# Mars Sample Return: Project Science

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Outline of talk:

I. Science Management (PSG, SOWG, Workshops)

II. Science Requirements

III. Sample Contamination Working Group

# Mars Surveyor Program

| *The Common Thread* | *Primary Goals* | | *Resulting Knowledge* |
|---|---|---|---|
| WATER | LIFE | Evidence of Life: Past or Present | Understand the Potential for Life Elsewhere in the Universe |
| | CLIMATE | Weather Processes & History | Understand the Relationship to Earth's Climate Change Processes |
| When Where Form Amount | RESOURCES | Environment & Utilization | Understand the Solid Planet: How it Evolved & its Resources for Future Exploration |

# Mars 03/05 Baseline Science Objectives

1.) Further our understanding of the potential and possible **biological history** of Mars

2.) Search for indicators of past and/or present **life**

3.) Improve our understanding of **climate** evolution and planetary history

4.) Improve our understanding of constraints on the amount and history of **water** on and within Mars

5.) Acquire data to identify areas of possible interest for future scientific **exploration**

6.) Determine the nature of local surface **geologic processes** from surface morphology and chemistry

7.) Determine the spatial distribution and composition of minerals, rocks and soils surrounding the landing sites

8.) Allow for conduct of **HEDS** investigations: Mars environment-human risks and resources, response of biology to environment, technology demonstration critical to human exploration

# Mars Sample Return 2003/2005 Project

Launch May 2003: Lander, MAV, Rover (Delta III-class)

- Arrive at Mars December 2003
- 90 Sols to collect ≥ 500 g rock and soil samples
  - Preliminary design, approximate and subject to change:
  - Rover-collected: drill approx. 35 rock cores (≈4g each) and a few 5 g soil samples (cores or scoop, t.b.d.)
  - Lander-collected: ASI drill cores: approx. 325 g soil or rock, from depths of 0-50 cm
- Launch MAV March 2004 (max. isolation of individual samples)

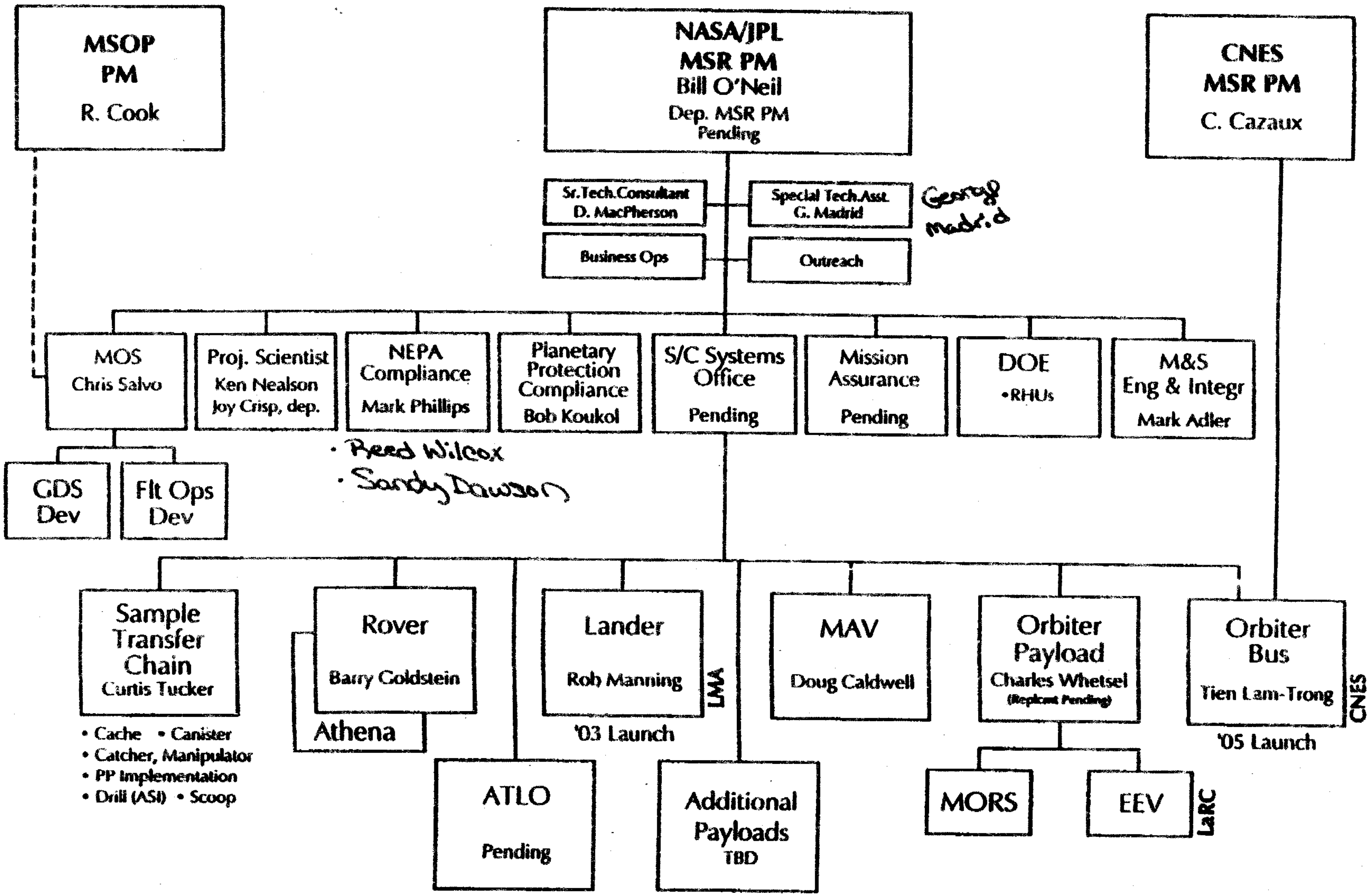
Launch August 2005: Lander, MAV, Rover, CNES Return Orbiter (CNES Ariane 5)

- Arrive at Mars July 2006
- 70? Sols to collect ≥ 500 g rock and soil samples
- Launch MAV October 2006

Leave Mars July 2007

Return two samples to Earth October 2008 $T < 50^{o}C$, < 2000 g's

# Mars Sample Return Project Organization
(Revision Draft)




MSOP: Mars Surveyor Operations Project
MORS: Mars Orbit Rendezvous System
PP: Planetary Protection
MAV: Mars Ascent Vehicle
EEV: Earth Entry Vehicle

