

Protecting our Planet from Extraterrestrial Life:

Safe Solar System Exploration

John D. Rummel

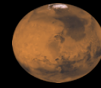
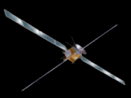
SETI Institute and

McGill University

<jrummel@seti.org>

Importing Astronomical “Samples”: The Dark Side of Astrobiology

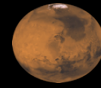
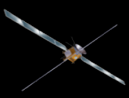




Astrobiology's “Big Questions”

- How does life begin and evolve?
- Does life exist elsewhere in the Universe?
- What is the future of life on Earth and beyond?

– *To the extent that those answers can be found within our own solar system*



COSPAR Planetary Protection Policy:

Protect Science, Protect the Earth

- “The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized”

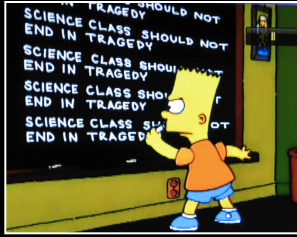
Avoid forward contamination; don't “discover” life we brought with us

- “The Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from by a spacecraft returning from an interplanetary mission”

Avoid backward contamination; don't contaminate the Earth

- “For certain space-mission/target-planet combinations, controls on organic and biological contamination carried by spacecraft shall be imposed”

Tailor requirements by target location and mission type



In the words of Bart Simpson*,

“Science Class Should Not End in Tragedy”

**Skinner's Sense of Snow*, December 17, 2000

Apollo-Era “Restricted Earth Return” Back Contamination’ Control is Not a Guide for Future Missions



What happened to the water that got into the capsule?



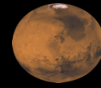
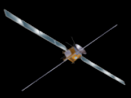
But we didn't go to the Moon to find life, and most scientists didn't believe that the Moon had any.

Apollo-Era Restricted Earth Return: Lax ‘Back Contamination’ Control, But *We Got E.T.!*

The character, “Keys” in E.T. was intended to be the NASA Planetary Protection Officer (although that role was vigorously denied by the NASA General Counsel, who pointed to *Immigration and Naturalization*).



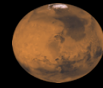
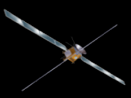
Under NPD 8020.14, the Planetary Quarantine Officer could arrest anyone who was “extraterrestrially exposed,” although technically only while they were on the grounds of the MSC. It was cancelled in 1992.



Biological Invasions are No Joke (1)

1. In 1859, an English farmer by the name of Thomas Austin introduced just 24 grey rabbits to his plot of land in Australia to remind him of home
 - They caused serious erosion of soils across the continent by overgrazing and burrowing, and are believed to be the most significant known factor for species loss in Australia's history
 - By 1900, the Australians were killing 2 million rabbits a year, without lowering the population
 - They are currently controlled by an introduced virus (rabbit haemorrhagic disease virus [RHDV] or myxomatosis)





Biological Invasions are No Joke (2)

2. The Kudzu vine was first brought to the United States in 1876 when it was featured at the Philadelphia Centennial Exposition as a hardy, fast-growing vine that could help inhibit soil erosion
- It is also known as the "mile-a-minute vine" or "the vine that ate the South"
 - Kudzu has been spreading across the U.S. at a rate as fast as 150,000 acres annually, due primarily to the fact that its individual vines can grow upwards of a foot per day



Winter



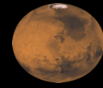
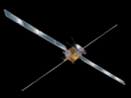
Spring



Mid-Summer



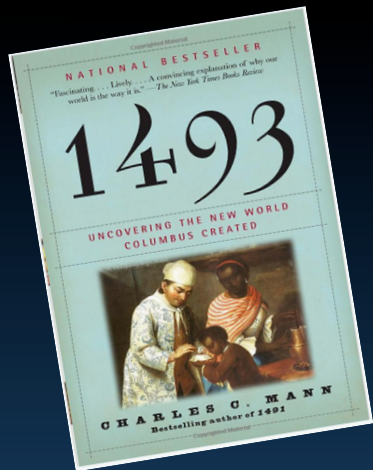
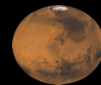
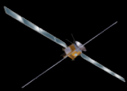
Early Fall



Biological Invasions are No Joke (3)

