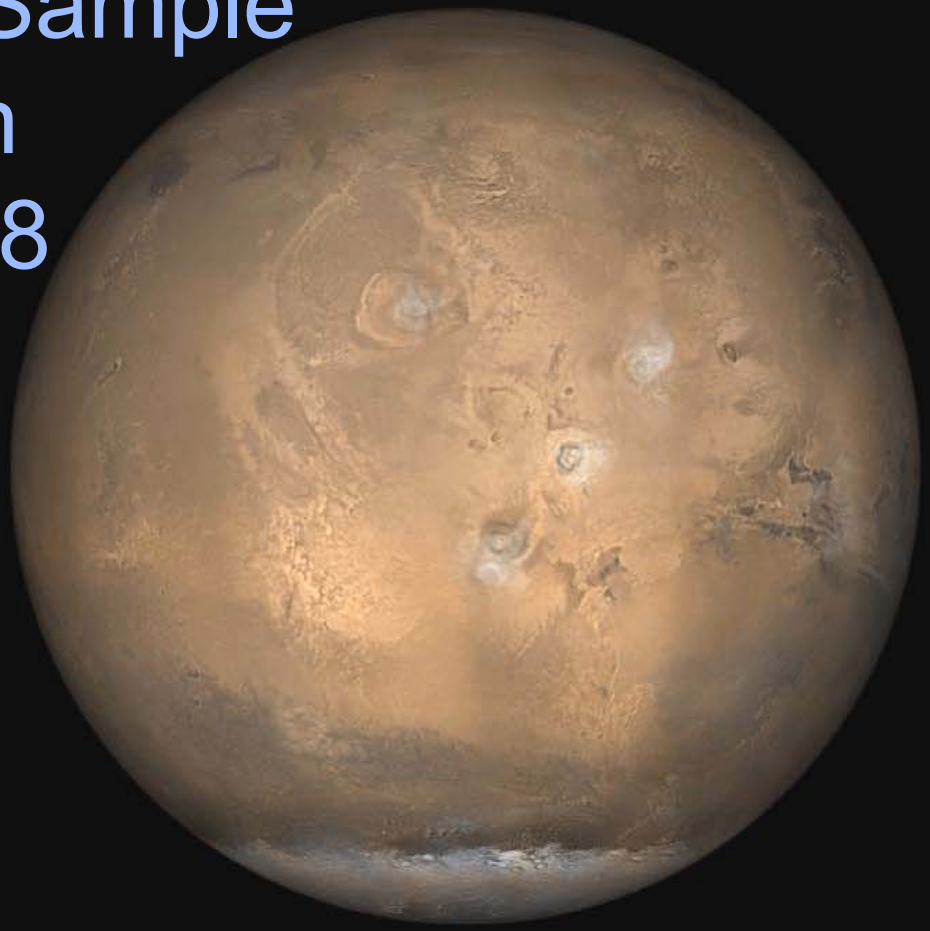
Planetary Protection for Mars Sample Return
4/21/08



Catharine A. Conley
Planetary Protection Officer
NASA HQ

Basic Planetary Protection Policy

(Paraphrased)

- Preserve planetary conditions for future biological and organic constituent exploration
  - *avoid forward contamination; preserve our investment in scientific exploration*
- To protect Earth and its biosphere from potential extraterrestrial sources of contamination
  - *avoid backward contamination; provide for safe solar-system exploration*

Complies with Article IX of the 1967 Outer Space Treaty

The Basic Rationale for Planetary Protection Precautions

(as written by Bart Simpson, Dec. 17, 2000, “Skinner’s Sense of Snow”)

Science class should not end in tragedy....
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Science class should not end in tragedy....
Science class should not

NASA Planetary Protection Policy

- The policy and its implementation requirements are embodied in NPD 8020.7F *(NASA Administrator)*
  - Planetary Protection Officer acts on behalf of the AA for Science to maintain and enforce the policy
  - NASA obtains recommendations on planetary protection issues (requirements for specific bodies and mission types) from the National Research Council's Space Studies Board
  - Advice on policy implementation to be obtained from the NAC Planetary Protection Subcommittee
- Specific requirements for robotic missions are embodied in NPR 8020.12C *(AA, SMD)*
  - Encompasses all documentation and implementation requirements for forward and back-contamination control
- Specific requirements for human missions are under development

