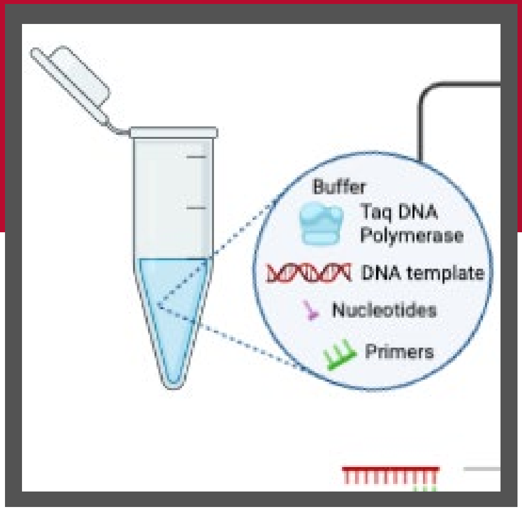
QUANTIFICATION

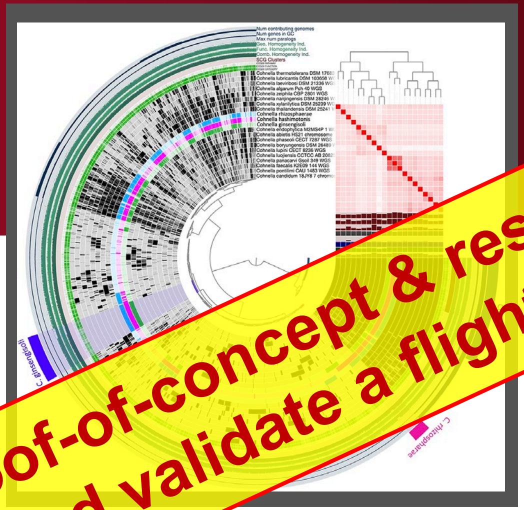
- Contamination levels guide assembly and cleaning practices.
- Enables statistically significant measurements.

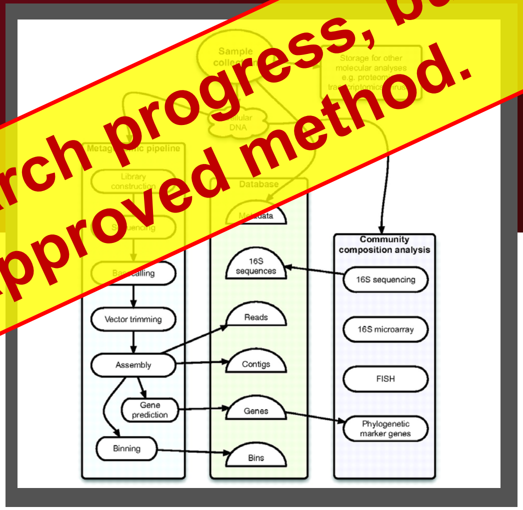
IDENTIFICATION

- Spacecraft “Passenger list”
- Informs PP models
- Needed for return sample science
- Advances PP research

PP Community Molecular Capabilities







Assay Development

qPCR Detection in Built Environments

Hendrickson et al. 2021

Parker et al. 2020

Mahnert et al. 2015

dPCR Pilot Study

Guan 2021 (JPL internal report)

Cleanroom Microbiome

Blachowicz et al. 2022

Malli Mohan et al. 2020

Weinmaier et al. 2015

Checinska et al. 2015

Vaishampayan et al. 2010

La Duc et al. 2009

Sequencing/Bioinformatics

Simpson et al. 2022

Wood et al. 2021

Workflow Development

Highlander et al. 2023

Danko et al. 2021

All previous efforts have been great for proof-of-concept & research progress, but none is at a scale large enough to verify and validate a flight-approved method.

Strategy for advancing molecular methods for planetary exploration

Apply expertise in metagenomics at NASA Centers, industry and academia that can be brought to bear in advancing the technology.

JPL and its partners have had a specific focus on the methods for handling low biomass found in planetary clean rooms and expected in planetary environments.

