MICROBIOLOGICAL CLEANLINESS OF THE MARS EXPLORATION ROVER SPACECRAFT

L. Newlin (1), J. Barengoltz (1), S. Chung (1), L. Kirschner (1), R. Koukol (1), F. Morales

(1) Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91109, USA

The soon to launch Mars Exploration Rover twin spacecraft, each involving a lander and a rover scheduled to land on Mars in January and February of 2004, are required to comply with the National Aeronautics and Space Administration planetary protection regulations for such space missions. The microbial cleanliness requirements are driving a major effort to assemble clean spacecraft and to verify and maintain their cleanliness.
Planetary protection for Mars missions is described, and the approach being taken by the Mars Exploration Rover Project is discussed. Specific topics include alcohol wiping, dry heat microbial reduction, microbiological assays, and the Kennedy Space center's PHSF clean room. Current best estimate for the number of aerobic spores to be found on the spacecraft at launch are presented and compared to the Viking 1975 and Mars Pathfinder 1996 values.

clearance
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Microbiological Cleanliness of the Mars Exploration Rover (MER) Spacecraft*

L. Newlin

J. Barengoltz, S. Chung , L. Kirschner, R. Koukol, F. Morales

Jet Propulsion Laboratory

4800 Oak Grove Drive

Pasadena, California 91109, USA

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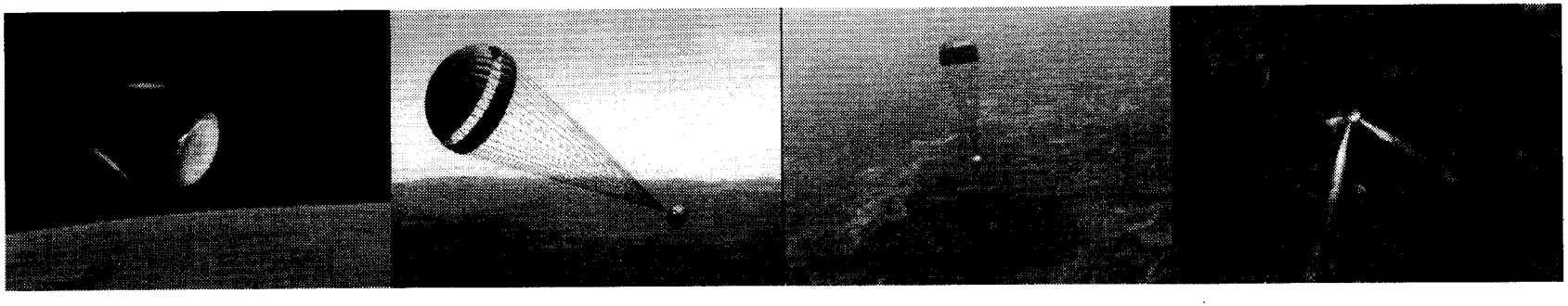
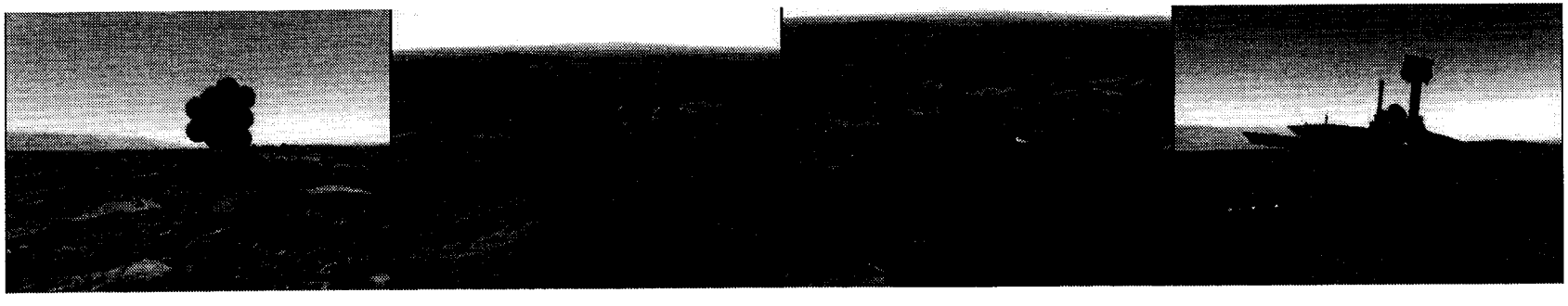
Mission Overview

