Planetary Protection For Mars Sample Return

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17 June, 2011

Why Planetary Protection?

1 Protect Earth and its biosphere from potential extraterrestrial sources of contamination

– *Simple prudence; protect the Earth!*

2 Preserve planetary conditions for future biological and organic constituent exploration

– *Protect our investment in space science and exploration*

Early Concerns: Protecting Science during Space Exploration

27 June 1958, Volume 127, Number 3313

SCIENCE

Moondust

The study of this covering layer by space vehicles may offer clues to the biochemical origin of life.

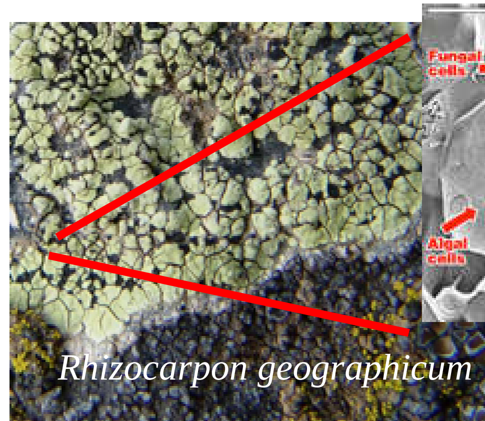
Joshua Lederberg and Dean B. Cowie

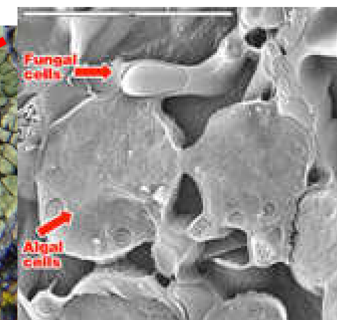
tions are very small, they are perhaps large enough to initiate the condensation. If this point is granted, it would then be necessary to examine the capture of a second atom of hydrogen or of carbon by the CH molecule. Because of the abundance of hydrogen, the first is more probable but the calculation of the probability of formation of the CH_2 molecule is very difficult. It is possible that some more hydrogen atoms attach themselves to the CH_2 molecule (CH_2 CH_3 CH_4 ?) but before long it is mainly atoms of much larger mass (C, N, O, . . .) which are captured because the large molecule

"…we urgently need to give some thought to the conservative measures needed to protect future scientific objectives on the moon and the planets"

Microbes are Everywhere on Earth

Most organisms live in fairly complex communities, in which members share resources and improve community survival