Structure a directed development program with four program elements to validate and verify technology for flight use:

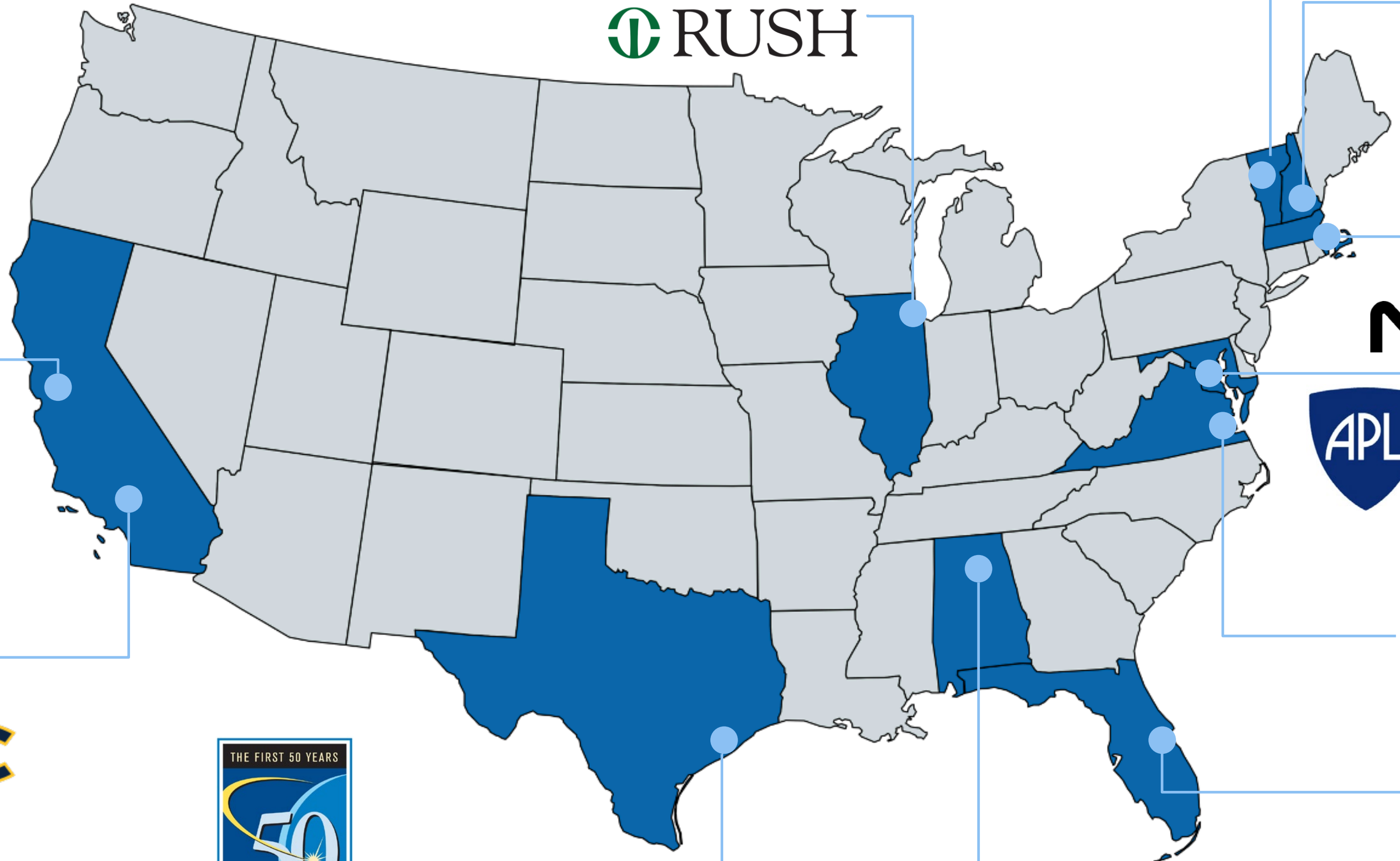
- Sample Collection
- Sample Processing
- Bioinformatics
- Relevant Organism Assessment

Community workshops:

- JPL 2022 - Metagenomics for Planetary Protection
- NASA Ames 2024 - Metagenomics in Spaceflight

Partners in Planetary Protection Molecular Biology Research

illumina
QIAGEN
Oxford NANOPORE Technologies
BIO-RAD
INTUS BIOSCIENCES



The University of Vermont
University of New Hampshire
RUSH
Massachusetts Institute of Technology
Lawrence Livermore National Laboratory
BERKELEY LAB
JGI JOINT GENOME INSTITUTE DEPARTMENT OF ENERGY
NASA Ames Research Center
NIST
UNIVERSITY OF MARYLAND
APL
NASA Goddard SPACE FLIGHT CENTER
JPL
Caltech
NASA LARC Langley Research Center
THE FIRST 50 YEARS JOHNSON SPACE CENTER
AI BIOSCIENCES, INC.
HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY
NASA MSFC Marshall Space Flight Center
NASA KENNEDY SPACE CENTER KSC

JPL Spectrum of Planetary Protection Expertise

Flight Implementation

Microbial Archiving

Biotechnology Development

Lab Management

Systems Engineering

Contamination Control

Materials and Processing

BPP Group

Collaboration w/ BPP Group

Contamination Control Enhancements to PP Implementation

Operational strategies, e.g.