Launch/Cruise

EDL

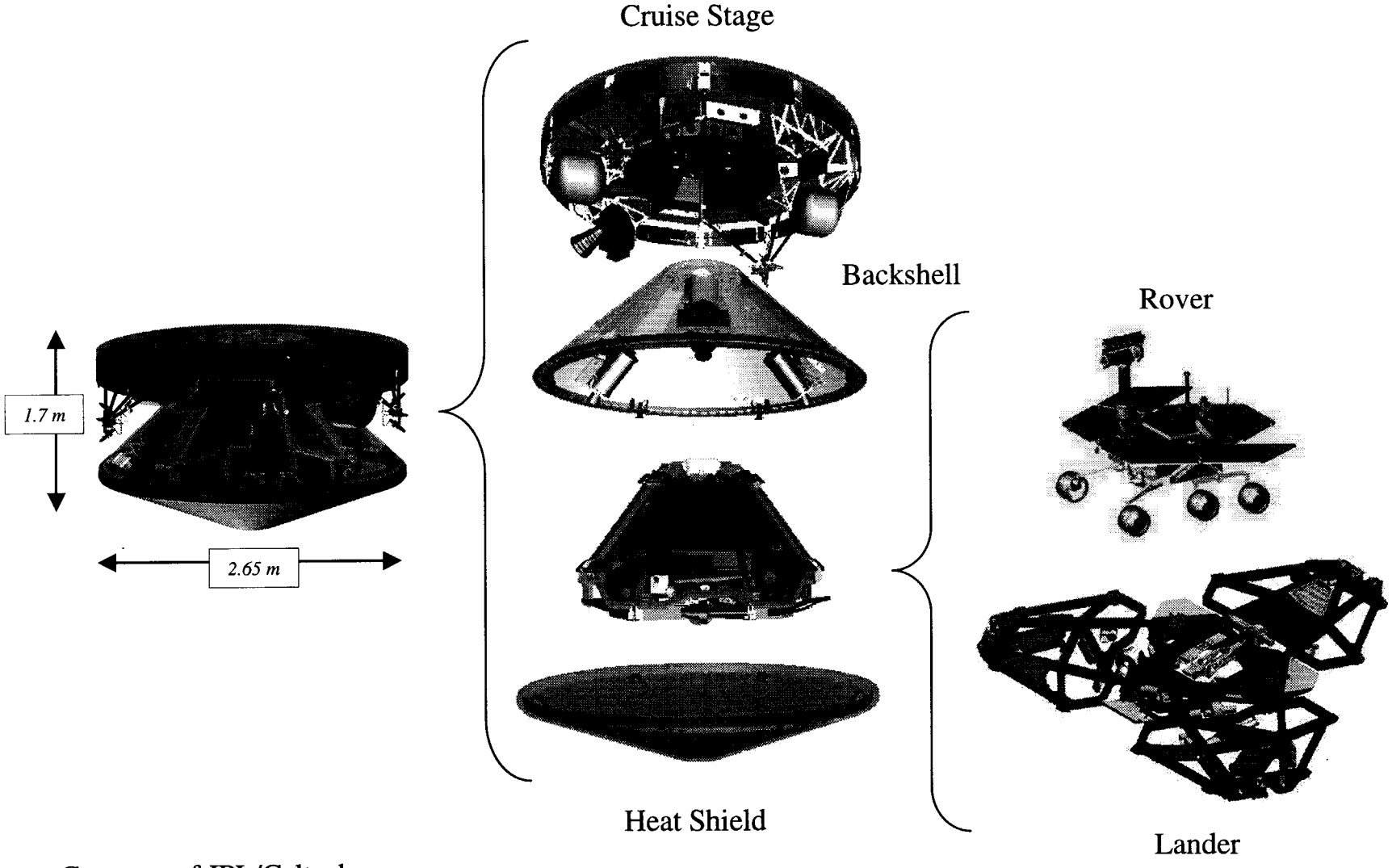


Surface



Images From Mission Animation by Dan Maas
Courtesy of JPL/Caltech