Planetary Protection Mission Categories

PLANET PRIORITIES		MISSION TYPE	MISSION CATEGORY
A	Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted.	Any	I
B	Of significant interest relative to the process of chemical evolution, but only a remote chance that contamination by spacecraft could jeopardize future exploration. Documentation is required.	Any	II
C	Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which could jeopardize a future biological experiment. Substantial documentation and mitigation is required.	Flyby, Orbiter	III
		Lander, Probe	IV
All	Any Solar System Body	Earth-Return *"restricted" or "unrestricted"*	V

The Mars Science Strategy, revised: geology is what we can see

Common Thread

i.e., rocks...

W A T E R

When
Where
Form
Amount

Geology

Climate

Life

Prepare for Human Exploration

Understand the geological processes affecting Mars' interior, crust, and surface

Characterize the present and past climate and climate processes

Understand the potential for life elsewhere in the Universe

Develop the Knowledge & Technology Necessary for Eventual Human Exploration

Category IV Requirements for Mars

All landers to Mars must carry < $5x10^5$ heat-resistant organisms ('spores') in total (surface, mated, and embedded), and < $3x10^5$ on exposed surfaces, distributed at < 300 'spores' per m^2.

Category IVb missions comprise lander systems carrying instruments designed to investigate extant Martian life, and must meet either of these more stringent requirements:

Exposed surfaces of the entire landed system must be cleaned and treated to produce a 4 decade reduction in the above levels, or to levels driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent.

OR

All surfaces that may contact the samples must be cleaned and treated to produce a 4 decade reduction, and a method to prevent recontamination be in place. Modeling must demonstrate a low probability of recontamination from untreated hardware.

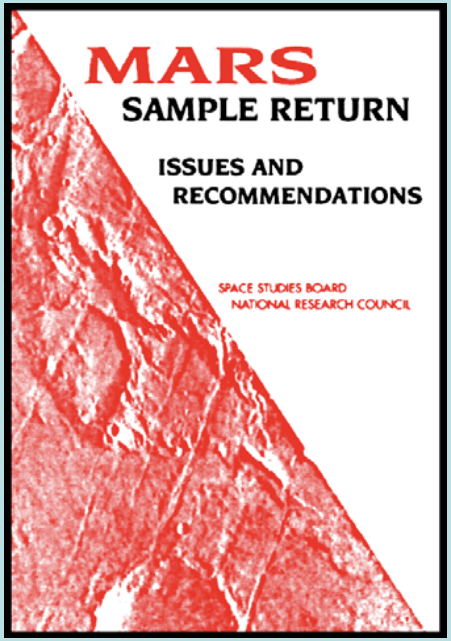
Subsystem vs. System-level Microbial Reduction

- Viking took a system-level approach, using Dry Heat Microbial Reduction to reduce spore counts by 4 decades. It worked -- we didn't grow Earth life in the Viking life-detection experiments
- All subsequent Mars landers have used a subsystem-level approach: Spacecraft were cleaned to meet 'Viking pre-sterilization' levels ($<3x10^5$ exposed surface 'spores' at $<300/m^2$, $<5x10^5$ 'spores' total). For Phoenix, which will dig into a 'special region', the arm was enclosed in a biobarrier and treated with an approved 4-decade microbial reduction, to protect the arm from recontamination until the biobarrier is opened on Mars. This was not cheap.
- MSR will require very complex landed systems: not just an MER-style rover, but also the returned-sample containment system and the Mars Ascent Vehicle. A subsystem level approach for microbial reduction on the landed elements of MSR will be very challenging.

System-level reduction would also allow access to Special Regions.

