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Mars Technology Program

Planetary Protection Technology Development

Technical Lead: Ying Lin
Jet Propulsion Laboratory

March 6, 2006

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Goals and Objectives

To develop technologies that will enable NASA to build, launch, and operate a mission that has subsystems with different Planetary Protection (PP) classifications, specifically for operating a Category IVb-equivalent subsystem from a Category IVa platform.

(http://research.hq.nasa.gov/code_s/nra/current/nra-03-oss-01-int/index.html)

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Differences Between Mission Category IVa and IVb

IVa: Requires bioburden reduction	IVb In addition to IVa requirements:
No sterilization is required	Terminal sterilization of spacecraft is required.
<300[a] cultivable bacterial spores/m^2 of exposed area and 300,000 bacterial spores per landing event[b].	<30 viable organisms per landing events[b].
Assay process selective for culturable bacterial spores.	All viable organisms are counted.
No probability calculations are required.	Less than or equal to 1% probability of single viable earth organism contaminating planetary soil/rock sample[c].

a <300 culturable bacterial spores/m2 translates into approximately <300,000 viable organisms/m2

The specific values apply to Mars only; the values for other targets for which landers are Category IV missions are determined on a case by case basis.

c This requirement is a special rule for Mars sample return only.

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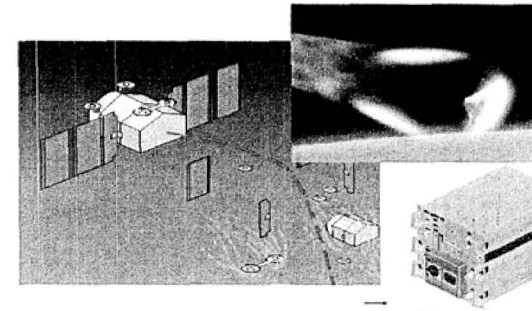
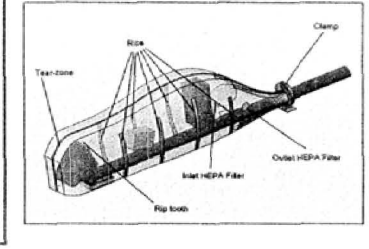
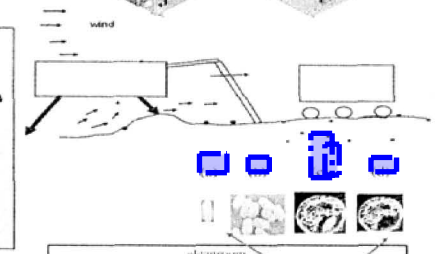
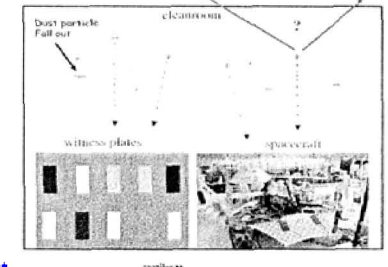
Description

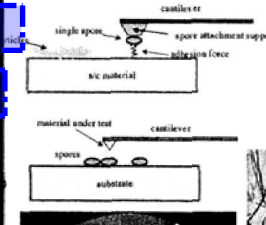
- *To develop technologies needed to meet PP requirements for the next decade missions*
  - Improve cleaning and validation methods
  - Enable cross contamination avoidance and risk prediction capability
  - Develop sample handling system

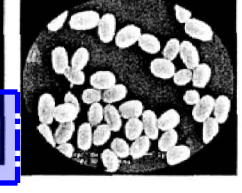


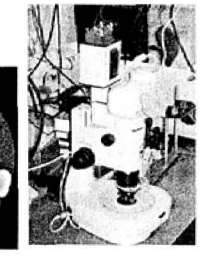












Tasks List & Budget ($K)	Year 1	Year 2	Year 3	Total
Cleaning to Achieve Sterility	278	367	378	1023
A Rapid Single Spore Enumeration Assay	310	308	317	935
Light Weight Biobarrier Technology	308	327	310	945
Spore Adhesion for Contamination Transport Model	295	312	320	927
Near Field and Integrated Particle 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

