Mars Sample Return Planning: Sample Containment and The Draft Test Protocol

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Planetary Protection Subcommittee (PPS) Meeting
NASA HQ  August 4, 2010
**MSR, Containment & The Draft Protocol**

**Decision Making about Planetary Protection**

**Context:**
- Containment
- Accumulating Information & Iterative Process

**Priorities -- Identifying Needs**
- Science – Biological vs. Planetary
- Legal / Policy
- Facility/Technical

**Process in Retrospect - Strategies**

**Lessons Learned... and Issues TBD**
Sample Return Mission: Many Technologies, Activities, Locations

PHASE I
SPACECRAFT OPERATIONS

PHASE II
RECOVERY

PHASE III
LRL
SAMPLE CREW SPACECRAFT

CREW RETRIEVAL

LRL
RELEASE

MQF

APOLLO BACK CONTAMINATION PROGRAM
Rigorous Test Protocol…
No ET Life or Biohazards
On the Moon…
Astronauts and Rocks
Released From Quarantine

NASA Team Members prepare the first container of lunar samples for transport back to Houston. Apollo 11 returned 46 lbs. of lunar content.
Fast Forward to ‘90’s

- **Martian Meteorite** (Aug. 1996)
- **Pathfinder and Sojourner** (July ‘97)

*Even as ALH debate continued...*

- NASA began Planning MSR missions—
  - Mars opportunities every 26 months
  - 2003, ‘05, Samples Returned ‘07

- Recognized changes since Apollo
  - Science, technology, legal/policy, public

- Misc. studies underway.. MELTSWG (Quarantine, Curation, etc.)

- NASA Asked NRC to study MSR issues (‘96-97)
• **NASA Charge to Committee:**
  - Likelihood of Return ET Life in Samples
  - Risk of Pathogenicity or Large Scale Impacts
  - How Reduce risks?

• **NRC Recommended: Conservative Approach**

• **Containment**
  - Samples contained & treated as potentially hazardous
  - No uncontained martian materials returned to Earth (unless sterilized)
  - Break Chain of Contact with Mars; Maintain Containment Integrity
  - On Earth, No distribution of unsterilized materials unless
    - Rigorous analyses demonstrate no ET life or biological hazard
    - Materials sterilized first

• **Sample Evaluation**
  - Rigorous analyses… Protocol TBD

• **Program Oversight**
  - Establish Interagency Panel to coordinate & advise on implementation
  - Administrative structure within NASA to verify & certify PP adherence

• **Keep Public Informed**
Priorities/ Issues of Importance - Pre-Protocol Workshops

No Existing Facility meets containment & science needs
Tension over Biohazard and Planetary Science Needs (cleanliness)

- **Containment** - Build on Apollo but update and revise
  - Focus on Sample Canister and Receiving Laboratory (BSL-4)
  - Mission Architecture– PP concerns built into many part of mission
  - Identified R&D needs (filtration; canister verification; false positives; cleanliness, sterilization, etc).

- **Life Detection** – Preliminary Protocol built on
  - Organic chemical analyses/detection (functional groups assoc. with energy transfer)
  - Light and/or electron microscopy (SEM, TEM)– for screening
  - Culturing of secondary importance
  - NASA needs to focus on new life detection technologies/methods

- **Biohazard**  Preliminary Testing Protocol
  - Emphasized Chemical Toxicity & Pathogenicity
  - In vitro methods rather than whole organism tests
  - Microcosm tests for ecosystem effects (TBD)
  - Attempt to outline Criteria for Release (no consensus)

- **Oversight/ Certification/ Verification**
- **Legal Requirements /Compliance**
- **Public Information**
Mars Sample Handling/ Protocol Workshops
(Planned 1999  Implemented 2000-02)

Protocol Process

1. Workshop 1: March 2000 Bethesda MD (Rummel & Race, 2000)
2. Workshop 2: Oct. 2000, Bethesda MD (Race et al. 2001a)
3. Workshop 2a: Nov. 2000, Rosslyn VA (Bruch et al, 2001)
5. Workshop 4*, June 2001, Arlington VA (Race et al., 2001)
  * Advance Copy (May 2001) of SSB/COMPLEX Rept.: Quarantine & Certification of Martian Samples

THEN

• Consensus Working Draft of Protocol, June 2001
• Oversight and Review Committee  (Oct-Nov 2001) (NYC)
  (NOTE: Post 9/11 and Anthrax Attacks)

• Draft Test Protocol for Detecting Possible Biohazards in Martian Samples Returned to Earth (October 2002)
Entire Protocol = “Rigorous Analyses” Plus...