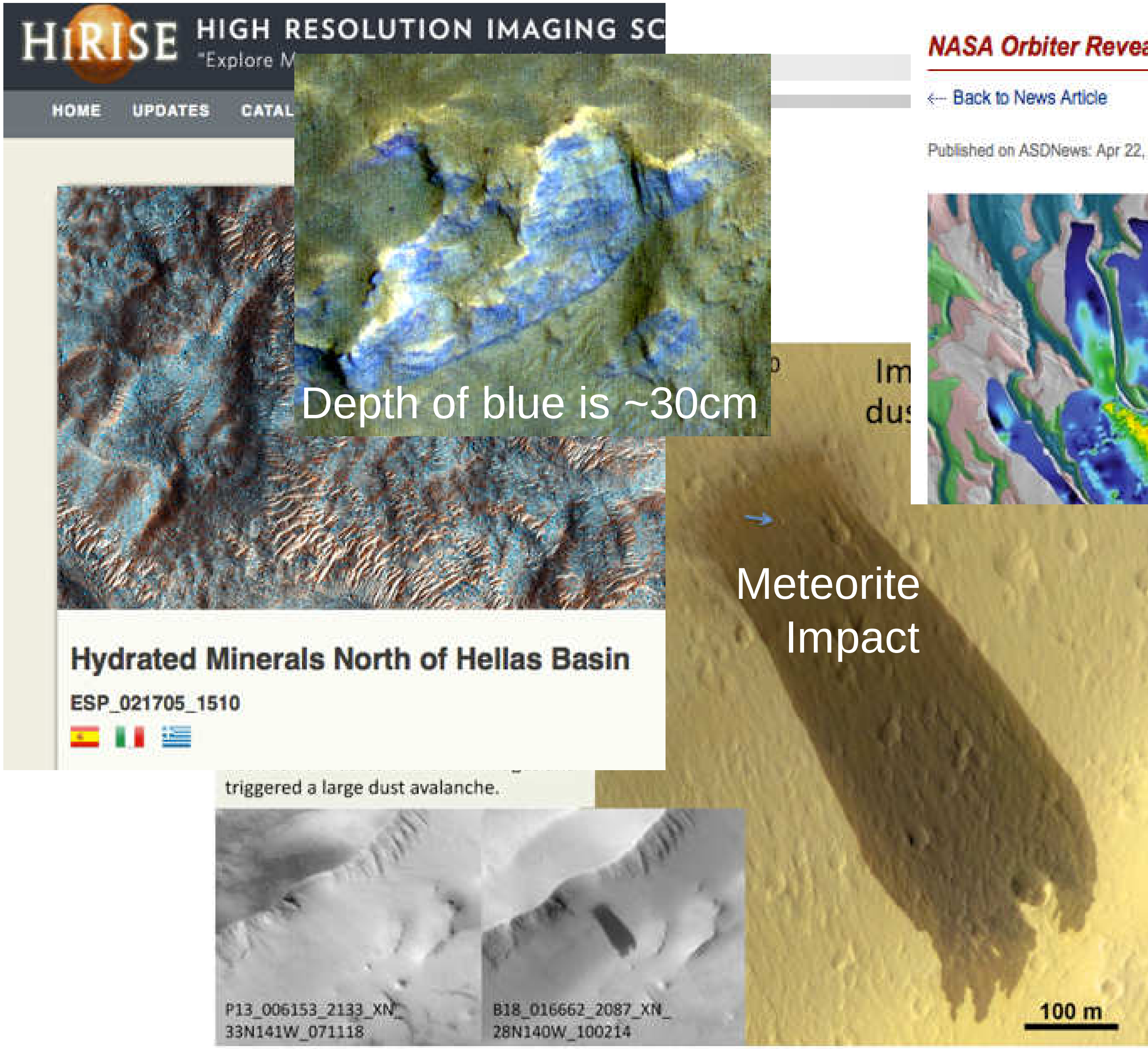


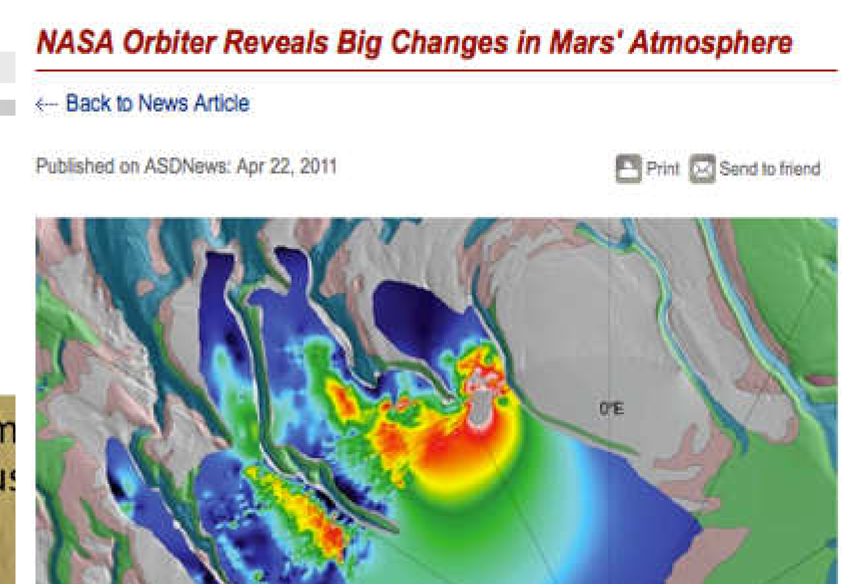


Lichen survives space exposure

Some communities are made up of small numbers of species: frequently found in more ‘extreme’ environments

Mars is a diverse and changing place...