3. The chestnut blight was accidentally introduced to North America around 1904 when *Cryphonectria parasitica* was introduced into the United States from Japanese chestnut nursery stock
 - The fungus is spread by wind-borne ascospores affecting the American chestnut tree
 - In the first half of the 20th Century it killed an estimated 4 billion trees, having a devastating economic and social impact on communities in the eastern United States
 - In the Appalachian Mountains, one in every four hardwoods had been an American chestnut

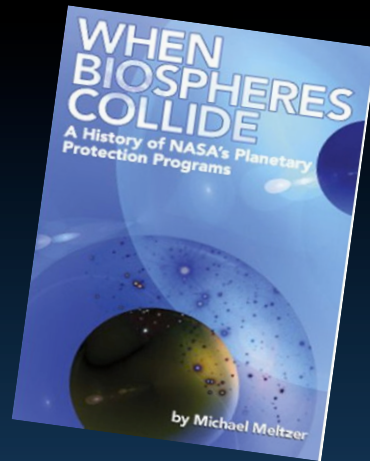




Planetary Protection

Fulfills a Dual Purpose:

- ✓ Ensure that *science is not compromised*
- ✓ *Safeguard Earth's biosphere* from harmful contamination carried in returned samples



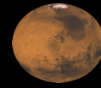
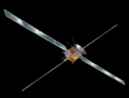
Embodied in the **UN Outer Space Treaty of 1967**

Consensus Policies Developed by **COSPAR** since 1958

Planetary Protection Measures for Robotic & Human Missions

- Updates based on Changes in Science
- Avoid:
 - ✓ Forward Contamination
 - ✓ Backward Contamination

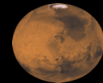
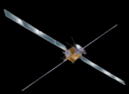




Astrobiology Strategy (2015)

“What role does planetary protection play in astrobiology?”

- How do we mitigate the bias in our search for life on other worlds that would be introduced if we – either accidentally or through human exploration – brought Earth-based life with us to other planets?
- If astrobiological research requires samples to be returned to Earth from potentially habitable environments, how do we protect Earth life from competition or invasion from alien organisms?”



- SSB (1998) *Evaluating the Biological Potential in Returned Samples from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making*

— Was applied to these three sample return missions for their approval as “unrestricted Earth return”:



Stardust

OSIRIS-REx



Hayabusa

COSPAR Policy Adopted from SSB Small Bodies Report

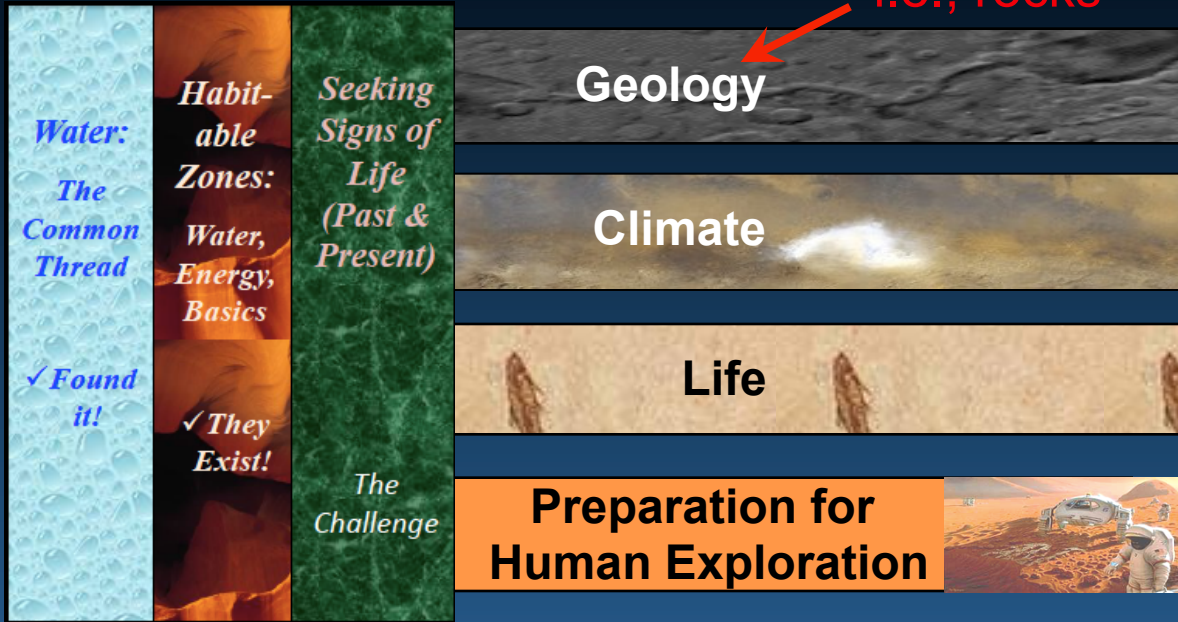
Category V. Determination as to whether a mission is classified “Restricted Earth return” or not shall be undertaken with respect to the best multidisciplinary scientific advice, using the framework presented in the 1998 report of the US National Research Council’s Space Studies Board entitled, *Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making* (SSB 1998). Specifically, such a determination shall address the following six questions for each body intended to be sampled:

1. Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?
2. Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?
3. Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO₂ or carbonates and an appropriate source of reducing equivalents) in or on the target body to support life?
4. Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160°C)?
5. Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?
6. Does the preponderance of scientific evidence indicate that there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

For containment procedures to be necessary (“Restricted Earth return”), an answer of “no” or “uncertain” needs to be returned to all six questions.

The Mars science strategy, reorganized: Study samples to aid in understanding...

Common Threads



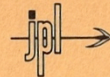
i.e., rocks

- 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
- Develop the knowledge & technology necessary for eventual human exploration

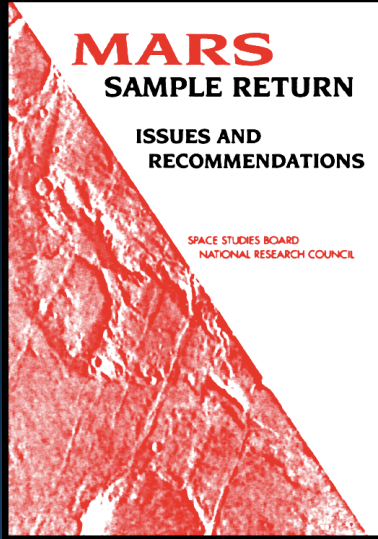
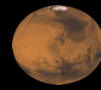
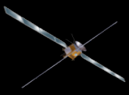
MARS SURFACE SAMPLE RETURN QUARANTINE PLANNING STUDY

FINAL PRESENTATION

17 November 1976



JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, California



US Space Studies
Board (1997)
Recommendations
on Mars Sample
Return

- Samples returned from Mars should be contained and treated as though potentially hazardous until demonstrated 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 that the sample does not 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

SSB Recommendations for Mars Sample Return (cont.)

Technology Issues

- Avoiding contamination of returned samples with organisms or organic material of terrestrial origin–

“It will be important to stringently avoid the possibility that terrestrial organisms, their remains, or organic matter in general could inadvertently be incorporated into sample material returned from Mars. Contamination with terrestrial material would compromise the integrity of the sample by adding confusing background to potential discoveries related to extinct or extant life on Mars....Because the detection of life or evidence of prebiotic chemistry is a key objective of Mars exploration, considerable effort to avoid such contamination is justified.”

- In-flight sterilization
- Sample handling and preservation
- Ensuring sample containment
- Avoiding return of uncontained martian material



Prior-to or with Humans on Mars: Category V Restricted Earth Return Requirements

NASA/CP—2002-211842



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

MARS

SAMPLE RETURN

ISSUES AND RECOMMENDATIONS

SPACE STUDIES BOARD
NATIONAL RESEARCH COUNCIL

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**Mars Sample Return backward
contamination - Strategic advice
and requirements**
Report from the ESF-ESSC Study Group on MSR Planetary
Protection Requirements.

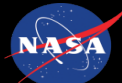
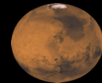
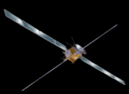
- Previous requirements developed over decades of MSR preparation and adopted by COSPAR
- ESA and NASA are continuing a program of requirements refinement
- Key recommendations driving implementation:

NRC: samples returned from Mars by spacecraft should be contained and treated as though potentially hazardous until proven otherwise

ESF: a Mars sample should be applied to Risk Group 4 (WHO) *a priori*

NRC: No uncontained martian materials ... should be returned to Earth unless sterilized. ESF: the probability of release of a potentially hazardous Mars particle shall be less than one in a million