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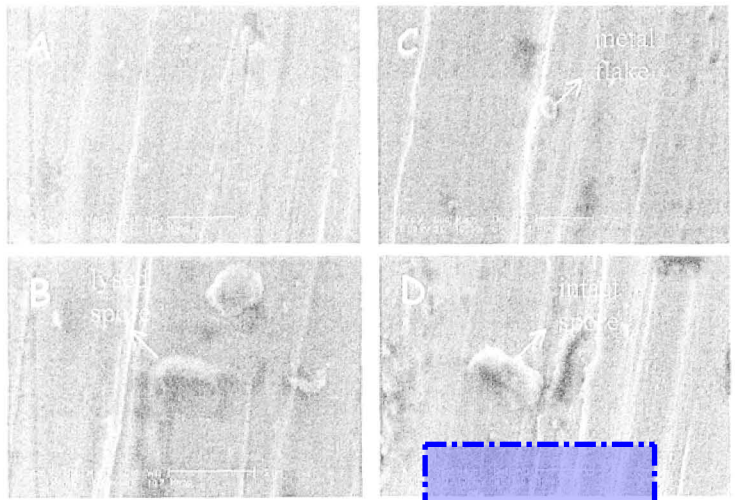
Cleaning to Achieve Sterility



Objectives:

- Adapt and refine existing techniques and methodologies for comparative evaluation of cleaning systems for removal of spores.
- Compare the effectiveness of three state of the art cleaning systems on
  1. Surfaces
  2. Piece parts
  3. Subsystems
- Report and recommend cleaning systems for materials, component/piece parts, and subsystems.

PI: Roger Kern, JPL
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Participating Organizations:

- Jet Propulsion Laboratory
- JSC – White Sands Testing Facility
- HyperFlo Corporation

Facilities:

- JPL Precision Cleaning Operations
- JSC-WSTF Ultra Pure Water Cleaning Facility
- HyperFlo Liquid Boundary Layer Disruption System

Funding Profile ($K):

Year 1	Year 2	Year 3
278	367	379

Milestones:

FY04: Establish contracts.

FY05: Demonstrate concept enabling results, spore aerosol deposition and cleaning validation.

FY06: Characterization and comparison of cleaning methods on coupons and realistic components.

FY07: Report cleaning results on spacecraft surface coupons and make recommendations.

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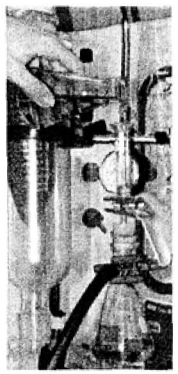
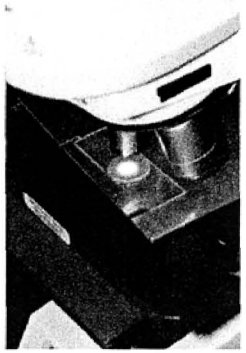
A Rapid Single Spore Enumeration Assay



1. Filter

2. Transfer Filter Membrane
3. Induce germination or physically lyse spores.



4. Time-Gated Imaging

Objectives:

- **Develop a novel rapid single spore enumeration assay (RapidSSEA) for the validation of spacecraft bioburden reduction.**

Demonstrate methods of bacterial spore detection based on DPA-triggered Tb luminescence and lifetime-gated imaging to enumerate single spores on filter membranes.

Demonstrate enumeration of bacterial spores with RapidSSEA on a timescale of minutes as opposed to 3 days when the NASA standard assay is used.

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Facilities:
JPL - The Photonics Research Laboratory
JPL - The Bio-instrument Development Laboratory

Funding Profile ($K):

Year 1	Year 2	Year 3
310	308	317

Milestones:

FY05 – Image laboratory strains of bacterial spores on quartz slides with lifetime gated imaging microscope.

FY06 – Image laboratory and environmental strains on filter membranes.

FY07 – Compare RapidSSEA with other bioburden assay results.