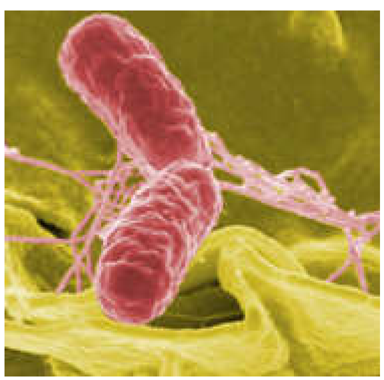


MRO's Context camera (CTX) acquired the image at lower left on18 Nov 2007 and the adjacent image on 14 Feb 2010, showing a large new slope streak

Introduced Organisms Can Have Ecological Impacts

Most stable communities are resistant to invasion by novel species

Salmonella typhimurium express more virulence genes after cultured growth in space



However, sometimes organisms with novel capabilities can sweep through a community

International Agreements on Planetary Contamination/Protection

- The Outer Space Treaty of 1967:
  - Proposed to the UN in 1966
  - Signed by the US and Soviet Union in January 1967
  - Ratified by the US Senate on Apr. 25th, 1967
- Article IX:

  "...parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose..."

  "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies."

  (http://www.state.gov/t/ac/trt/5181.htm)

Committee on Space Research (COSPAR) Planetary Protection Activities

- COSPAR maintains the international consensus planetary protection policy for the 1967 UN Space Treaty.
- COSPAR's Planetary Protection Panel was formed to:
  - Develop, maintain, and promulgate planetary protection knowledge, policy, and plans to prevent the harmful effects of such contamination
  - Provide an international forum for exchange of information in this area through symposia, workshops, and topical meetings at COSPAR Assemblies
  - Inform the international community, e.g., the Committee on the Peaceful Uses of Outer Space (COPUOS) of the United Nations, as well as various other bilateral and multilateral organizations, of COSPAR decisions in this area.
- Current Policy approved by COSPAR Bureau and Council in 2011.
  - Policy is revisited regularly through Panel activities.

Planetary Protection Mission Constraints

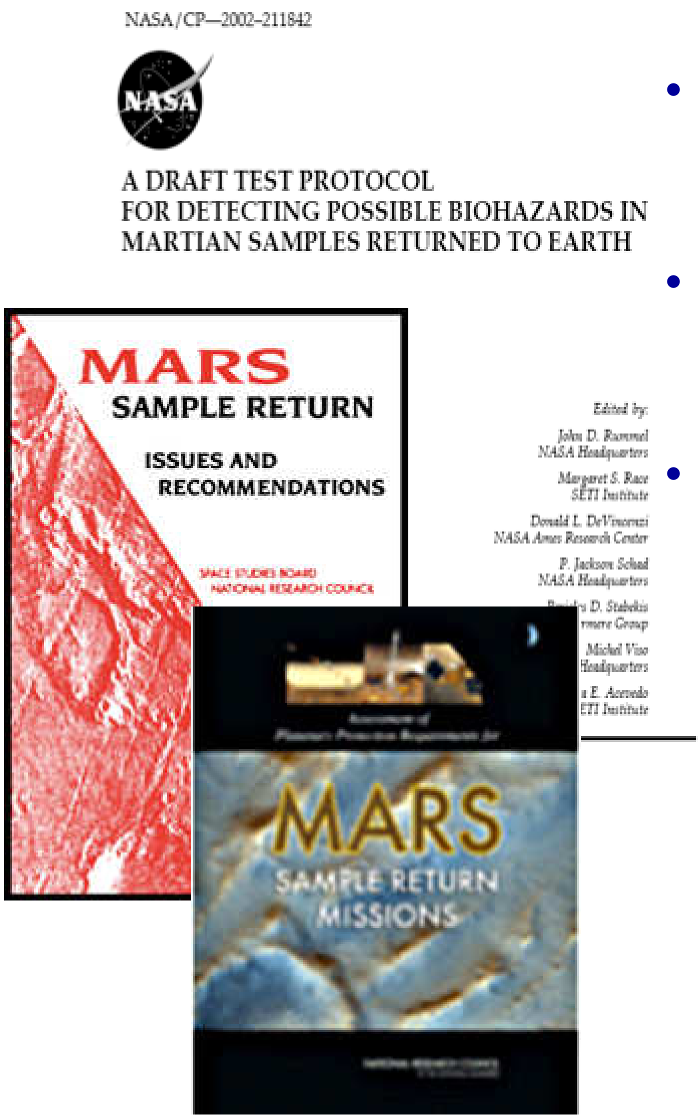
- Depend on the nature of the mission and on the target planet
- Assignment of categories for each specific mission/body is to take into account current scientific knowledge based on recommendations from scientific advisory groups
- Examples of specific measures include:
  - Constraints on spacecraft operating procedures
  - Spacecraft organic inventory and restrictions
  - Reduction of spacecraft biological contamination
  - (Mars) Constraints on landing sites for unsterilized spacecraft carrying a perennial heat source
  - Restrictions on the handling of returned samples