1. Containment

Figure 2. A simplified overview of the Draft Protocol showing the 3 main segments: Physical/Chemical processing, Life Detection, and Biohazard testing.
Entire Protocol = "Rigorous Analyses" Plus...

1. Containment

2. Initial Processing

3. More P/C tests; sample selection

3. Pristine Curation
Entire Protocol = “Rigorous Analyses” Plus...

1. Containment

2. Initial Processing

3. More P/C tests; sample selection

3. Pristine Curation

4. Life Detection

4. Biohazard Testing

Environment & Health Monitoring and Safety

Database & Info Handling

Personnel Management, Training, Oversight Committees
Figure 3. The Physical/Chemical processing will occur in four sequential stages leading into the Life Detection and Biohazard testing. The numeric annotations refer to numbered sections of text below, which elaborate on the proposed P/C steps.
Nitrogen Gas Environment
15C
1 mg/sample

SELECTED SUB-SAMPLES

Gas
Filtrate
Flow cytometry sorting

-

Laser Raman
PCR Sequencing

+

LAL
Culture/Microscopy

If <2000μ

If >2000μ

Pebbles-cores

If cracks or pores/
preparation homogenates

Broad Band Fluorescence

3D Tomography

Sealed container in an
outside X-ray facility
(benchtop systems
under development)

Laser Raman benchtop
instrument

Non-destructive

Figure 4. Life Detection Process Flowchart.
GAS PHASE (adjacent to Mars samples)

FILTRATION (cut-off TBD)

SAMPLE
Fines 50–100 g
Rocks/Cores?

BIOHAZARD TESTING

HAZARD TESTING
Chemical & Radiological Tests

SAMPLE PREPARATION
• Raw material
• Extracts

INPUT FROM LIFE DETECTION TESTING

IN VITRO TESTS
CELL CULTURES TBD EXAMPLES:
• Initial:
  • Human cell lines
  • Primary cell cultures
  • Mouse cells
  • Microbial systems
• Subsequent:
  • Secondary mammalian cell cultures
  • Plant cell systems
  • Additional microbes
  • Other species

MOLECULAR BIOLOGY TESTS
• DNA damage
• Altered gene expression
• Altered proteins/metabolites

IN VIVO TESTS
WHOLE ORGANISM SYSTEMS TBD EXAMPLES:
• Murine (SCID mice)
• Insects (Drosophila)
• Mammalian eggs
• Bird & fish eggs
• Fish (zebrafish, medaka)
• Plants (Arabidopsis, rice)

MODEL ECOSYSTEM

ADDITIONAL IN VIVO, IN VITRO, & MOLECULAR TESTS TO BE CONDUCTED IN FPL-8 IF INITIAL CELL CULTURE TESTS ARE NEGATIVE

Data Interpretation
Table 1. Anticipated laboratory conditions and PPL categories. Note: Levels of cleanliness associated with each PPL are TBD and should be defined explicitly well in advance of sample return.

Figure 6. Sequential containment requirements by test category.
Additional Considerations Related to Containment and Protocol

Facility, Technological & Other Concerns

• ? If ET life discovered: Review adequacy of facility, tests, equipment and emergency plans etc.
• International Complications? (where will sample go?)
• Need organized Communication Plan in advance
• Contradictory/Inconsistent Results—Multidisciplinary Input
• Ensure application of Release Criteria (international review)
• Anticipated Breach of Containment/Emergency Plans
• Documentation of Operations, Biosafety etc.

Maintain and Update Protocol

• International review with partners (national academies of science)
• Ethical and Public Reviews of Sample Return
• Future Modifications to Protocol (in advance and real time)
Figure 11. Protocol update and implementation process.
Where We Stand Now

2009 NRC Study: Reassessment of MSR

• Concur with 1997 Study plus:
  – Verify Seal- Emphasis on containment rather than Monitoring en route
  – Need Examine Samples at Microscale (address sample heterogeneity)
  – Small Amounts of Materials (Representative; Non-Destructive?)
  – Transport Containers (multiple labs?)
  – Criteria for Release TBD
  – Longer Time to Commission Labs (10 years+)

• Other Concerns
  – EIS complications? (Based on BSL-4 lab concerns)
  – Question about Animal Studies- (Needed? Advances in Molec. Biol.)
  – False Positives of concern to both PP and Science
  – Public Opposition? ($$; Risks; ex. ICAMSR)
  – Wild Card: ET Discovery; Ethics and PP

NASA-ESA Joint MSR missions:
2016, 2018, 2020+
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QUESTIONS?