11 Aug 99 WJO

NEPA - National Environmental Protection Act
Athena - science payload on

# Mars 2003 Sample Return Project Science Group (PSG)

CoChairs: Ken Nealson (Proj.Sci.), John Grant (NASA HQ)
Members: Joy Crisp, Steve Squyres, Ray Arvidson
Future Members: key people appointed by CoChairs from among the NASA-selected Co-Is and PIs (Athena Team, HEDS, ASI payloads)
First PSG meeting in January 2000?, meet twice a year

PSG helps to optimize mission science return and to resolve conflicting science requirements

PSG may form Working Groups to gather information and study and debate science requirements, policies, and science trade-offs as they affect the scientific success of the mission. Currently, we have one: Science Operations Working Group (SOWG)

# First set of impact tests at Langley:

3 types of rock: chalk, limestone, basalt
- 7mm-diameter cores from a standard drill
- irregular ends, some broken into 2-3 pieces

5 tests: 200, 400, 600, 800, and 1000 g’s
- Peak ≈ 1800 g's for about 0.5 msec in a 4 msec test

18 rock cores per test

Different clearances between core and cylinder hole

Half of the cores were impacted on the base of the cylindrical cores, the other half were on their side

# Acceleration/Shock Requirements

## Critical g-levels for soils?

Soil *physical properties* that may be lost:
- particle-size distributions (breakage of grains), porosities, permeabilities, structures that vary with depth, intergranular cementation

Gooding [1990] used an empirical model to estimate that Viking soil samples (drift, cloddy, and blocky) would likely fail at 7 to 35 g's

Failure depends on length of core and orientation of core when it hits, density of material, and other factors

These low g-levels may not be practical for 03/05

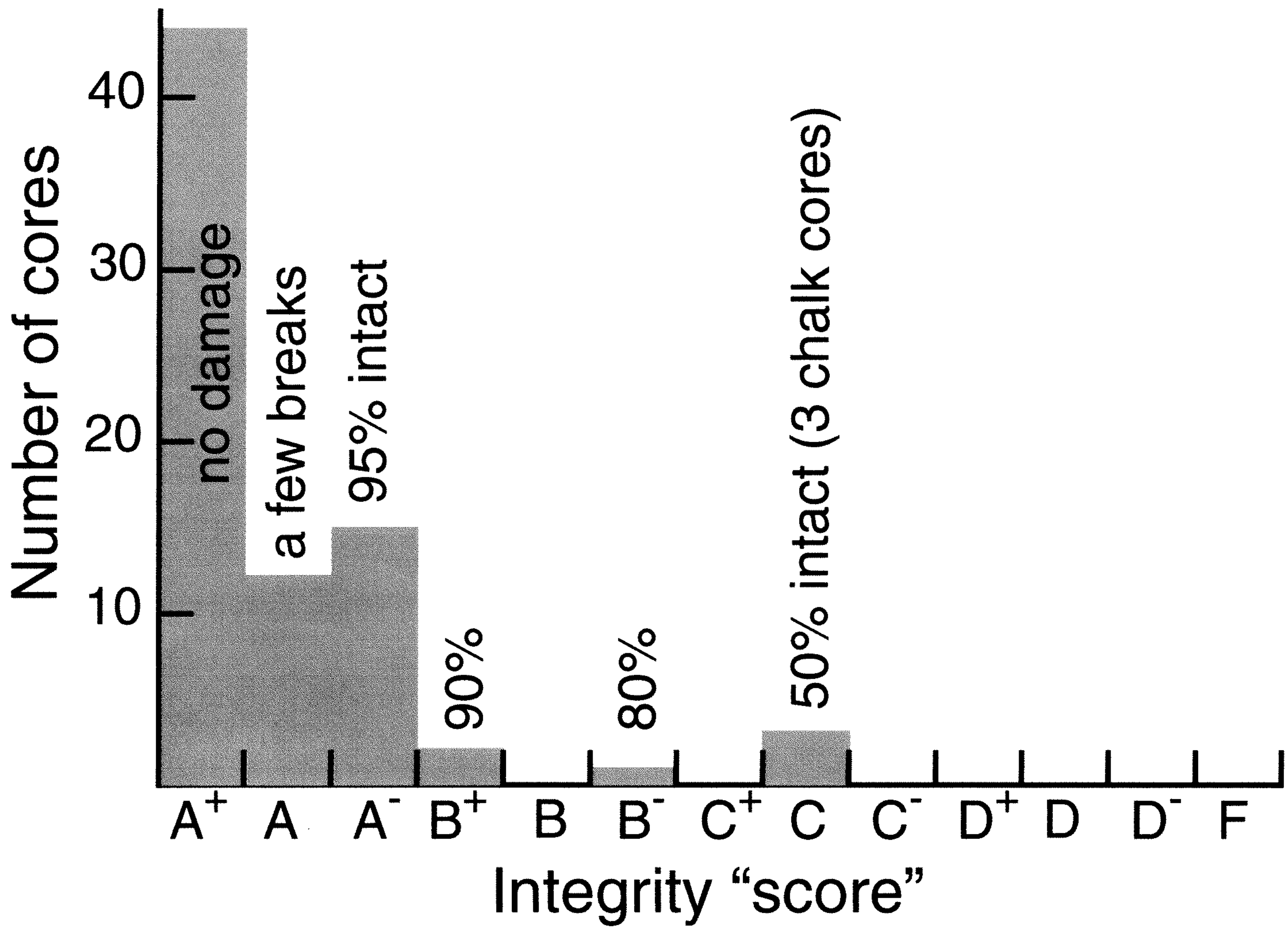
# Critical g-levels for rocks?

Fragile rocks are similar to soils. Low g-levels may be required to preserve *physical properties*: porosity, permeability, grain size distribution, textures, grain cementation.

| | Gooding [1990] g-level estimate for 1-gram cube of basalt |
|---|---|
| *Rock crushing* strengths $10^7$-$10^8$ Pa | 500-5000 |
| *Demagnetization* somewhere below $10^9$ Pa | $5\times10^4$ |
| *Mineral transformations*, melting at $10^{10}$ Pa | $5\times10^5$ |

Current requirement: < 2000 g's

Fragile rocks may break up somewhat, unsure about the remnant magnetism.