W. Peet, 1967

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 compromise future investigations. Documentation is required.	Any	II
C	Of significant interest relative to the process of chemical evolution and/or the origin of life and for which scientific opinion provides a significant chance that contamination could compromise future investigations. Substantial documentation and mitigation is required.	Flyby, Orbiter	III
		Lander, Probe	IV
All	Any Solar System Body	Earth-Return *"restricted" or "unrestricted"*	V

Testing Martian Samples on Earth



- Previous requirements developed over a decade of MSR preparation and adopted by COSPAR

- ESA and NASA are continuing a program of requirements refinement

- Key recommendations from NRC-SSB 2009:

  - "…samples returned from Mars by spacecraft should be contained and treated as though potentially hazardous until proven otherwise.

  - No uncontained martian materials, including spacecraft surfaces that have been exposed to the martian environment, should be returned to Earth unless sterilized."

COSPAR Guidelines for Mars Sample Return

- "... the outbound leg of the mission shall meet Category IVb requirements..."
- "... the canister(s) holding the samples returned from Mars shall be closed, with an appropriate verification process, and the samples shall remain contained ... transport to a receiving facility ... opened under containment."
- "The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars. ..."
- "Reviews and approval of the continuation of the flight mission shall be required ..."
- "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."

Evolution of Requirements – Earth Protection

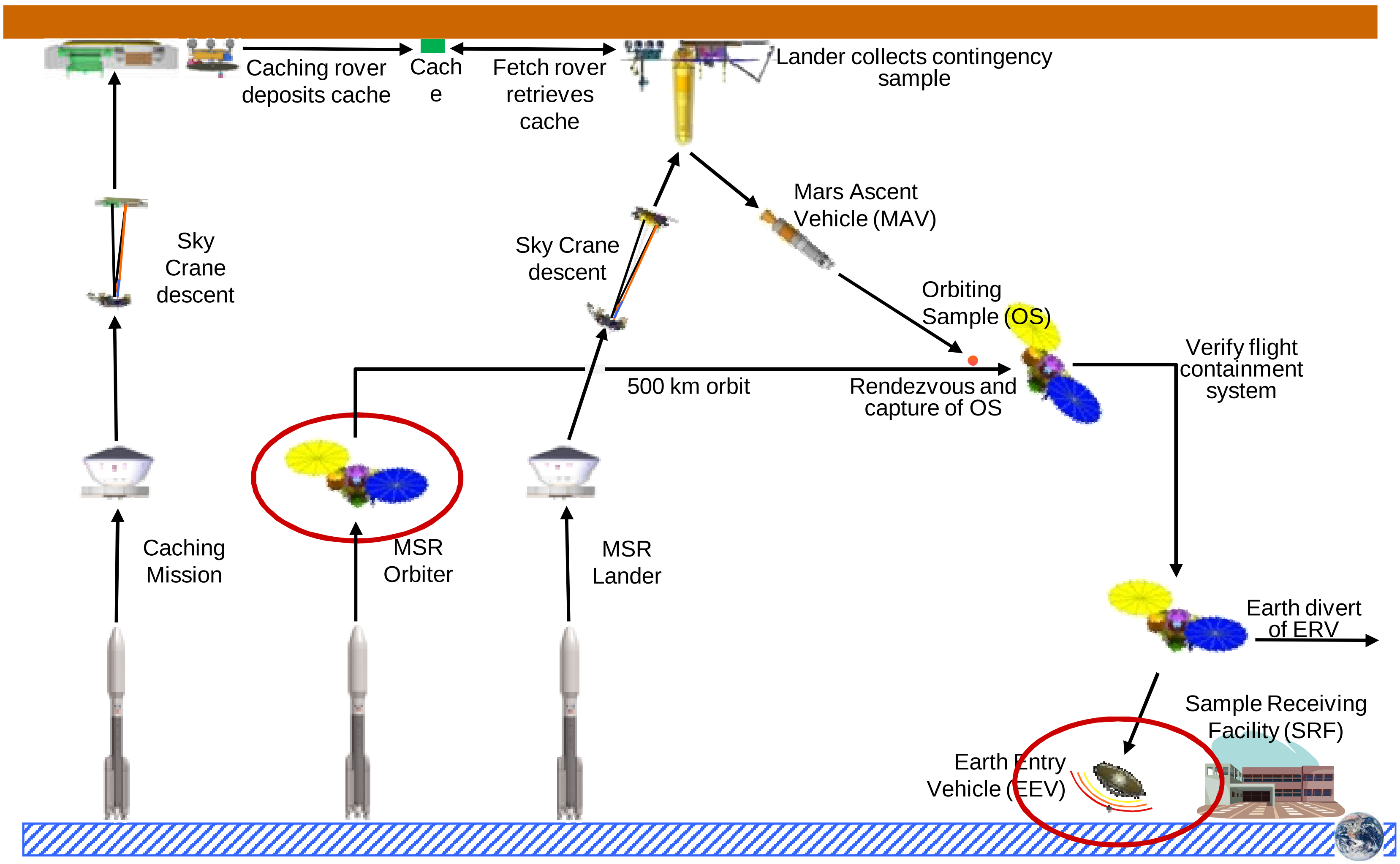
Previous guidance: The probability that a single unsterilized particle of 0.2 micron diameter or greater is released into the Earth environment shall be less than 10^{-6}.