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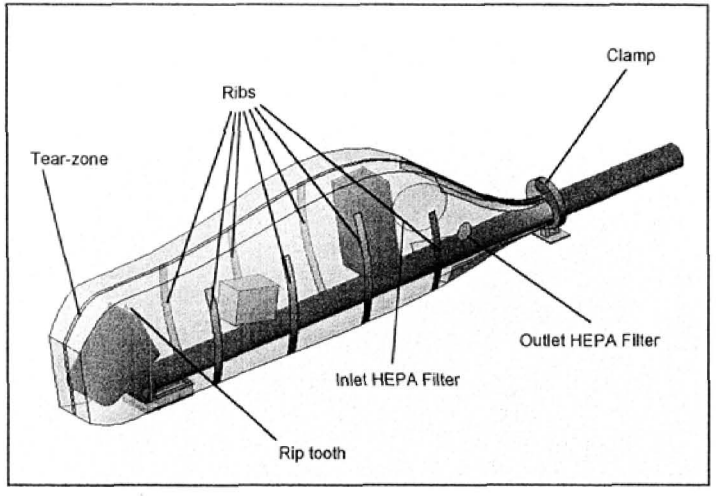
Light-weight Biobarrier Technology



Objectives:

- Develop biobarrier technology that will enable NASA to build, launch, and operate missions that have subsystems cleaned to both Planetary Protection (PP) category IVa and IVb specifications.
- Offers a practical solution to implement sterilization and isolation of subsystem for PP IVb and IVc missions.

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Facilities:

JPL – fabrication, material & deployment testing, environmental testing, dry heat, bio-assay

Steris Corp. – H_2O_2 chamber

Funding Profile ($K):

Year 1	Year 2	Year 3
308	327	310

Milestones:

FY04 – Biobarrier material selection, preliminary design of deployment mechanism.

FY05 – Complete design of deployment mechanism, build and begin testing proto-type, HEPA filter design & fab.

FY06 – Complete testing of proto-type, begin verification of microbial reduction process.

FY07 – Complete microbial reduction verification, documentation.

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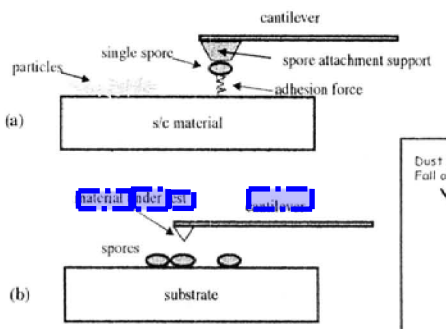
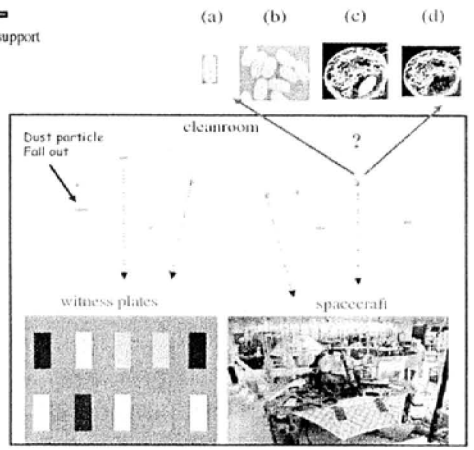
Spore Adhesion for Contamination Transport Model





Objectives:

- To obtain knowledge and data sets of spore association and adhesion to dust particles and spacecraft necessary for developing high fidelity contamination transport models in support of Mars landing and sample return mission PP requirements.
- To understand spore association with dust particulates by measuring the number of spores on particles of various sizes in a clean room environment.
- To investigate spore adhesion to its carriers by AFM measurements of adhesion forces among spores, particles, and spacecraft material surfaces.

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Co-I: Jack Barengoltz, JPL
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Participating Organizations:

- JPL Microbiology Laboratory
- JPL Biomolecule Detection Laboratory (BDL)
- JPL Analytical Chemistry Laboratory
- JPL Spacecraft Assembly Facility

Funding Profile ($K):

Year 1	Year 2	Year 3
295	312	320

Milestones:

- FY04 Instrument purchase and training.
- FY05 Complete microbe distribution per particle size for clean room air and spore accumulation on spacecraft.
- FY06 Complete particle size-dependent swab sampling efficiency study. Single spore attachment for AFM.
- FY07 Complete AFM measurement of adhesion forces.