Number of cores
40
30
20
10
no damage
a few breaks
95% intact
90%
80%
50% intact (3 chalk cores)
A+
A
A-
B+
B
B-
C+
C
C-
D+
D
D-
F
Integrity "score"

# Mars 2003 Sample Contamination Working Group Meeting August 31, 1999

Sample Contamination Working Group:
Provides advice to the Mars Sample Return Project on biologic, organic, and inorganic contamination issues

☞ This meeting's focus: science recommendations on the degree of terrestrial biologic and organic cleanliness

Follow-on to a "get acquainted telecon" June 18

The Group members were selected by the Project Scientist with approval and additions from NASA Headquarters.

## Group members in attendance:

Ken Nealson, Joy Crisp, Carl Agee, Carl Allen, Andre Brack, Max Coleman, Andre Debus, Theirry Heulin, Chuck Klein, Brian Lanoil, Gene McDonald, Clive Neal, Larry Nyquist, Dimitri Papanastassiou, Daniel Prieur, Steve Squyres, David White

## Group members who could not attend:

Jeff Bada, Steve Benner, Angioletta Coradini, Dave DesMarais, Don DeVincenzi, Bob Hodson, Eric Mathur, Jim Papike

GOAL: For the Group to reach a consensus (all in agreement) by 5:00pm on our recommendations.

* **Group Vision:** Returned martian samples which have levels of terrestrial contamination, which are sufficiently low to retain most of the geologic, biologic, and chemical integrity of the samples and to minimize the chance of a "false positive" identification of prebiotic signatures or (fossil or extant) Martian life.

* **Group Purpose:** To define science requirements related to terrestrial contamination levels that are achievable and scientifically defensible, to provide the science justification, and to make recommendations as to how these can be achieved.

* **Group Mission:** To make science recommendations regarding sample contamination minimization and implementation to the Mars Sample Return Project.

* **Meeting Purpose:** To reach a consensus (acceptance) on specific science requirements

# Near-term Milestones for Mars Sample Return Project

**SRR: System Requirement Review: September 14-16, 1999**

Response to L1 Reqs., CNES, & interfaces between mission elements

**PDR: Preliminary Design Review: December 7-9, 1999**

Preliminary design is complete and complies with requirements
Project is ready to proceed with detailed design

**CDR: Critical Design Review: December, 2000**

Final design is complete, ready to proceed with fabrication, assembly, integration, and test

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Cleaning/Sterilization Methods affect: cost, schedule, design, materials, assembly & integration approach

PP likely to select a few of most promising clean/steril./valid. methods VERY SOON, and complete the methodologies and analyze test results within 6 months

## *Planetary Protection:*

Set the Standards → Meet the standards →

Live with the program → No compromises

## *Engineering and Implementation:*

Define needs → Specify methods →

Get approval → Implement

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## *Science Protection:*

Settle on What is Wanted → Try to meet these goals →

Continually Improve → Live with what you can do (budget, time)

→ Trade and compromise space is here

## *Research and Development:*

Define needs → Develop methods → Improve methods

# What are the Planetary Protection Requirements on levels of biologic and organic contaminants?

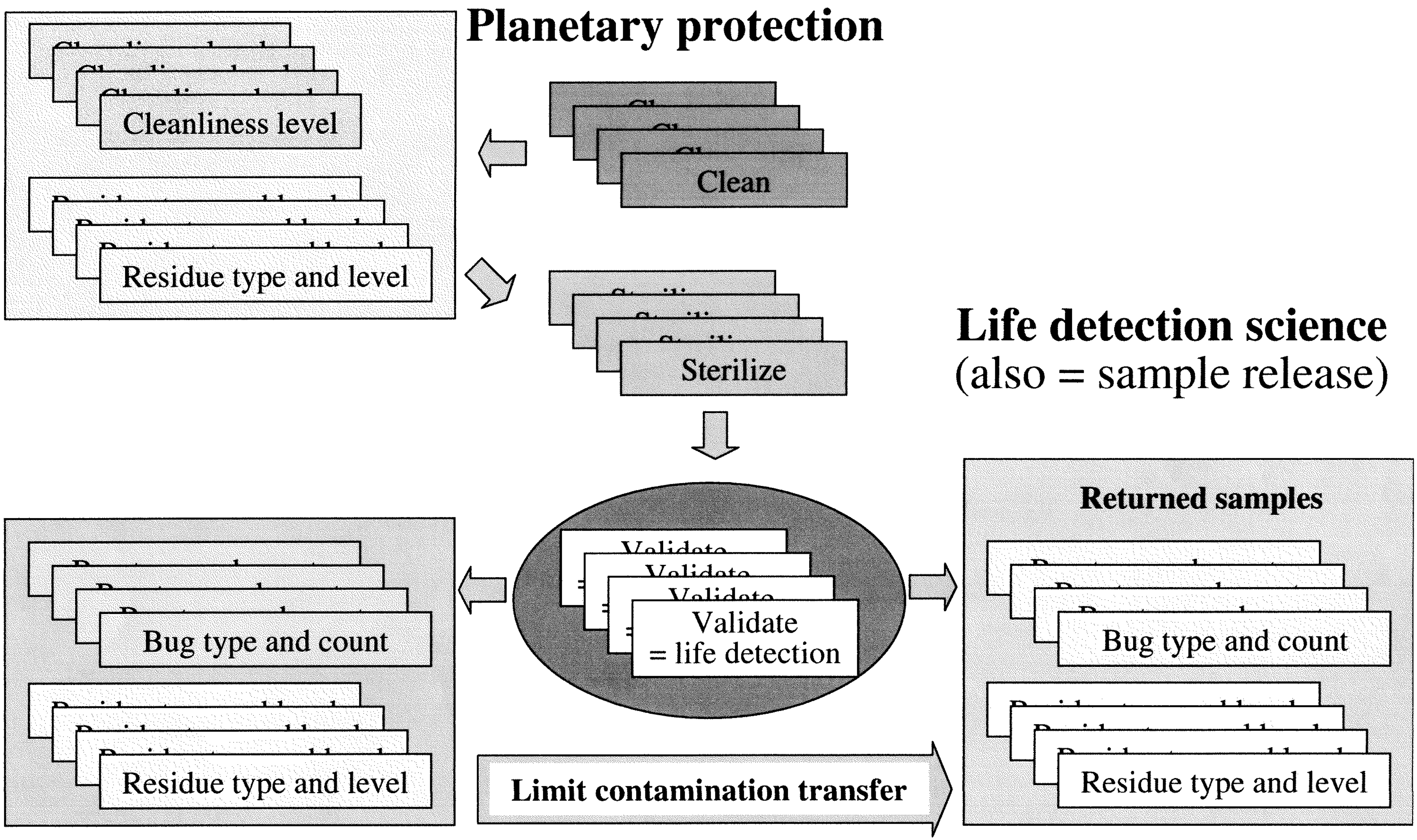
From John Rummel's 6/14 letter to the Project, with my comments in brackets:

[for the lander and rover]
"**Bioburden on exposed surfaces** shall be equivalent to the Viking post-sterilization surface bioload (by inference, **a total of 30 spores**..."