- Hardware assembly to minimize cross-contamination.
- Contamination control through strategic operations

Mechanical design e.g.

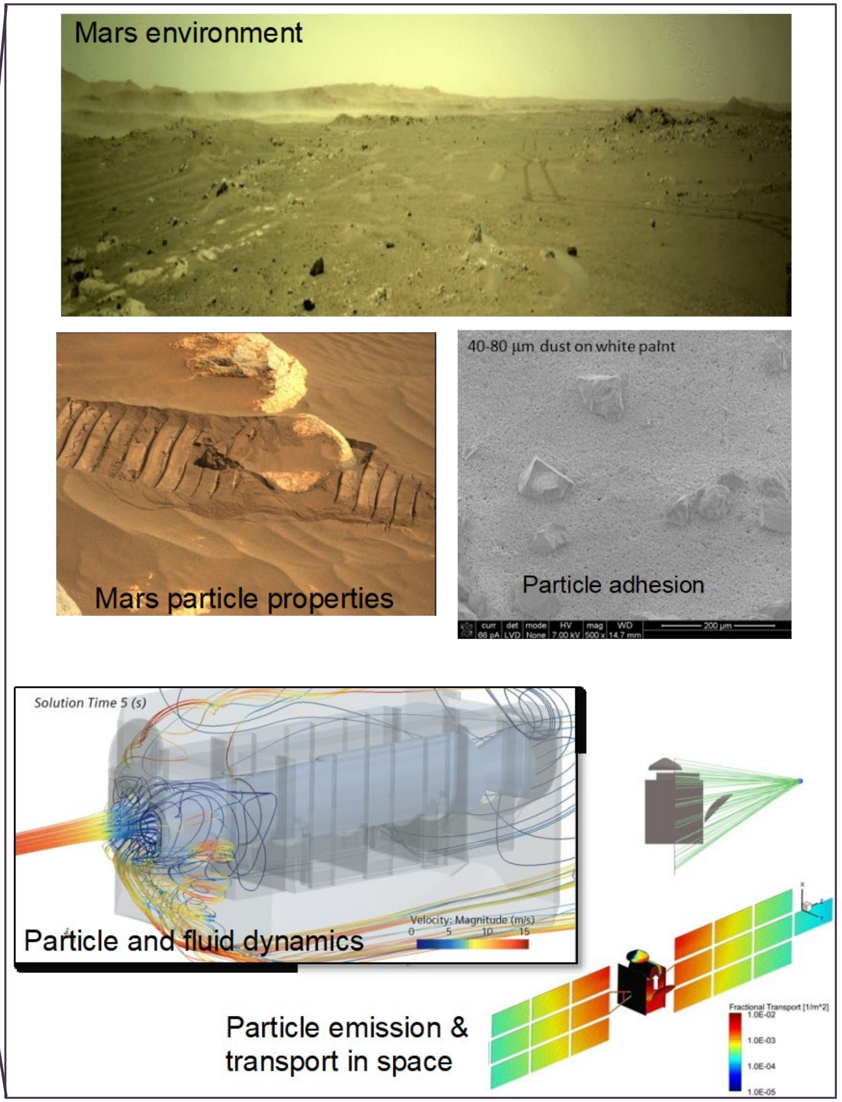
- Dust covers
- Fastener counterbores

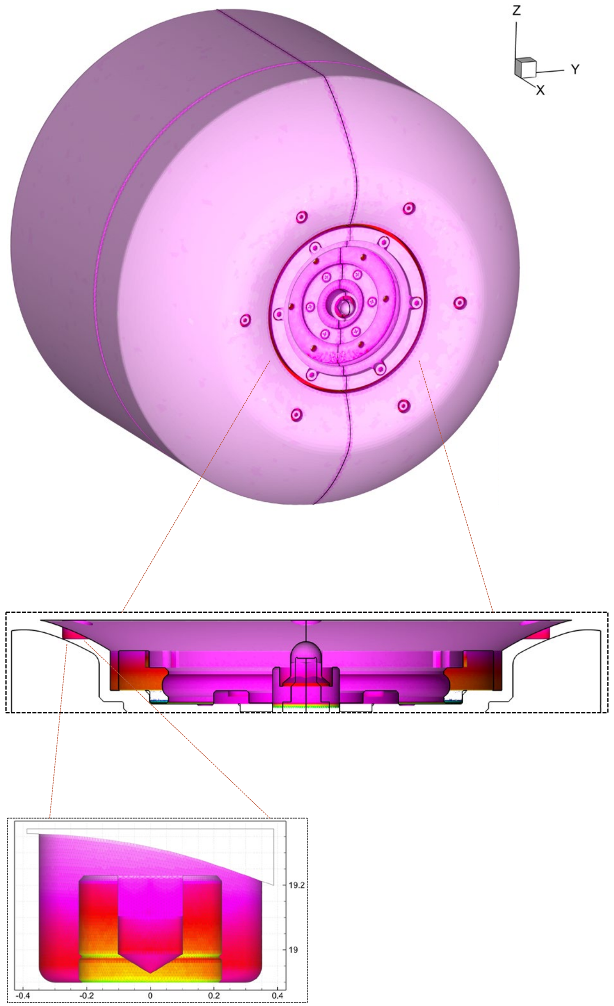
Particle transport and fluid dynamics modeling