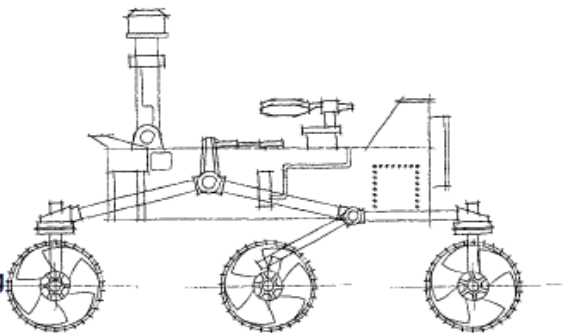
Both: Protocol development is still in early stages



Mars 2020

Spacecraft and Mission Introduction, Science
Cleanliness and Planetary Protection Work-to-Date

Planetary Protection Subcommittee Meeting
NASA HQ
12/9/15



Mars 2020 Project

CL# 15-5533

Meanwhile, the Mars 2020 mission is planned as the first mission in a series that will include the first sample-return for the Mars Program*

We would probably like to avoid studying round-trip contamination from those missions, as well

* It is possible that SpaceX/Elon Musk will take a more direct approach sometime in the mid-2020s. They are covered by the same treaty as NASA, et al.

DECADAL SURVEY MSR CONCEPTS

Sample Caching Rover



- MSL-heritage Skycrane EDL
- MAX-C Rover (solar powered)
 - Sample Caching System
 - Instrument suite for sample selection/context
 - 2 integrated caches, each w/ 19 sample tubes

Key Technologies

- Sample Caching System
- Terrain Relative Navigation

Sample Return Lander



- MSL-heritage Skycrane EDL
- Pallet Lander
 - Fetch Rover (157 kg)
 - Mars Ascent Vehicle (2-stage Solid-Solid)
 - 17-cm OS