"...**the probability of a single viable Earth organism contaminating the samples** returned to Earth within each sample return canister (orbiting sample/OS) is < $10^{-2}$."

"The OS/EEV... (**organic contamination specifications** for Planetary Protection **are TBD**, pending protocol requirements)."
[OS = Orbiting Sample, EEV = Earth Entry Vehicle]

# Choices, choices




**We cannot afford all combinations, must take a holistic/system view**

## Some of the main discussion points of the June 18 telecon

Witness plates are an important component of being able to intepret any biologic and organic contamination in the returned sample canisters from Mars.

We may be able to distinguish martian biologic/organic materials from terrestrial, but not everyone agrees.

Tracers: (1) if found in the returned sample, we'd know it was from Earth, (2) geochemistry would be compromised by isotopic or inorganic tracers, (3) should not leave considerable residues when applied, (4) should be relatively inert during the trip from Earth to Mars to Earth, (5) could allow detection of minute quantities through label amplification techniques.

Spacecraft Contamination Control used to this terminology:

NASA Contractor Report 4740 Contamination Control Engineering design Guidelines for theAerospace Community, 1996 AC Tribble et al., unclassified, 130pp.

**I. Particulate Contamination**
Agressive, perhaps achievable: S/C: Level 150-200 per MIL-STD 1246C = One 150-µm particle with a pre-defined size/number distribution (linear plot: log number versus log size).    STC parts: Level 50

**II. Molecular Contamination**
Agressive, perhaps achievable: S/C: $\leq$ 1 µg/cm$^2$ (Level A per MIL-STD 1246C)
STC parts: 250 ng/cm$^2$

Need to equate bio-indicators (DNA, proteins, adenines, polar lipids, amino acids, PAHs, LAL, cells) with S/C contamination levels.

MSR PS/PP: Run an experiment with sand in tubes, various cleaning, steriliz., analysis methods, another meeting Oct 14-15 to assess the results.

(handout)

Mars Sample Return 2003 Science Operations Working Group Charter
7/28/99
Draft 1.1

1. Overview

The Science Operations Working Group (SOWG) for the 2003 Mars Sample Return (MSR) Mission is a working group formed by the Project Science Group (PSG) that focuses on operations and archiving. The PSG is responsible for maintaining and updating the SOWG Charter. The Lander Science Operations Subgroup (LSOS) of the SOWG focuses on lander payload-specific issues and activities associated with operations. The Athena Rover Science Operations Subgroup (ARSOS) of the SOWG focuses on rover-specific issues and activities associated with operations.

During the MSR development phase the SOWG will:
(a) Develop a Science Plan and associated observational strategies consistent with the 2003 MSR Mission objectives. This Plan will be subject to approval by the PSG.

(b) Advise the PSG on the ground data system architecture and tools needed to support operation of the payloads and facilities on thelander, and the rover and the Athena Payload for the 2003 MSR Mission.

(c) Provide support for operational readiness tests for the 2003 MSR Mission.

(d) Develop an Archive Generation, Validation, and Delivery Plan for the 2003 MSR Mission.

(e) Ensure that operations and archive planning include consideration of public outreach and educational activities and products for the 2003 MSR Mission.

During the MSR 2003 Mission the SOWG will:
(a) Provide Science Plan updates to the PSG and generate prioritized operational strategies that can be implemented by the LSOS and ARSOS Core Operations Teams (see below). The Science Plan updates, prioritized observational strategies, and sequences will be subject to approval by the PSG. The Core Operations Teams will facilitate generation of conflict-free sets of sequences for the lander and rover, respectively, both for nominal operations and in response to mission anomalies. The SOWG Chairman will try to resolve conflicts associated with plans and will take any unresolved conflicts to the PSG for resolution. Whenever the PSG is unable to satisfactorily resolve these conflicts, the Project Scientist shall recommend solutions to the Program Manager.

(b) Ensure the generation, validation, and release of documented archives to the Planetary Data System on a timely basis.

(c) Ensure that education and outreach activities are properly supported by acquisition of relevant data, generation of appropriate products, and distribution of the products using appropriate outreach and education forums.

The SOWG Chair is a scientist selected by the PSG Co-Chairs. The SOWG Members will consist of payload principal investigators or their designates, appropriate MSR and MSOP personnel, and other persons selected from the PSG by the PSG Co-Chairs. The LSOS Chair will be a principal investigator of one of the lander payloads and the LSOS Members will consist of representatives from each lander payload and relevant MSR and MSOP personnel. The ARSOS Chair will be the Athena Science Payload Principal Investigator and the ARSOS Members will consist of an integrated team of Athena Investigators and relevant MSR and MSOP personnel. The LSOS and ARSOS Members are all Members of the SOWG.

## II. Core Operations Teams

The LSOS COT will be an integrated team of scientists and engineers who generate, under SOWG guidance, conflict-free sequences of commands for lander-based payloads and facilities. The LSOS COT Chairman will be appointed by the Project and will be in residence at JPL to ensure close cooperation among COT Members and among LSOS COT, MSR, and MSOP personnel.

The ARSOS COT will be an integrated team of engineers and Athena Payload Investigators who generate, under SOWG guidance, conflict-free sequences of commands for the rover and the Athena Payload. The ARSOS COT Chairman will be the Athena Payload Principal Investigator or his designate. The ARSOS COT Chairman will be in residence at JPL to ensure close cooperation among COT Members and among COT, MSR, and MSOP personnel.

## III. Core Archiving Team

The Core Archiving Team (CAT) will be a subgroup of the SOWG responsible for implementing archiving plans. The CAT Chair will be appointed by the Project and will include representatives from each lander payload and facility team, the rover and Athena Payload, and Project personnel involved in archiving telemetry and SPICE data.

(handout)

# APPENDIX B-3 TO THE MARS SURVEYOR PROGRAM PLAN: PROGRAM LEVEL REQUIREMENTS FOR THE MARS SAMPLE RETURN MISSIONS IN 2003 AND 2005

13. REFERENCE DOCUMENTS

14. APPROVALS

# APPENDIX B-3 TO THE MARS SURVEYOR PROGRAM PLAN:
## Program Level Requirements for the Mars Sample Return Missions in 2003 and 2005

## 1. SCOPE

This appendix to the Mars Surveyor Program Plan identifies the science, technical and programmatic funding and schedule requirements for the development and operation of the '03 and '05 Mars Sample Return missions of the Mars Surveyor Program (MSP). Requirements begin in Section 4. Sections 1, 2 and 3 are intended to establish the context for the requirements that follow.