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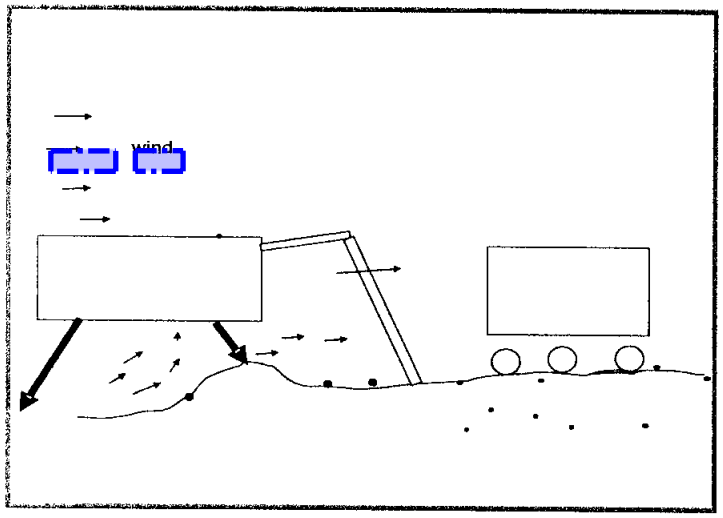
Near field and integrated particle transport models



Objectives:

- Develop, test, and validate a particle transport model based on GEANT4 applicable to during landing and operations on the surface of the Mars.
- Offers an advanced particle transport model with capabilities to include complex hardware geometry and predict trajectory of particle transport.

PI: Partha Shakkottai, JPL
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Facilities: Caltech super computer
Wind tunnels (ASU)
Mars simulation Wind Tunnel (NASA Ames)

Funding Profile ($K):

Year 1	Year 2	Year 3
332	381	291

Milestones:

FY05 Develop near field model.

FY06 Incorporate data into the model and start model validation.

FY07 Complete model validation and write final report.

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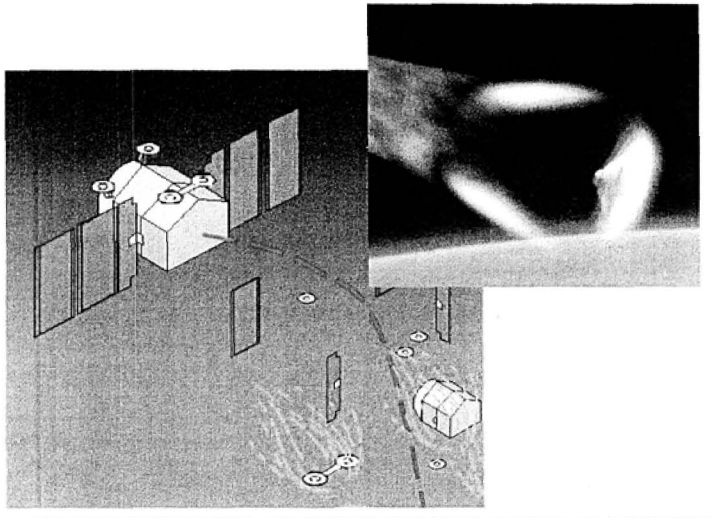
Development of the Mars Orbital Debris Analysis Code



Objectives:

- Develop a thermal analysis tool that can be used to quickly determine if small spacecraft debris will meet the planetary protection sterilization requirements at any point along a breakup trajectory.
- Offer an advanced analysis tool with potential to reduce PP implementation cost.

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Participating Organizations: LaRC

Funding Profile ($K):

Year 1	Year 2	Year 3
204	206	0

Milestones:

FY05 Complete development of individual models (atmosphere, aerodynamic, trajectory, aeroheating, and thermal).

FY06 Integrate models into code. Code validation and documentation.

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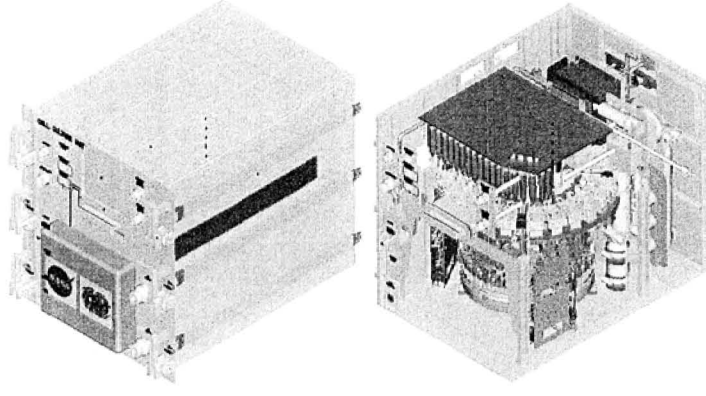
Contained Sample Handling and Analysis System (CSHAS)