Spacecraft Configuration



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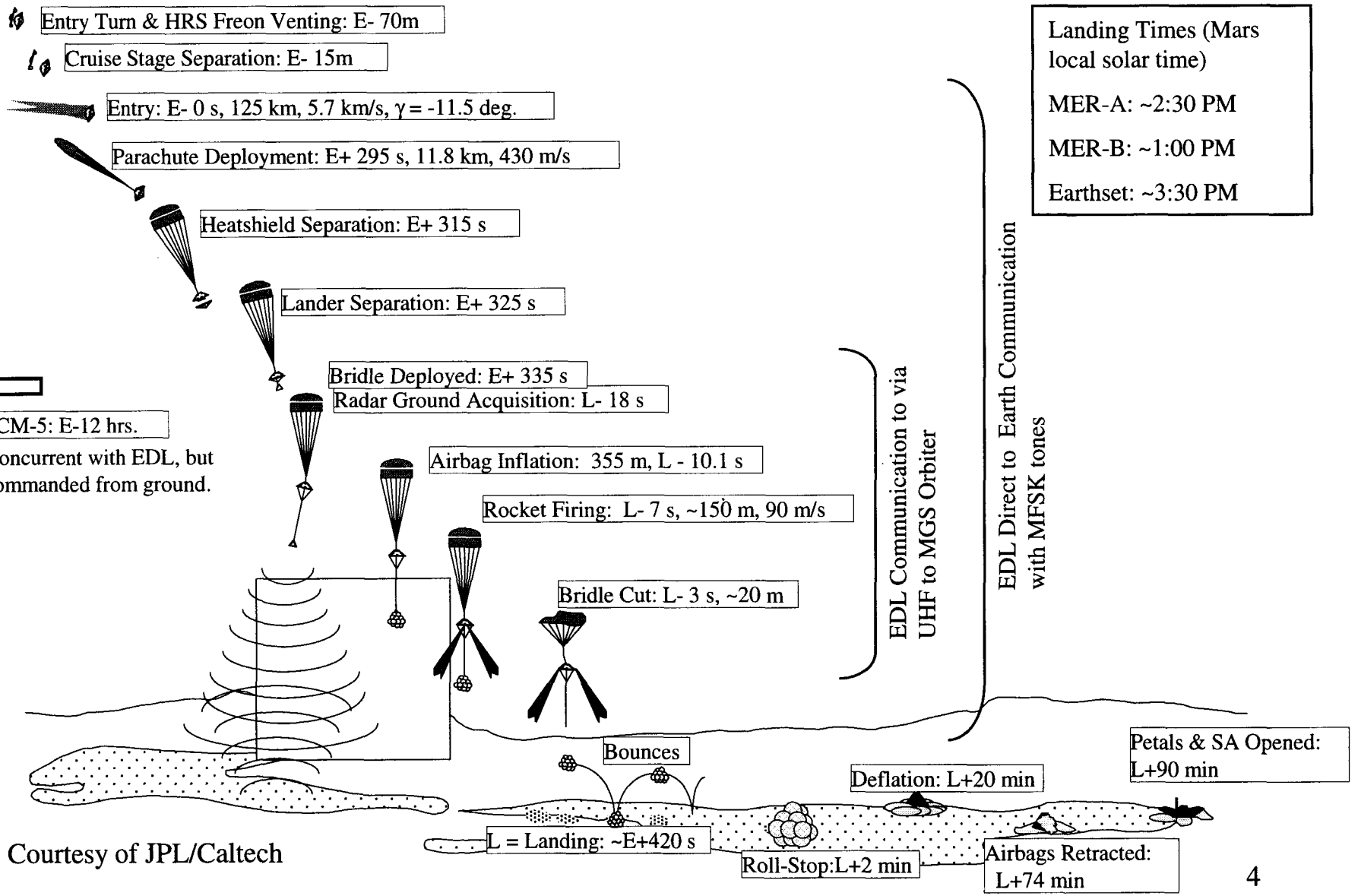
Entry, Descent & Landing (EDL) Scenario