This appendix serves as the basis for mission assessments conducted by NASA Headquarters during the formulation and development period and provides the baseline for the determination of the science mission success during the operational phases.

The Mars Surveyor Program will conduct detailed surface and orbital studies to expand our knowledge of Mars and enable the selection of samples for return to Earth. The scientific goals of the program are to understand the climate, resources and potential for life on Mars. The science strategy includes the completion of the global reconnaissance of the planet, surface exploration, and sample return missions. The Mars Surveyor 2003 (Mars-2003) lander and rover, and Mars Surveyor 2005 (Mars-2005) orbiter, lander and rover projects (jointly referred to as the Mars Sample Return mission) support these science objectives by exploration of the ancient highlands of Mars in order to characterize the surface environments in terms of its geologic and hydrologic history.

The Mars Surveyor Program will conduct scientific and technology investigations related to the Human Exploration and the Development of Space (HEDS) goals of preparing for human exploration of Mars and astrobiology, contingent upon an approved HEDS Program Plan and budget.

Changes to information and requirements contained in this document require approval by the Office of Space Science, NASA Headquarters.

## 2. SCIENCE AND EXPLORATION DEFINITION

### 2.1. Baseline Science Objectives

The Mars Sample Return missions will conduct Mars surface sample collection, analysis and return in support of the following science objectives:

1. Further our understanding of the potential and possible biological history of Mars
2. Search for indicators of past and/or present life on the Mars surface.
3. Improve our understanding of Mars' climate evolution and planetary history

4. Improve our understanding of constraints on the amount and history of water on and within Mars
5. Acquire data to identify areas of possible interest for future scientific exploration.
6. Determine the nature of local surface geologic processes from surface morphology and chemistry.
7. Determine the spatial distribution and composition of minerals, rocks and soils surrounding the landing sites.

### 2.2. Baseline Exploration Objectives

The MSR missions will also allow for the conduct of science and technology investigations in support of the following (subject to the availability of HEDS enterprise funding):

8. Understand and characterize the physical and chemical environment of Mars, specifically as related to risk to and resources for human explorers
9. Characterize the response of biology to the Mars environment
10. Demonstrate technologies which will be critical to human exploration and which require testing in the actual Mars environment in order to gain sufficient confidence for their use in an operational system

## 3. PROJECT DEFINITION

### 3.1. Project Organization and Management

The Mars -2003 and Mars-2005 missions will be combined and organized as a stand-alone project named the Mars Sample Return (MSR) Project within the Space and Earth Sciences Program Directorate at the Jet Propulsion Laboratory (JPL).

Program management authority for the Mars Surveyor Program has been delegated from the Associate Administrator for the Office of Space Science (AA/OSS) through the JPL Center Director to the Director for Space and Earth Sciences at JPL. JPL has appointed a MSR Project Manager who reports through the Mars Surveyor Program Manager to the Director for Space and Earth Sciences. The MSR Project Manager is responsible for the overall success of the MSR Project and is accountable to the AA/OSS for the scientific and programmatic success of the project. The MSR Project Manager is responsible for design, development, test, and launch of the spacecraft, and coordinating the work of contractors and investigators. For the scientific investigation and data verification tasks, the Principal Investigator (PI) and/or Science Manager will use the set of approved co-investigators, amended by any approved changes subsequent to the release of this appendix.

The JPL Program Management Council (PMC) is the governing PMC for the MSR Project. The JPL Center Director is responsible for certifying MSR flight readiness to the Associate Administrator for the Office of Space Science. The AA/OSS is the approving authority for proeeding through formulation, implementation, launch, operations, and termination phases.

### 3.2. Project Acquisition Strategy

Through the exercise of an option in the Mars-1998 contract, MSR landers will be built by Lockheed Martin Astronautics (LMA) of Denver, Colorado, contingent on their satisfactory performance on prior MSP projects.

The MSR 2005 orbiter and launch system is expected to be delivered by the French Space Agency (CNES).

The MSR rovers are expected to be provided by JPL; the Mars 2003 rover will be built in-house, and the Mars 2005 rover will be sub-contracted to industry as a "build to print" contract. The Athena payloads are to be developed by the Athena PI, and implemented in collaboration with JPL.

Mars ascent vehicles (MAVs) for caching surface and subsurface samples in Mars orbit will be developed by JPL in partnership with industry and other agencies, with eventual transfer to an industrial partner who will provide subsequent flight hardware units.

The Italian Space Agency (ASI) may provide subsurface drilling and sample collection capability for the landers.

Any payload selection beyond that already mentioned will take place via the AO process, which will be conducted by NASA Headquarters.

## 4. REQUIREMENTS

Unless otherwise stated, the requirements enumerated in this section should be viewed as capabilities required of the missions and the systems being utilized to carry them out, rather than specific operational objectives to be achieved during the missions. During actual flight, prudent operational decisions may result in systems being purposely used to less than required capability, if to do otherwise would jeopardize mission integrity, safety or success.

### 4.1. Project Requirements

The MSR Project shall fly a Martian surface lander in 2003. The lander shall carry a rover and a Mars ascent vehicle. By working with CNES the MSR project will exploit every possibility to fly another Lander/Rover/Ascent Vehicle combination on the Ariane 5 launch vehicle in 2005; it is also intended that CNES provide an orbiter capable of returning Sample Canisters from different landing sites back to Earth in 2008.

Landing sites will be chosen and sample collection designed to maximize the probability of returning samples that may indicate past or extant life, or environments for such life, subject to mission risk considerations.

More specifically, the MSR Project shall meet the following requirements:

1) Return at least one set of samples from the surface of Mars back to Earth by 2008, with a goal of returning sets of samples from two different regions of the planet.