SSB Advice on Mars Sample Return

(update in progress)



http://books.nap.edu/openbook.php?record_id=5563

- Samples returned from Mars should be contained and treated as though potentially hazardous until proven otherwise
- If sample containment cannot be verified en route to Earth, the sample and spacecraft should either be sterilized in space or not returned to Earth
- Integrity of sample containment should be maintained through reentry and transfer to a receiving facility
- Controlled distribution of unsterilized materials should only occur if analyses determine the sample not to contain a biological hazard
- Planetary protection measures adopted for the first sample return should not be relaxed for subsequent missions without thorough scientific review and concurrence by an appropriate independent body

Category V Requirements for Mars
(NPR 8020.12C)

The Earth-return mission is classified "Restricted Earth return" and is subject to the following requirements:

a. Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol or in the search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all subsequent Mars missions.

b. Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition. A redundant, fail-safe containment procedure...

How do you ‘sterilize’ something when you don’t know what it is?

– The only way to be sure is to destroy it utterly: break molecular backbone (C-C) bonds. Meteorites land without containment, but they’ve been exposed to millennia of solar radiation.

Even afterwards, returned samples still must be verified to be harmless, so ‘sterilization’ en route wouldn’t get you home free...

Category V Requirements for Mars (cont.)

b. [...] A redundant, fail-safe containment procedure with a method for verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

c. The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars. No uncontained hardware that contacted Mars, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the Mars environment shall be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.

d. Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth entry.

e. For unsterilized samples returned to Earth, a program of life detection and biohazard testing or a proven sterilization process shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

Avoiding Back Contamination: Sample Handling

1. Sample Collection at Mars

↓

2. Sample Contained and Isolated

↓

3. Sample Retrieval on Earth

↓

4. Sample Receiving Facility

A) Preliminary Evaluation
- Protect Earth & Protect Samples
- Examination, cataloging and processing
- Sterilization capability