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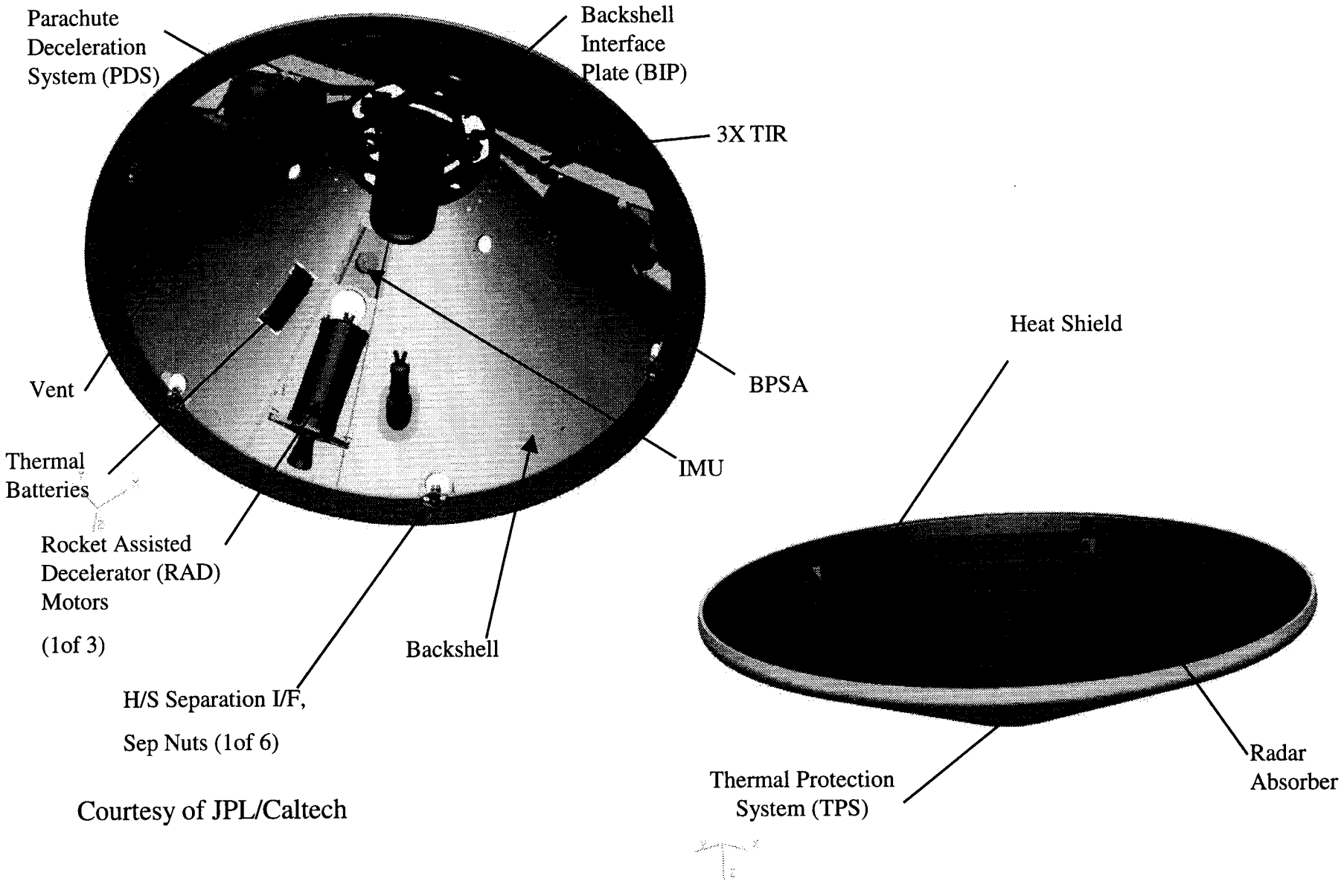
Aeroshell Configuration