Key Technologies

- Mars Ascent Vehicle
- Fast Fetch Rover

Sample Return Orbiter

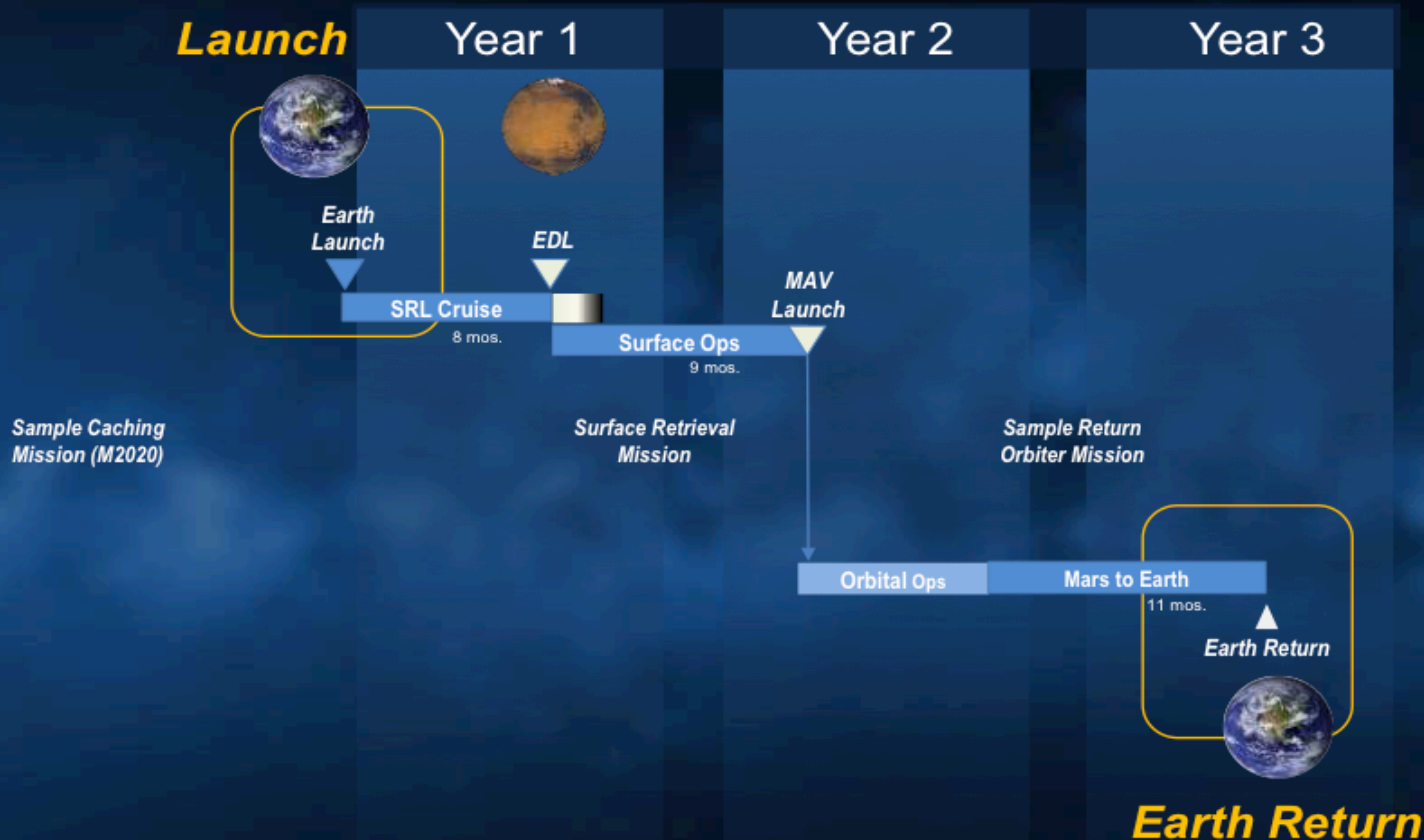


- Round-trip Orbiter (Chemical Propulsion)
 - MOI, Aerobrake
 - OS Rendezvous & Capture
 - Earth Return
 - Earth Entry Vehicle
- Mars Returned Sample Handling

Key Technologies

- OS Rendezvous and Capture
- Back Planetary Protection

NOTIONAL MSR TIMELINE



SAMPLE RETURN: KEY REQUIREMENTS

LAND in the right place

Land in small landing error ellipse (≤ 10 km) to access M2020 sites



COLLECT samples fast

Long traverse with tight timeline



- 130 sols for driving km (rover odometry)
- 20 sols for tube pickup (1 tube/sol)
- 90 sols for faults/anomalies/engineering activities



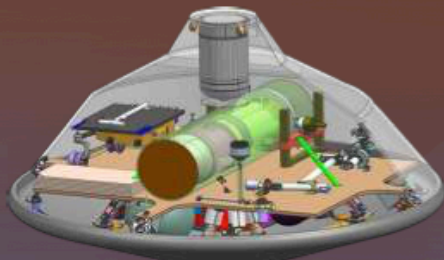
Get it BACK

Launch, rendezvous and return



TWO LANDER CONCEPTS

2017 Highly Integrated Concept



*Propulsive Platform Lander (PPL) Concept
Packaged in MSL 4.5m Aeroshell*

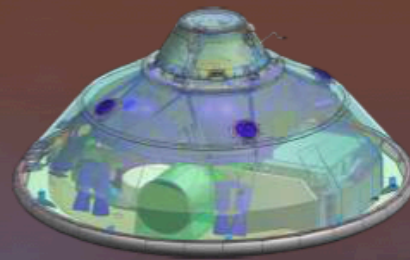


*Propulsive Platform Lander
Concept Deployed*

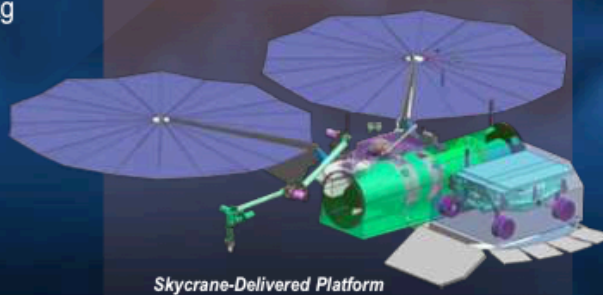
Common Attributes

- Identical cruise and entry architecture
- ~ 10 km landing ellipse
- ~ 900-1000 kg landed useful mass
- Accommodates ~ 600 kg MAV and Fetch Rover

Evolved 2011 Decadal Concept



*Skycrane-Delivered Platform Concept
Packaged in MSL 4.5m Aeroshell*



*Skycrane-Delivered Platform
Concept Deployed*

Two concepts that leverage Mars program legacy system capabilities

NOTIONAL SAMPLE RETURN ORBITER

Design for Orbital Rendezvous & Fast Sample Return

- Rendezvous & Capture
- Containment and Earth Planetary Protection
- Communication Relay Support for Surface Ops and Critical Events
- Return to Earth, either via
 - Direct return to Earth
 - Deliver to cis-lunar space for human-assisted returns