Exterior and cutaway views of the ISS Cell Culture Unit — the starting point for CSHAS development

Objectives:

- Adapt NASA Cell Culture Unit (CCU) for use as Mars returned sample and handling instrument in Sample Receiving Facility
- Advance resulting system technology to TRL-4 (breadboard system in laboratory environment)

PI: Joe Parrish (Payload Systems)
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Participating Organizations:
Payload Systems Inc. Cambridge, MA
MIT, Cambridge, MA

Funding Profile ($K):

Year 1	Year 2	Year 3
239	308	352

Milestones:

FY05 CSHAS requirements definition; feasibility assessment of CCU as basis for CSHAS.

FY06 Preliminary design for CCU flight system & CSHAS ground system implementation; functional modifications to enable Mars returned sample handling, analysis, bioisolation.

FY07 CSHAS breadboard system fabrication.

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Performance Metrics

Planetary Protection Tasks	Current Capability	Anticipated Capabilities
Cleaning to Achieve Sterility	<300 Spores/m^2	<0.03 Spores/m^2
A Rapid Single Spore Enumeration Assay	Single cultivatable spore 1/2 hours	Single spore 1/1 hour
Light Weight Biobarrier Technology	None	Available
Spore Adhesion for Contamination Transport Model	None	Information available
Near Field and Integrated Particle Transport Model	Yes. Far field line source models for uniform and isotropic winds exist	Near field model
Mars Orbital Debris Analysis Tool	Yes. Excel model	Improved FORTRAN executable model
Contained Sample Handling and Analysis System	Yes (CCU)	Improved sample containment

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Relevancy to Planned, Proposed and Possible Future Missions

Planetary Protection Tasks	Relevancy (H/M/L)	Phoenix (2007)	MSL (2009)	Telecom/ Science Orbiter	Scout	AFL	MID ROVERS	Deep Drill	Current TRL	EOT* TRL (Year)
Cleaning to Achieve Sterility	H		✓	✓	✓	✓	✓	✓	3	6(2007)
A Rapid Single Spore Enumeration Assay	M		✓	✓	✓	✓	✓	✓	3	6(2007)
Light Weight Biobarrier Technology	H	✓	✓	✓	✓	✓	✓	✓	3	6(2007)
Spore Adhesion for Contamination Transport Model	H		✓	✓	✓	✓	✓	✓	3	6(2007)
Near Field and Integrated Particle Transport Model	H		✓	✓	✓	✓	✓	✓	3	6(2007)
Mars Orbital Debris Analysis Tool	H		✓	✓	✓	✓	✓		4	4(2006)
Contained Sample Handling and Analysis System	L								2	4(2007)

* EOT – End of Task

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First Year Accomplishments

Planetary Protection Tasks	Schedule	Resources	Major Accomplishments
Cleaning to Achieve Sterility	G	G	Complete the cleaning effectiveness evaluation on coupon surfaces.
A Rapid Single Spore Enumeration Assay	G	G	Demonstrated single spore imaging using RapidSSEA
Light Weight Biobarrier Technology	G	G	Completed the prototype biobarrier fabrication, deployment, and material compatibility testing
Spore Adhesion for Contamination Transport Model	G	G	Obtained the data on average spores per airborne particles
Near Field and Integrated Particle Transport Model	G	G	Particle motion in uniform wind was demonstrated on an elementary model
Mars Orbital Debris Analysis Tool	Y	Y	Task is behind schedule due to reprioritization of NASA resources
Contained Sample Handling and Analysis System	G	G	Defined a sample handling architecture

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Author Bio

Dr. Ying Lin is a senior member technical staff at JPL's biotechnology and planetary protection group. She has a BS in chemical engineering from Tsinghua University and a Ph.D. in Chemistry from University of Arizona. She has extensive research experience in chemistry, biochemistry and chemical engineering. She is the PI and Co-I of several proposals funded by JPL and NASA on planetary protection. She is currently a technical lead for the planetary protection tasks for Mars Technology Program.

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