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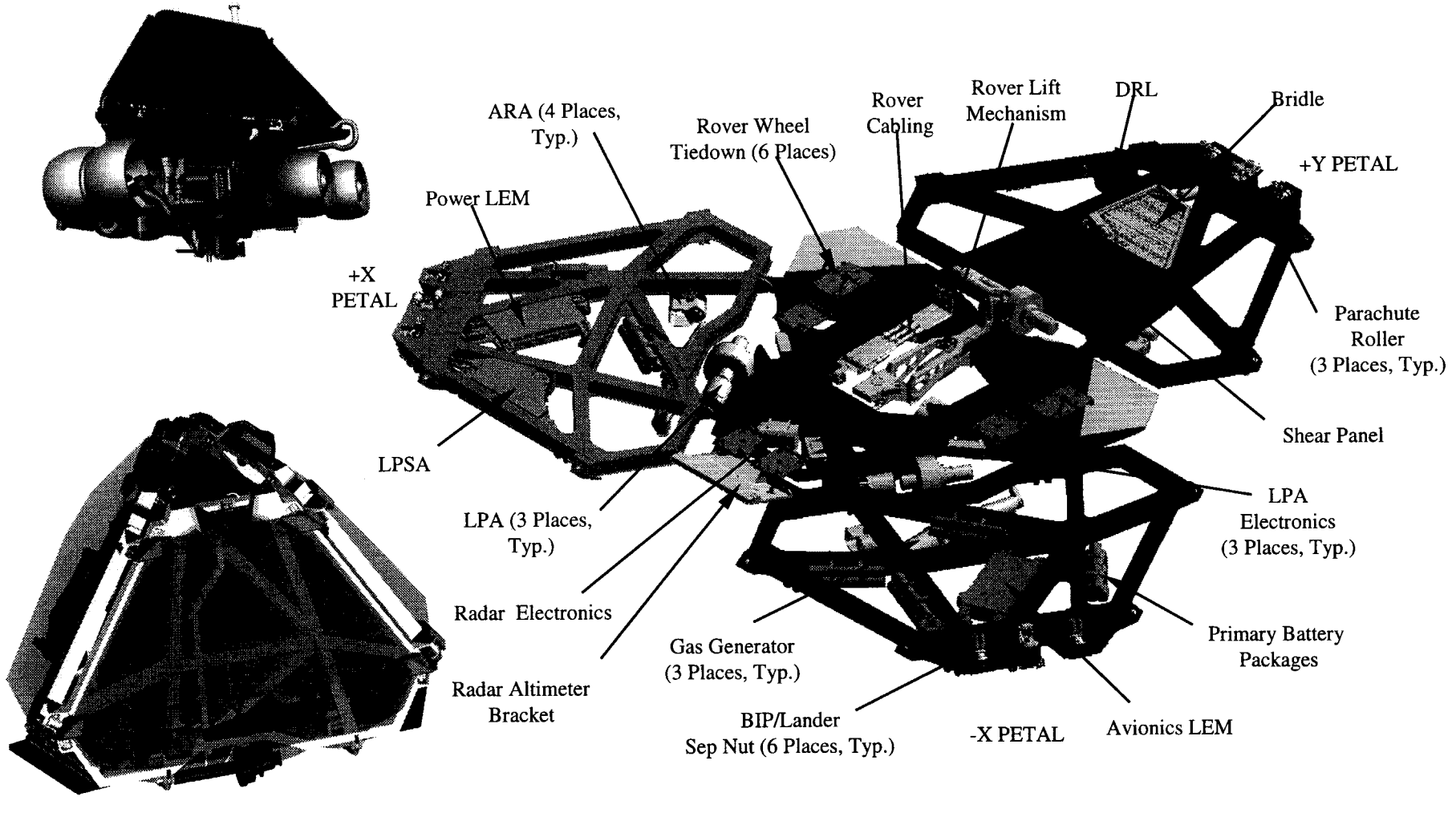
Lander Configuration



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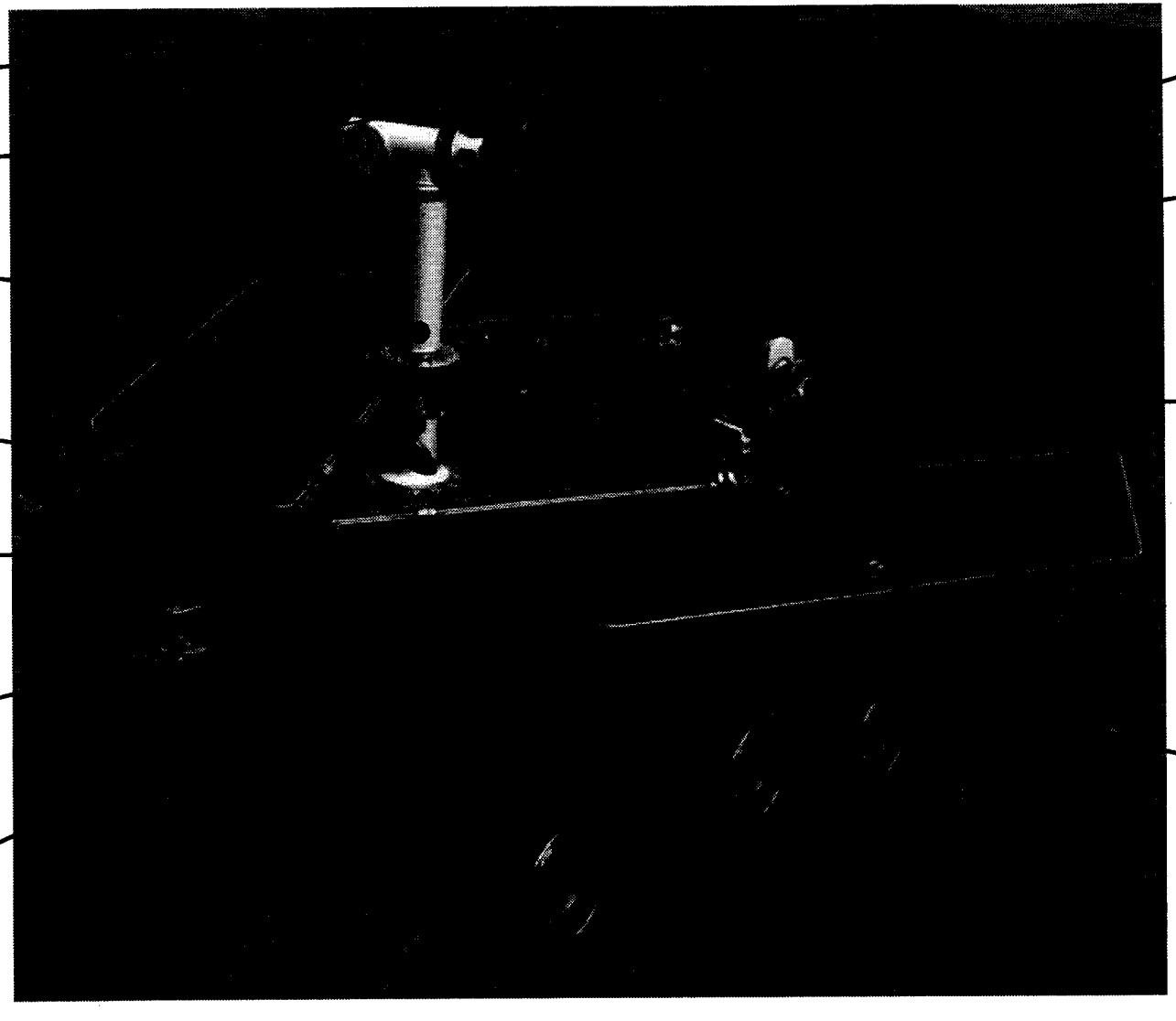
Rover Configuration