2) Launch a lander and rover to Mars in 2003 launch opportunity, and an orbiter, lander and rover to Mars in the 2005 launch opportunity.
3) Derive the lander spacecraft and rover designs for the 2003 and 2005 missions from a common hardware architecture.
4) Preclude the use of nuclear electric power sources. Radioisotope heater units may be used on landed elements.
5) Archive the acquired science/technology data in the Planetary Data System following a period of less than 6 months for verification, validation, and calibration.
6) The project will work closely with the quarantine and curation team to develop and coordinate a plan for collection of the samples upon their return to Earth and safe transfer to designated secure sites for initial characterization, quarantine and hazard assessment, and for eventual curation and archival purposes.
7) Support planning for future Mars projects through data acquisitions with special emphasis on those observations which could influence landing site selection for future projects.
8) Develop all systems to be consistent with MSOP capabilities and use MSOP for mission operations.
9) Assure that all elements of the mission comply with forward and backward planetary protection requirements, policies and procedures, as specified in NPD 8020.7, NPG 8020.12 and subsidiary documentation, including the Mars Surveyor Program Planetary Protection Plan.
10) Design a United States-only contingency plan for project implementation in the event that one or all international partners are unable to deliver promised capabilities in time to ensure mission success.

### 4.2. '03 Lander Mission Requirements

1) The primary lander payload shall consist of:
   (a) Mars surface rover capable of supporting operations of the Athena payload.
   (b) Athena payload consisting of: panoramic camera stereo/color imager, mini-TES infrared spectrometer, Raman spectrometer, microscopic imager, APXS, Mossbauer spectrometer, mini-corer, sample container, as identified in the selected science proposal.
   (c) Mars sample transfer mechanisms and support infrastructure.
   (d) Mars sample return canister and Mars ascent vehicle.
   (e) Lander-based sample acquisition system to support the collection of samples from the vicinity of the lander and place them in the Mars ascent vehicle. These samples complement the rover samples and will constitute contingency samples in the event of rover failure. The lander-based sample acquisition system shall have a goal of providing samples to the lander-based additional payloads.
   (f) Lander-based camera system for imaging of the immediate lander environment, proximal rover operations, and contingency sample acquisition.

2) The lander shall accommodate at least 40kg of additional payload. The additional payload may include science and technology experiments from

international partners and HEDS-funded human exploration technology experiments.

3) Total sample mass collected (by both rover-based and lander-based means) and launched into Mars orbit during the mission shall be at least 500 grams with a goal of 1000 grams. The sample collection, transfer, and MAV launch systems shall each be capable of handling at least 45 rock cores/fragments plus 10 additional soil/regolith samples. The diversity of the samples collected during each mission will be sufficient to characterize the range in lithologic, pedogenic, and regolith composition and texture encountered in the vicinity of the landing site as defined by the science team after landing. The sample mass used to characterize each lithologic, pedogenic, and regolith component shall be at least 5 gms and at least 35 of these samples shall be collected using the rover-based payload. Context for all samples shall be provided by use of instrumentation on the rover and/or lander.
4) The MAV shall place the samples in Mars orbit for recovery by the Mars 2005 orbiter, with an orbit lifetime that will allow recovery by a Mars 2007 mission in the event of a Mars 2005 orbiter failure.
5) Samples launched by the MAV shall be maintained under conditions suitable for preserving their potential biological and geological integrity until return to Earth.
6) The mission shall be compatible with launch on a Delta III-class expendable launch vehicle.
7) The lander shall be capable of deploying at a selected site within a 20-degree-wide latitudinal band, centered about the –5° latitude line.
8) The lander and rover shall acquire science data and samples for 90 sols, with a goal of rover science data acquisition for 180 sols. The project will develop a mission plan that will define all of the investigations required to meet science objectives during these periods. The mission plan will be approved by NASA Headquarters prior to launch and at least 75% of the data scheduled for acquisition during the primary mission, as specified in the mission plan, will be collected and returned to Earth. As a goal, at least 75% of the data scheduled for acquisition during the extended mission (defined as Mars surface operations which take place after the MAV launch, or after 90 sols), as specified in the mission plan, will also be collected and returned to Earth.
9) Mission communications shall be compatible with any NASA-supplied or NASA-compatible international telecommunications infrastructure (such as the Mars Express orbiter); the lander and rover shall support two-way UHF communication with such orbiting assets. Mission success shall not, however, depend on their availability, and the lander will support direct communications with Earth.
10) The rover shall be capable of operations beyond direct line-of-sight by the lander, and over the horizon from the lander.
11) The rover shall demonstrate a total traverse path length of at least 1 km. This requirement shall be a secondary priority to the primary rover operational objective of acquiring samples and placing them on the MAV. Thus, it is recognized that operational considerations may require that this requirement be satisfied during extended mission operations after MAV launch.

### 4.3. '05 Orbiter Mission Requirements

Under the current architecture, the Mars 2005 orbiter will be provided by CNES, and will be capable of carrying the Earth Entry Vehicle (EEV) for collected Mars samples. The Mars 2005 orbiter will be launched on an Ariane 5 expendable launch vehicle, as a co-payload with the Mars 2005 lander. The primary functions of the orbiter shall be to rendezvous with and capture the sample return canisters placed in Mars orbit by the Mars 2003 lander mission and Mars 2005 lander mission, and safely return the collected samples to Earth for recovery at a controlled landing site. If CNES should be unable to provide this capability, then this requirement will be revised to make the JPL Mars Program Office responsible for the development and delivery of the Mars 2005 orbiter, to be launched on a Delta III-class expendable launch vehicle.

### 4.4. '05 Lander Mission Requirements

1) The lander design shall be the same as the Mars 2003 lander design.
2) The primary lander payload shall consist of:
   (a) Mars surface rover capable of supporting operations of the Athena payload; the rover design will be the same as the Mars 2003 rover design.
   (b) Athena payload consisting of: panoramic camera stereo/color imager, mini-TES infrared spectrometer, Raman spectrometer, microscopic Imager, APXS, Mossbauer spectrometer, mini-corer, sample container, as identified in the selected science proposal.
   (c) Mars sample transfer mechanisms and support infrastructure.
   (d) Mars sample return canister and Mars ascent vehicle.
   (e) Lander-based sample acquisition system to support the collection of samples from the vicinity of the lander and place them in the Mars ascent vehicle. These samples complement the rover samples and will constitute contingency samples in the event of rover failure. The lander-based sample acquisition system shall have a goal of providing samples to the lander-based additional payloads.
   (f) Lander-based camera system for imaging of the immediate lander environment, proximal rover operations, and contingency sample acquisition.
3) The lander shall accommodate at least 40 kg of additional payload. The additional payload may include science and technology experiments from international partners, space science and HEDS-funded human exploration technology experiments.
4) Total sample mass collected (by both rover-based and lander-based means) and launched into Mars orbit during the mission shall be at least 500 grams with a goal of 1000 grams. The sample collection, transfer, and MAV launch systems shall each be capable of handling at least 45 rock cores/fragments plus 10 additional soil/regolith samples. The diversity of the samples collected during each mission will be sufficient to characterize the range in lithologic, pedogenic, and regolith composition and texture encountered in the vicinity of the landing site as defined by the science team after landing. The sample mass used to characterize each lithologic, pedogenic, and regolith component shall be at least 5 gms and at least 35 of these samples shall be collected using the rover-based payload. Context for all samples shall be provided by use of instrumentation on the rover and/or lander.