Size limit: Limit based on NRC-SSB report "Size limit for very small microorganisms". Unpublished work has identified smaller microbes in the < 0.1 micron range in caves and the marine environment; this will be revisited in a dedicated workshop in late 2011 or early 2012.

Probability limit: Currently evaluated in an ESA funded contract to the European Science Foundation (ESF). Team includes representatives from COSPAR and nominees from the NRC-SSB. Draft of final report will be available end of 2011.

Next steps: Dedicated COSPAR workshop, including external stakeholders, i.e. authorities, to review these reports in spring 2012 in Alpbach, Austria, and preparation of White Paper for the COSPAR General Assembly in July 2012.

Affected Systems



Consequences of Requirement

Previous guidance: The probability that a single unsterilized particle of 0.2 micron diameter or greater is released into the Earth environment shall be less than 10^{-6}.

Critical planetary protection task for MSR at campaign level: Allocate reliability of safety critical functions for hardware and mission phases over the entire campaign.

Critical design approach to meet planetary protection requirements: **Risk based design, accounting also for common cause/mode failures, drives redundancy and diversity of system design.** Usually not used for robotic missions to that extent but for man-rated system; need to go beyond man-rated systems because consequences go beyond occupational risk potentially also affecting general public. Fault tree needs to become the best friend of system engineer from the very begin!

Orbiter System: Potential affected sub-systems are data handling, GNC, power, propulsion to support safety critical functions, i.e., verification of biological containment system, Earth divert manoeuvre.