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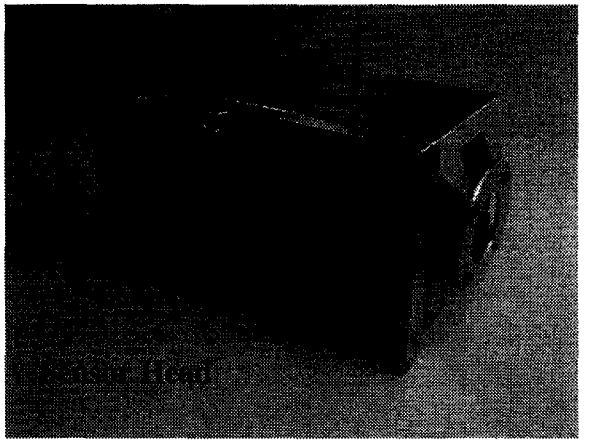
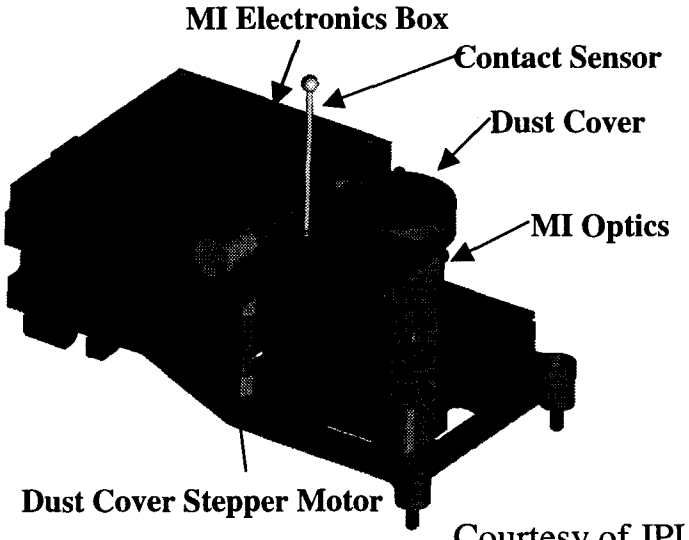
In-Situ Instruments

Alpha Particle X-Ray Spectrometer (APXS)