5) The MAV shall place the samples in Mars orbit for recovery by the Mars 2005 orbiter, with an orbit lifetime that will allow recovery by the Mars 2007 mission in the event of a Mars 2005 orbiter failure.
6) Samples launched by the MAV shall be maintained under conditions suitable for preserving their potential biological and geological integrity until return to Earth.
7) The mission shall be compatible with a launch on an Ariane 5, as a co-payload with the Mars 2005 orbiter, or a Delta III-class expendable launch vehicle as a primary payload.
8) The lander shall be capable of deploying at a selected site within a 20-degree-wide latitudinal band, centered about the –5° latitude line.
9) The lander and rover shall be capable of acquiring science data and samples for 90 sols, with a goal of rover science data acquisition for 180 sols. The project will develop a mission plan that will define all of the investigations required to meet science objectives during these periods. The mission plan will be approved by NASA Headquarters prior to launch and at least 75% of the data scheduled for acquisition during the primary mission, as specified in the mission plan, will be collected and returned to Earth. As a goal, at least 75% of the data scheduled for acquisition during the extended mission (defined as Mars surface operations which take place after the MAV launch, or after 90 sols), as specified in the mission plan, will also be collected and returned to Earth.
10) Mission communications shall be any NASA-supplied or NASA-compatible international telecommunications infrastructure (such as the Mars Express orbiter); the lander and rover shall support two-way UHF communication with such orbiting assets. Mission success shall not, however, depend on their availability, and the lander will support direct communications with Earth.
11) The rover shall be capable of operations beyond direct line-of-sight by the lander, and over the horizon from the lander.
12) The rover shall demonstrate a total traverse path length of at least 5 km. This requirement shall be a secondary priority to the primary rover operational objective of acquiring samples and placing them on the MAV. Thus, it is recognized that operational considerations may require that this requirement be satisfied during extended mission operations after MAV launch.

## 5. COST REQUIREMENTS

### 5.1. Cost Cap

The Mars Sample Return Project shall be designed to cost. Formulation and implementation costs shall be consistent with the Mars Surveyor Program development budget and profile.

The total development cost of the MSR Project shall not exceed $826.7M real-year dollars (exclusive of launch vehicle) during the period from formulation through launch plus 30 days for the final project of the MSR mission (nominally, this will be the period FY99 through FY05). The year-by-year budget profile and funding limits are detailed in Section F "Cost Commitments" of the Mars Surveyor Program (MSP) Program Commitment Agreement, and are included herein by reference.

The cost cap does not include sample handling after Earth landing or upgrades to Earth laboratories to prepare for sample arrival, which are to be funded separately.

### 5.2. Cost Management and Scope Reduction

The MSR project shall be bound by the requirements of the Mars Surveyor Program Risk and Descope Management Policy, under development by the MSP Program Office.

## 6. SCHEDULE REQUIREMENTS

The MSR Project shall meet the following Program-controlled and NASA Headquarters-controlled milestones:

| | |
|---|---|
| • Draft MSR Project Plan | May 99 |
| • System Requirements Review | Sept. 99 |
| • Mission/Flight Systems PDR | Dec. 99 |
| • NASA Phase C Confirmation Review (Approval to proceed to implementation, including final MSR Implementation Plan) | May 00 ** |
| • Mission/Flight Systems CDR | Dec. 00 |
| • 2003 Launch | May 03 ** |
| • 2005 Launch | Aug. 05 ** |

** NASA Headquarters-controlled milestones

## 7. MULTIMISSION NASA FACILITIES

The MSR Project will utilize NASA test and launch facilities at Kennedy Space Center for the Mars 2003 mission. The MSR Project will utilize NASA test and integration facilities at the Kennedy Space Center and CNES launch facilities in Kourou, French Guiana, for the Mars 2005 mission. If the current architecture changes and a United States-only project is implemented, then the Mars 2005 mission will utilize launch facilities at the Kennedy Space Center.

Sample curation and laboratory facilities will not be provided by the MSR Project.

## 8. EXTERNAL AGREEMENTS

The MSR Project will be bound by the NASA MOU with CNES regarding the CNES-provided Mars Orbiter and Ariane 5 launch of the 2005 mission, and the NASA MOU with ASI regarding subsurface sampling capability. Any additional agreements required for mission and project development and implementation shall be identified in the Project Plan.

## 9. PUBLIC OUTREACH AND EDUCATION

The MSR project shall develop and execute a Public Outreach Plan consistent with the requirements and guidelines comprising the MSP Education and Outreach policy now under preparation by the Space and Earth Sciences Program Directorate Outreach and Public Education Office at JPL.

The Project must be engaging to the public and perceived as a step forward scientifically from Mars Pathfinder, Mars 1998 and Mars 2001 projects. A public outreach and educational activity shall be budgeted at approximately 1% of the Project development budget. The Project shall provide for regular public release of imagery and other science/technology data via the Internet, as well as regular releases for public information purposes. The Project must support the public outreach and education activities specified in the selected science proposals.

## 10. COLLABORATION WITH HEDS ENTERPRISE

The MSR project shall work closely with designated representatives of the NASA Human Exploration and Development of Space (HEDS) Enterprise to provide opportunities for HEDS-funded experiments and technology demonstrations, and to utilize any relevant HEDS assets which provide an overall benefit to the program.

## 11. SPECIAL INDEPENDENT EVALUATION

The MSR Project will be guided by the requirements of the MSP Review and Evaluation Plan now under preparation by the MSP Program Office.

## 12. TAILORING (re: NPG 7120.5A)

The MSR project is to be conducted in a fashion that is compliant with NPG 7120.5A. Any unique approaches or tailoring requirements will be identified in the MSR Project Plan.