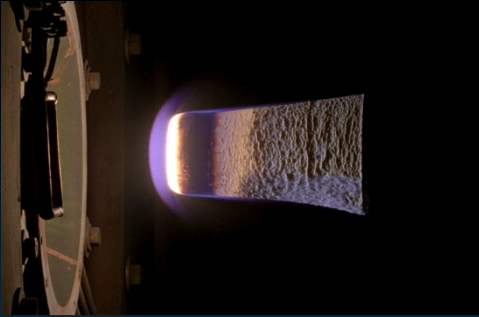
Implementation Options

- NASA provided
- Partner provided





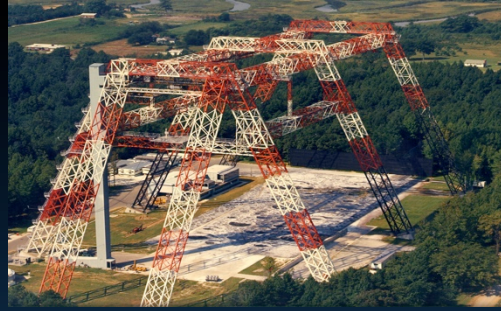
Development of the Earth Entry Vehicle



Arc jet testing



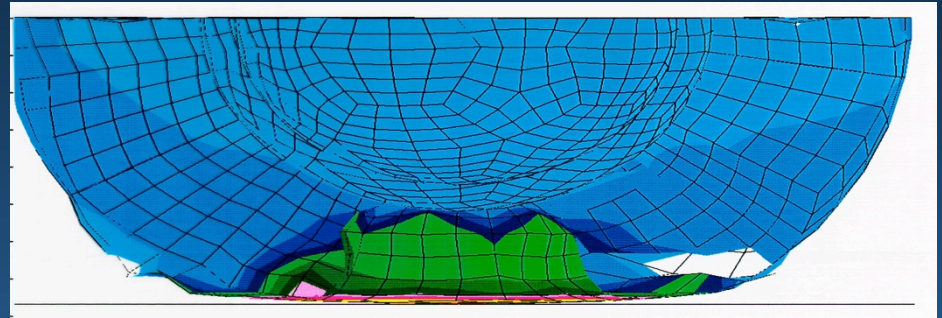
Wind tunnel testing



Impact protection testing



Drop testing at UTTR



Impact protection modeling

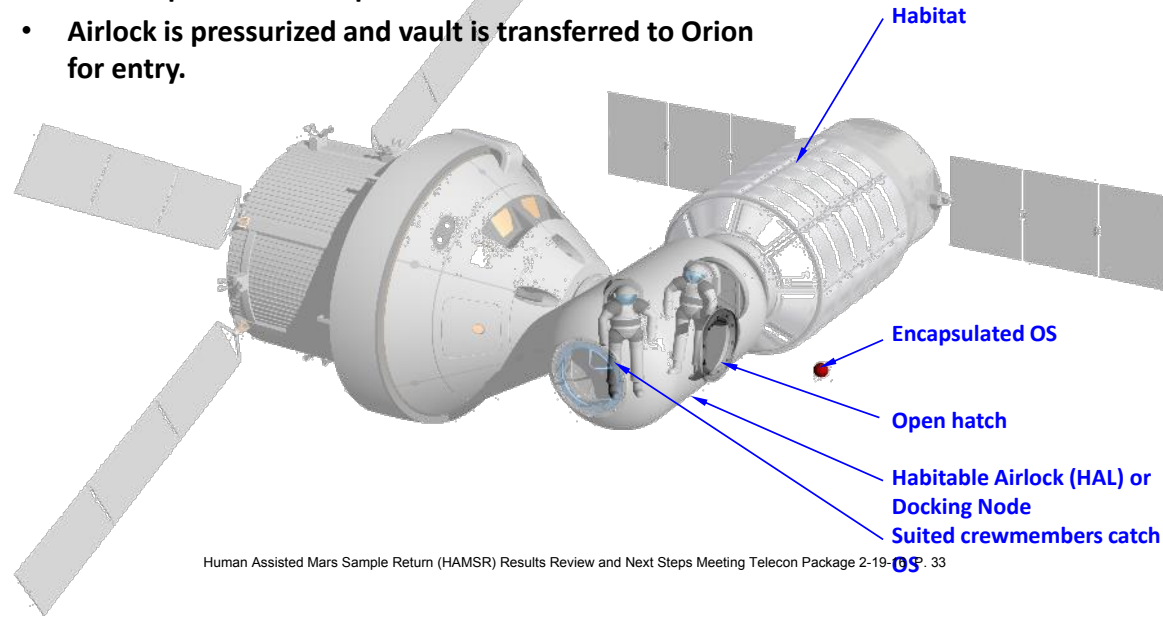
Predecisional. For planning and discussion purposes only.