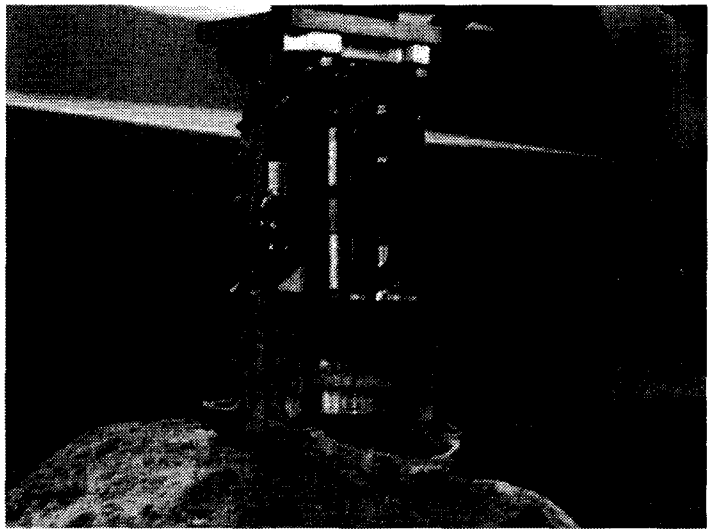
Mössbauer Spectrometer (MB)



Microscopic Imager (MI)



Rock Abrasion Tool (RAT)



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Planetary Protection Requirements

- **PP Category IV-A (MER Planetary Protection Plan, JPL D-19534):**
  - **Documentation**
  - **Probability of impact of Mars by the launch vehicle (or any stage thereof) shall not exceed 10^{-4}**
  - **Probability of accidental impact of Mars due to failure during cruise phase shall not exceed 10^{-2}**
  - **Spacecraft assembled in Class 100,000 clean facilities or better, with appropriate controls and procedures**
  - **Bioburden:**
    - **Total exposed surface bioburden of the landed hardware shall not exceed 3×10^5 viable spores at launch**
    - **Total (all surfaces, including mated, and in the bulk of non-metals) bioburden at launch of hardware for which a hard impact is planned shall not exceed 5×10^5 viable spores minus bioburden allocated to landed hardware (negotiated resolution, MPF precedent)**
    - **Average exposed surface bioburden of the landed hardware shall not exceed 300 viable spores/m^2 at launch**
  - **Organic materials:**
    - **List of organic materials and masses**
    - **50 g sample of any organic material of 25 kg or more is used**

Comparison of PP Implementation MER vs. MPF

Changes Necessitated by Differences in the Missions

- MER backshell exterior surface temperature < 500C during Mars atmospheric entry (MPF was hot enough)
  - MER backshell exterior surface accountable for spore count
  - MER cruise stage has to be clean (even though will be hot enough during entry to be sterilized) because source of recontamination for backshell (i.e., during launch)
  - MER fairing and 3rd stage also source of recontamination for backshell (i.e., during launch)

Comparison of PP Implementation MER vs. MPF

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Improvements in PP implementation

- More use of dry heat microbial reduction, enabled by earlier planning
- More use of High Efficiency Particle Arrestor (HEPA) filter isolation, enabled by earlier planning
- Better "sealing" of Rover Warm Electronics Box (WEB) behind its HEPA filter than the MPF Integrated Support Assembly (ISA)
- Accounting of total spore burden in backshell thermal protection system (TPS) and in structure - honeycomb composite substrate
  - TPS volume and internal surfaces of substrate "trim pieces" assayed directly
  - MER backshells underwent dry heat microbial reduction
  - in MPF and MPL analyses, these materials were thought to have been heated to very high temperatures for a long durations during cures in manufacturing - only true for heat shield. Error corrected for M'01.
- Use of biological indicators in Engineering Model (EM) parachute processing (non-standard heat process) and for flight backshells
- Advisory use of Limulus Amoebocyte Lysate (LAL) assay for rapid screening of surface cleanliness (separately funded research)
- Real measurements of spores in filtered purge gas