## 13. REFERENCE DOCUMENTS

1. Mars Surveyor Program Planetary Protection Plan
2. Mars Surveyor Program Sample Management Plan
3. Mars Surveyor Program Risk and Descope Management Policy
4. Mars Surveyor Program Education and Outreach Policy
5. Mars Surveyor Program Review and Evaluation Plan
6. Mars Surveyor Program Technology Plan
7. NPG 7120.5A: NASA Program and Project Management Processes and Requirements

## 14. APPROVALS

________________________

Mars Sample Return Project Manager (JPL)

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Mars Surveyor Program Manager (JPL)

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Director, Space and Earth Sciences Program(JPL)

________________________

Program Scientist, Mars Sample Return (NASA/OSS)

________________________

Program Executive for Solar and Planetary Exploration (NASA/OSS)

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Director, Advanced Technology and Mission Studies (NASA/OSS)

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Director, Mission & Payload Development (NASA/OSS)

________________________

Science Director, Solar System Exploration (NASA/OSS)

________________________

Associate Administrator, Space Science Enterprise (NASA/OSS)

(handout)

# MSR Planetary Protection Requirements

**Jack Barengoltz**

**MSR System Requirements Assessment**
**June 2, 1999**

# PP Requirement Levels

## Requirements to Be Documented in Project PP Plan

- Fundamental Requirements
  - NPD 8020.7E & NPG 8020.12B
- Mission Specific Requirements
  - found in NPG 8020.12B for specific category (mission type & targets)
- Additional Mission Specific Requirements
  - from NASA Planetary Protection Officer (PPO)
  - rulings & interpretations
- Acceptable Approaches to Compliance
  - negotiated between Project and NASA PPO

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# PP Requirement Levels

## Plans to Be Documented in Project PP Implementation and Actual Compliance in Pre-Launch Report

- Implementation Details
  - designed for specific Project elements
  - proposed by Project to NASA PPO for approval (in regard to adequacy for compliance with requirements)

# PP Requirement vs. Project Requirement Levels

| PP Requirement Level | Project Requirement Level |
| --- | --- |
| • Fundamental | • Level 1 |
| • Mission Specific | • Level 1 |
| • Additional Mission Specific | • Level 1 |
| • Acceptable Approaches to Compliance | • Level 2 |
| • Implementation Details | • Level 3 |

# Fundamental PP Requirements

- Protect the future exploration of Mars for life, remnants of past life, and the precursors of life
- Protect the Earth from possible hazards of returned extraterrestrial material

# Mission Specific PP Requirements

- Forward Contamination - Category IVA
  - landed hardware (aggregate):
    - exposed surfaces total spore burden < $3x10^5$ spores
    - exposed surfaces average spore burden density <300 spores/$m^2$
    - assembly and maintenance per Class 100,000
    - landing location reported
  - hardware intended to impact (aggregate):
    - treated per Category III Orbiter with inadequate lifetime
    - surface, mated, & encapsulated total burden < $5x10^5$ spores
    - spore burden **includes** landed spore value for a single mission
    - assembly and maintenance per Class 100,000
    - impact location reported (as feasible)

# Mission Specific PP Requirements
## (continued)

- Forward Contamination - Category IVB
  - landed hardware must be sterile
    - sterility per Viking Lander
    - possibly 30 viable, culturable microbes (spores plus non-sporeformers) (TBS by NASA PPO ruling)

# Mission Specific PP Requirements
**(continued)**

- Forward Contamination - Category III
  - orbiters with adequate lifetime
    - lifetime analysis to demonstrate .01 for launch through launch plus 20 years and .05 for period L+20 years to L+50 years
    - assembly and maintenance per Class 100,000
  - orbiters with inadequate lifetime and hardware intended to impact (aggregate):
    - surface, mated, & encapsulated total burden < $5 \times 10^5$ spores
    - assembly and maintenance per Class 100,000
    - impact location reported (as feasible)

# Mission Specific PP Requirements
**(continued)**

- Back Contamination - Category V, restricted Earth return
  - no accidental Earth impact
  - sterilization of hardware that contacts Mars, or containment
  - containment of unsterilized Martian material

# Additional Mission Specific PP Requirements

- MSR is a life detection mission (NASA PPO) so Forward Contamination - Category IVB
  - landed hardware must be sterile
    - possibly 30 viable, culturable microbes (spores plus non-sporeformers) (TBS by NASA PPO ruling)

# Additional Mission Specific PP Requirements (continued)

- MSP'05 Mission two missions or one (NASA PPO ruling TBS)
  - relative to Forward Contamination burden requirements
  - does CNES Orbiter have separate $5x10^5$ spore limit for hardware intended to impact from another $5x10^5$ spore allowance for the NASA Lander?
- Probability due to all causes of accidental release of Mars material into Earth ecosphere (NASA PPO ruling TBS)
  - leak in containment
  - accidental Earth impact

# Acceptable Approaches to Compliance

## Forward Contamination

- PP specifications of burden density
  - surfaces per Class of contamination control facilities
  - encapsulated burden per volume
- PP specification for standard dry heat process
  - reduction per process control
  - all other processes post-treat assay or (TBD) require indicator
- Direct standard microbial assay
- Entry heating and breakup analysis
  - allows reduction of total burden estimate for hardware intended to impact

# Acceptable Approaches to Compliance

## Forward Contamination (contimued)

- Instead of sterilization of **all** landed hardware (and **all** sample handling hardware), prevention of terrestrial contamination of the returned sample
  - priorities (in decreasing order) are: viable spores and non-sporeformers, non-viable microbes, microbial remenants, biological organics, and organics
  - allowable limits (TBD)

# Acceptable Approaches to Compliance

## Forward Contamination (continued)

- Decreasing hardware burden and cleanliness requirements depending on likelihood of terrestrial contamination of the sample
  - Lander per Category IVA requirements and isolated from below
  - Rover per Category IV B requirements (external surfaces sterile) and isolated from below
  - Sample Handling hardware surfaces sterile and biologically clean
- Analysis to predict worst-case cross contamination

# PP Implementation Details

- Element-specific Sterilization Methods (TBD)
- Element-specific Cleaning Methods (TBD)
- Cleaning Verification Methods (TBD)
- Hardware and operations design requirements to meet cross-contamination requirement
- Containment Methods (TBD)
- Containment Verification Methods
- Hardware and operations design requirements to meet Mars contamination release requirement

# SUMMARY
# Driving Requirements

- Prevention of terrestrial contamination of the sample
  - isolation design
  - operations with repeated return of the Rover
  - lander-based drill sampling beneath the lander
- Cleaning of the sample handling hardware
- Verification of the cleaning of the sample handling hardware
- Sterilization
- Containment of the sample
- Verification of containment of the sample