And then there are other ideas (less actionable...)



Scenario 5D – Capture by Hab via Airlock

- SRO rendezvouses with Habitat and release OS when Habitat has it in sight at a standoff distance of 100-200m.
- Habitat engulfs OS into unpressurized airlock where two suited crewmembers are waiting.
- Crew captures OS and places it in a robust vault.
- Airlock is pressurized and vault is transferred to Orion for entry.

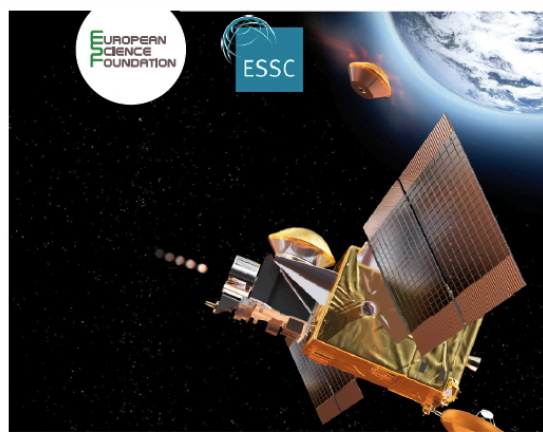


What do we do when we get the samples back??

The Quarantine and Certification of Martian Samples



Space Studies Board
National Research Council



Mars Sample Return backward contamination – Strategic advice and requirements

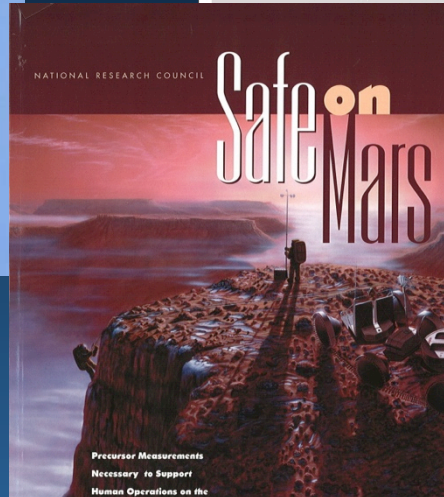
Report from the ESF-ESSC Study Group on MSR Planetary Protection Requirements.

Previous recommendations to be studied and updated.

NASA/CP-2003-211842



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



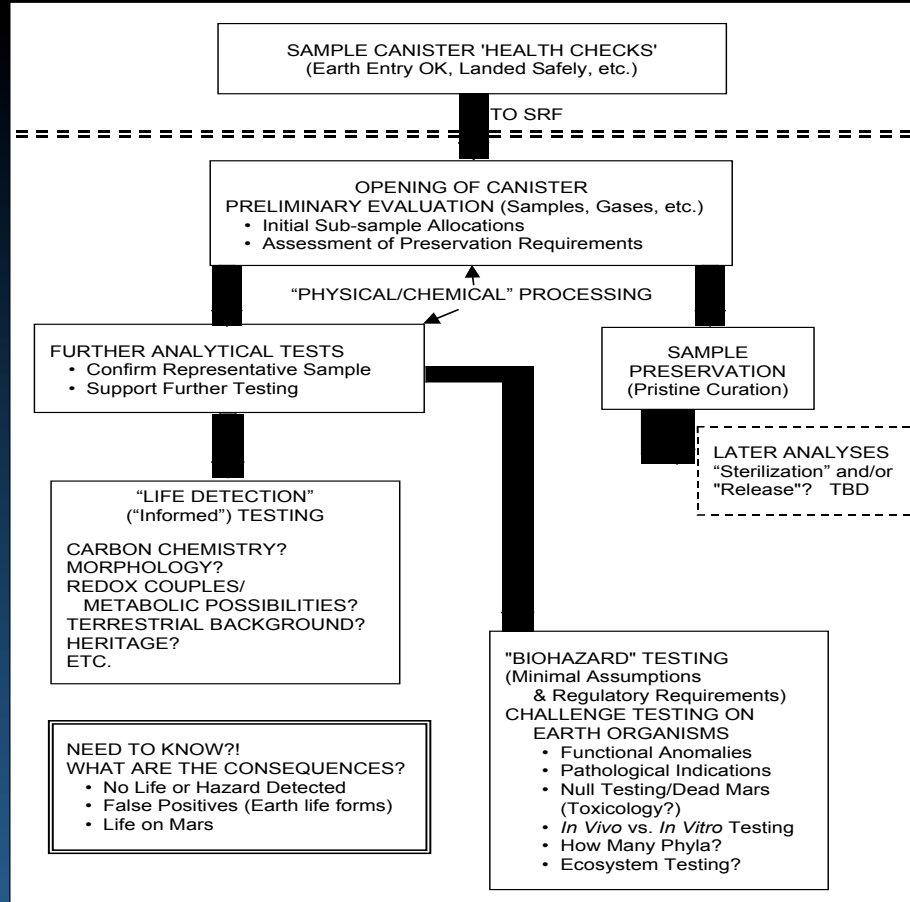
Precursor Measurements
Necessary to Support
Human Operations on the