MPF on Mars
Showing HEPA Filter on IPA

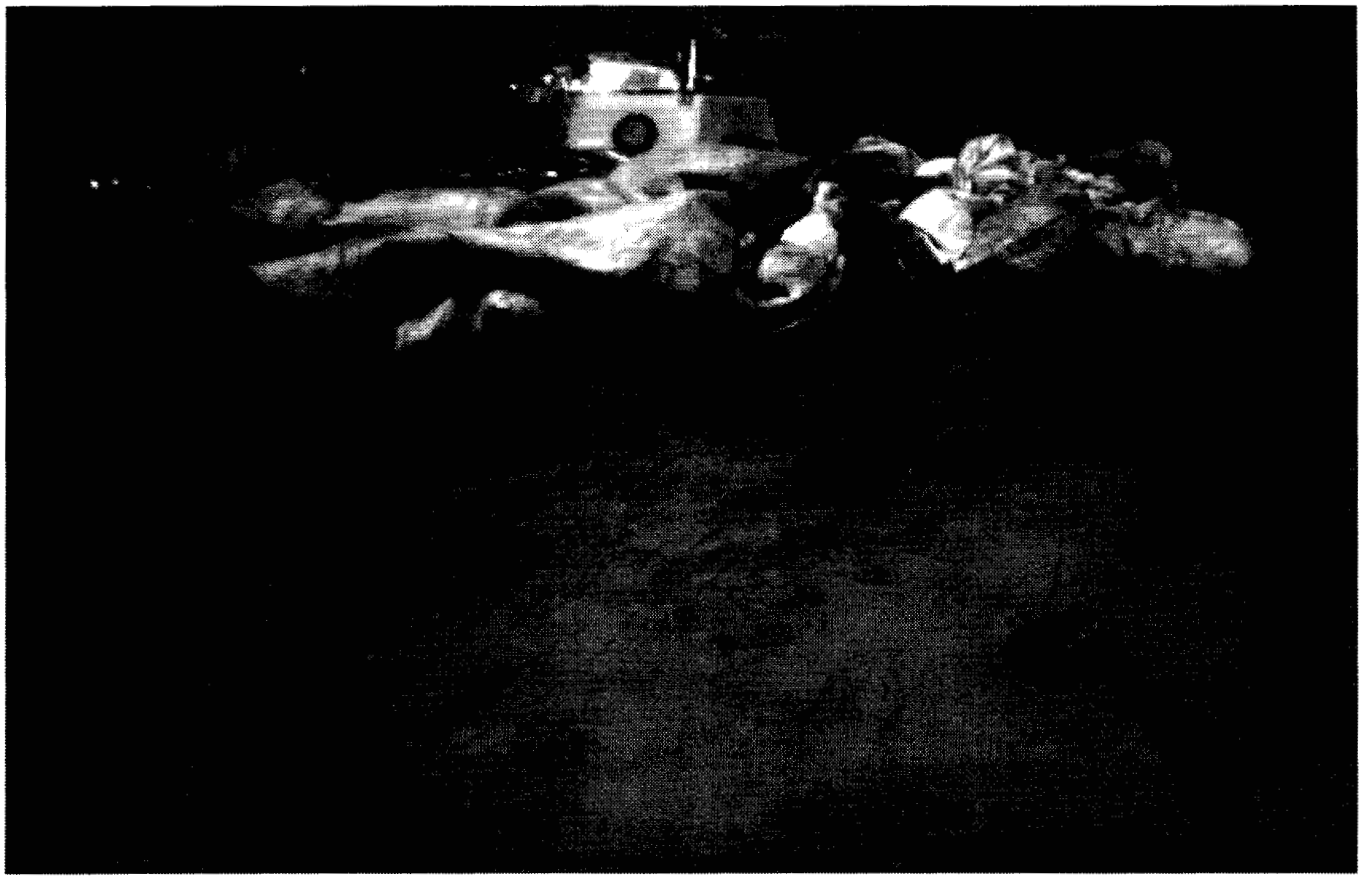

photo credit Sojourner

Courtesy of JPL/Caltech

Comparison of PP Implementation MER vs. MPF

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Challenges in PP Implementation

- Two spacecraft (two landers and two rovers) plus two cruise stages and two launch vehicles (with biological cleanliness measured) vs. one spacecraft (one lander and one rover)
- Tight schedule - 34 months from mission selection to launch
- Greater use of composites and honeycomb structures
- More electronics, batteries, and solid motors on MER backshell
- Increased accountable areas - larger parachute, airbags with twice as many layers
- Greater use of engineering models mounted to flight hardware during system tests

Planetary Protection
Status of Implementation

- **Implementation Plan (as of 01/28/02)**

Hardware By Approach	Fraction of Total Items*(No. of Items)
Dry Heat Microbial Reduction**	59% (254)
IPA Wipe / Rinse Only	26% (113)
WEB Exempt/ HEPA Isolation	13% (55)
Other	1% (5)

- **Best Estimate(9/13/02)*** versus the Spore Burden Requirements**
  - **Landed Hardware - Lander, rover, and parts of aeroshell and of EDL subsystem that are exposed even without impacting Mars**
    $1.7x10^5$ spores vs. $3x10^5$ spores (76 spores/m^2 vs. 300 spores/m^2)
  - **Impacting Hardware - Most of aeroshell, BIP, and backshell-mounted equipment (includes an allowance for part of cruise stage)**
    $1.2x10^5$ spores vs. $2x10^5$ spores
  - **Cruise stage (no requirement, values for source to backshell only)**
    590 spores/m^2

* Percentages based on number of line items, not surface area or bioburden allocation

** Includes Non-standard DHMR & entry sterilization

*** 3 sigma worst case