→

B) Hazard Testing
- Life/biohazard: Draft Test Protocol
- Certification

Transfer of sterilized sub-samples
Transfer of samples after Hazard Testing

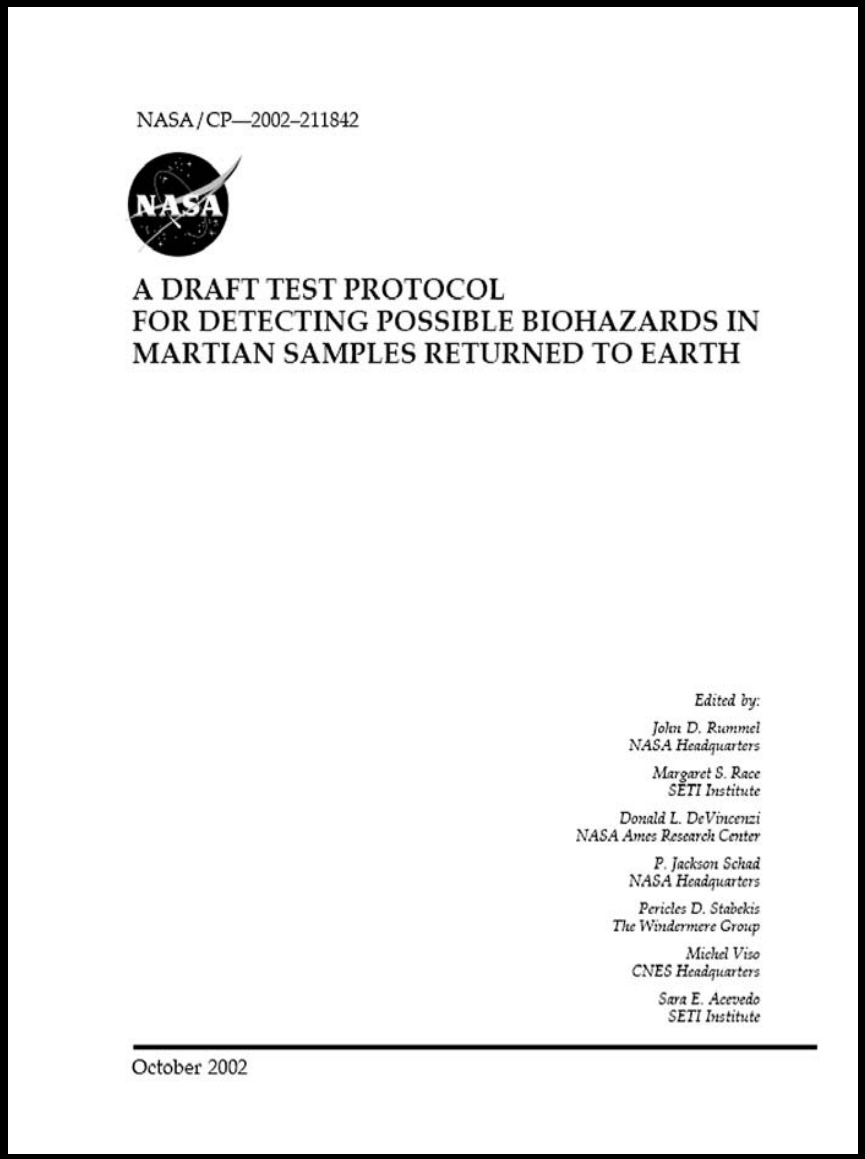
Transfer of non-hazardous sub-samples

5. Sample Curation Facility
- Detailed cataloging
- Isolation and preservation
- Processing
- Distribution

Key SRF Decision Issues
- NEPA compliance
- Location(s)
- Staffing
- Scope
  - Science
  - Future Human missions
- Acquisition strategy

Key SCF Decision Issues
- Location and Staffing

Analyzing Returned Samples: The Draft Test Protocol (2002, **update in progress**)



NASA/CP—2002–211842

A DRAFT TEST PROTOCOL
FOR DETECTING POSSIBLE BIOHAZARDS IN
MARTIAN SAMPLES RETURNED TO EARTH

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October 2002

Planetary Protection

Perform appropriate testing for biohazard evaluation and life detection

Comply with national regulations and legal constraints:

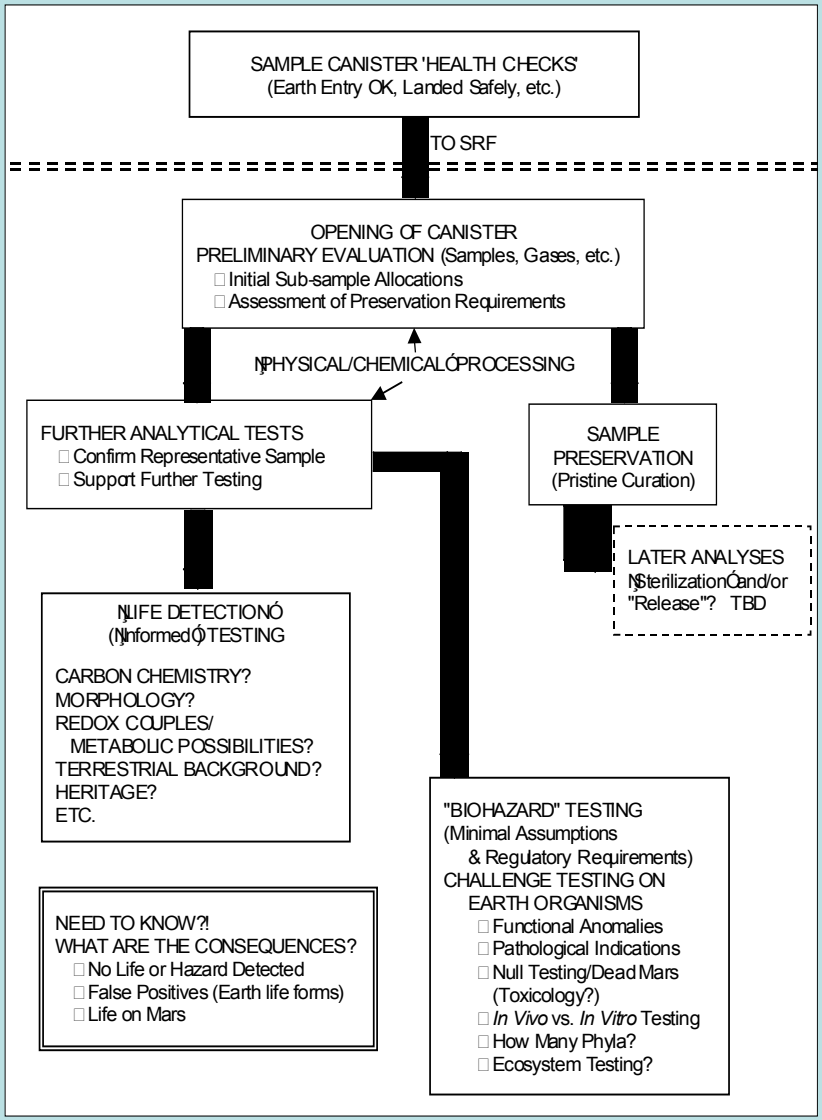
- US National Environmental Protection Act
- US Presidential Directive/National Security Council Memorandum #25