- Informs hardware design and operations

Future Developments/opportunities, e.g.

- Updates to the current scientific knowledge that impact PP risk assessments





1. Cooper, Moogega et al. (2024) Mars Sample Return Orbiting Sample as Primary Containment Vessel Backward Planetary Protection Design Considerations. 45th COSPAR Scientific Assembly. Held 13-21 July 2024.
2. Hoey, William et al. (2024). 3-D Ray-tracing Analyses and Design of the Mars Sample Return Orbiting Sample for Sterilization by Ultraviolet Radiation. 45th COSPAR Scientific Assembly. Held 13-21 July 2024.
3. Hoey, William, et al. "Launch recontamination: planetary protection models for particle transport in spacecraft payload fairing environments." 44th COSPAR Scientific Assembly. Held 16-24 July 44 (2022): 3287.
4. Shallcross, Gregory, et al. "Launch recontamination: the evaluation of particle adhesion and removal mechanisms in spacecraft payload fairing environments." 44th COSPAR Scientific Assembly. Held 16-24 July 44 (2022): 3283.
5. Mikellides, et al. "Experiments in particle resuspension and transport for the assessment of terrestrial-borne biological contamination of the samples on the mars 2020 mission, Planetary and Space Science, Volume 181, 2020, 104793.

Potential future infusion Opportunities/environments and challenges

Mars Sample Return Sample Retrieval Lander (SRL)

Compare culture and molecular.

Identify microbial species for better risk estimation.

Exobiology Extant Life Surveyor (EELS)

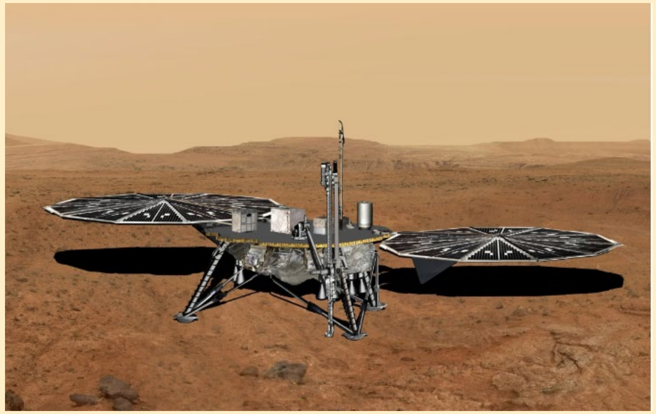
https://spacetech.jpl.nasa.gov/nex

Explore ocean worlds, assess habitability and ultimately search for evidence of life.

Mars Sample Receiving Project (SRP)

Metagenomics methods for trace bio-contaminants for more robust scientific interpretation.

Mars Life Explorer (MLE)



https://smd-cms.nasa.gov/wp-content/uploads/2023/10/mars-life-explorer.pdf

Seeking extant life. The MLE Study Team concluded that new approaches (e.g., nanopore genomics and proteomics), could be done within the anticipated PP budget.

PP must keep pace with / co-develop with Life Detection instruments.

Sets the baseline to be measured above / tests and calibrates instruments

Information from these efforts will be infused into Mars in-situ life detection and future icy worlds missions

Summary

- **Decades of Expertise:**
  - Established standards in sterilization and biological assessment since the 1950s.
- **Current and Future work focused on Innovative Molecular Methods:**
  - Characterizing spacecraft bioburden in low-biomass environments.
  - Faster, more accurate, and cost-effective than NASA Standard Assays.
  - Enhances forward contamination prevention and life-detection measurements.
- **Leverages partnerships with Contamination Control for Advanced Contamination Modeling:**
  - Developed cutting-edge models for microbial transport and spacecraft recontamination.

Thank you