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October 2002

Sample-Return Protocol Overview



Questions and Strategies for Decisions About the Release of Samples from Containment

<i>Item</i>	<i>Question</i>	<i>Strategy</i>
1	Is there anything that looks like a life-form?	Microscopy; Beam synchrotron or other non-destructive high-resolution analytic probes, particularly one that would allow testing un-sterilized (yet still contained) samples outside the main facility.
2	Is there a chemical signature of life?	Mass spec. and/or other analytical measurement systems (to be used in containment) that would identify biomolecules, chiral asymmetry, special bonding, etc.
3	Is there any evidence of self-replication or replication in a terrestrial living organism?	Attempts to grow in culture, in cell culture, or in defined living organisms.
4	Is there any adverse effect on workers or the surrounding environment?	Microcosm tests; medical surveillance of workers and monitoring and evaluation of living systems in proximity of receiving facility to ensure no release or exposure associated with operations of a sample receiving facility.

The 'Journey to Mars'

(NP-2015-08-2018-HQ, p. 1)



“What we learn about the Red Planet will tell us more about our Earth’s past and future, and may help answer whether life exists beyond our home planet. Together with our partners, we will pioneer Mars and answer some of humanity’s fundamental questions:

- *Was Mars home to microbial life? Is it today?*
- *Could it be a safe home for humans one day?*
- *What can it teach us about life elsewhere in the cosmos or how life began on Earth?*
- *What can it teach us about Earth’s past, present, and future?”*

COSPAR Human Exploration Principles



“The intent of this planetary protection policy is the same whether a mission to Mars is conducted robotically or with human explorers. Accordingly, planetary protection goals should not be relaxed to accommodate a human mission to Mars. Rather, they become even more directly relevant to such missions—even if specific implementation requirements must differ”

- Safeguarding the Earth from potential back contamination is the highest planetary protection priority in Mars exploration
- The greater capability of human explorers can contribute to the astrobiological exploration of Mars only if human-associated contamination is controlled and understood
- For a landed mission conducting surface operations, it will not be possible for all human associated processes and mission operations to be conducted within entirely closed systems
- Crewmembers exploring Mars, or their support systems, will inevitably be exposed to martian materials

*Developed following joint ESA-NASA Workshop; Kminek, G., Rummel, J., & Race, M. (2007). Planetary Protections and Human System Research & Technology. In ESA-NASA Workshop Report, ESA WPP-276, ESTEC, Noordwijk, The Netherlands.

Public Communication is an Issue

- e.g., the 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
 - For example, an Article by Olivia Judson in the April 19th, 2004 NY Times:

“Some Things are Better Left on Mars”

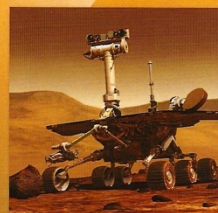
The New York Times



iMARS

Preliminary Planning for an International Mars Sample Return Mission

Report of the International Mars Architecture for the Return of Samples (iMARS) Working Group
June 1, 2008



Questions?