Ensure public communication and involvement to the extent necessary for public acceptance* of Mars Sample Return

The perceived benefits of Mars sample return <u>must</u> outweigh the costs

**and funding!*

Containtment and Testing of Returned Samples



- Facility planning must start ~10 years prior to sample return; milestones tied to mission events
- Protocol update: series of ~5 workshops over the next several years; public comment period and expert review
- Statistics and analyses to minimize amount of sample used for planetary protection
- Verson 1 ready for 2018/20/22 opportunity

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Public Communication is an Issue

- International Committee Against Mars Sample Return

ICAMSR

International Committee Against Mars Sample Return

- In the US, significant public opinion regarding environmental hazards and biocontainment facilities is complicated by distrust of government organizations
  - Article by Olivia Judson in the April 19th, 2004 NY Times:

    The New York Times

    “ Some Things are Better Left on Mars”

Don’t spill it!

New COSPAR Policy for Mars Special Regions

Definition

A Special Region is defined as a region within which terrestrial organisms are likely to replicate. Any region which is interpreted to have a high potential for the existence of extant martian life forms is also defined as a Special Region.

Given current understanding or terrestrial organisms, Special Regions are defined as areas or volumes within which sufficient water activity AND sufficiently warm temperatures to permit replication of Earth organisms. The physical parameters delineating applicable water activity and temperature thresholds, as well as a listing of physical features potentially associated with Special Regions are given below.

- Lower limit for water activity: 0.5; Upper limit: 1.0
- Lower limit for temperature: -25C; No Upper limit defined
- Timescale within which limits can be identified: 500 years

COSPAR Policy for Special Regions on Mars (cont.)

Observed features for which there is a significant (but still unknown) probability of association with liquid water, and which should be classified as special regions:

- Gullies, and bright streaks associated with gullies
- Pasted-on terrains
- Subsurface below 5 meters
- Others, to be determined, including possible geothermal sites, fresh craters with hydrothermal activity, modern outflow channels, or sites of recent seismic activity.

Spacecraft-induced special regions are to be evaluated, consistent with these limits and features, on a case-by-case basis.

In the absence of specific information, no Special Regions are currently defined on the basis of possible martian life forms. If and when information becomes available on this subject, Special Regions will be further defined on that basis.

Category IVc Requirements for Mars

Category IVc missions comprise lander systems that investigate Martian special regions. For such missions, whether or not they include life detection experiments, the following requirements apply:

Case 1. If the landing site is within the special region, the entire landed system shall be cleaned to Category IVa ("Viking pre-sterilization") burden levels and further treated to reduce the total biobuden by 4 decades.

Case 2. If the special region is accessed through horizontal or vertical mobility, either the entire landed system shall be sterilized to the Category IVb microbial burden levels, or the subsystems that directly contact the special region shall be sterilized to these levels and a method of preventing their recontamination prior to accessing the special region shall be provided.

NOTE: If an off-nominal condition (such as a hard landing) would cause high probability of inadvertent biological contamination of the special region by the spacecraft, the entire landed system must be treated according to the first approach.

Avoiding Back Contamination: A Candidate Mars Sample Handling Process

Planetary Protection

Facilities:

- Mobile Retrieval Units (MRU)
- Sample Receiving Facility (SRF)
- Sample Curation Facility (SCF)