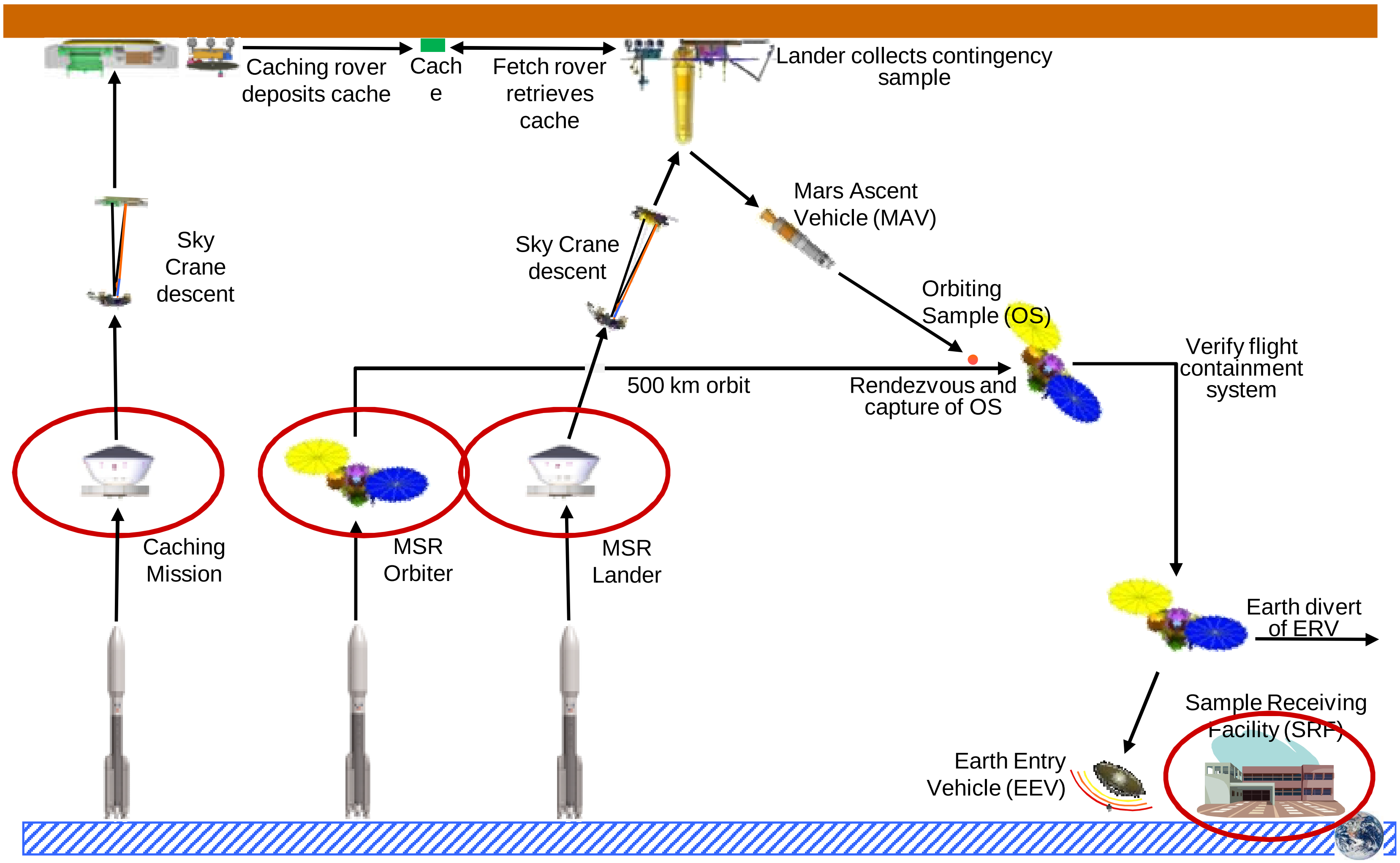
Earth Return Capsule: Potential affected sub-system are heat shield and stability during entry.

Evolution of Requirements - Bioburden

Campaign level requirement according to Planetary Protection Category V, restricted Earth return:

The subsystems (of one or several missions) which are involved in the acquisition, delivery (and storage), and analysis of samples used for life detection must be sterilized or cleaned to levels of bioburden reduction driven by the nature and sensitivity of the particular life-detection experiments (driven by the life detection and biohazard assessment protocol), and a method of preventing recontamination of the sterilized subsystems and the contamination of the material to be analyzed is in place.

Affected Systems



Upcoming Events

European Science Foundation (ESF) study under ESA contract on the level of certainty for the exclusion of an unintended release of a potential Martian life form into the Earth's biosphere. Draft final report due December 2011.

Sub-sampling approach with parametric analysis under ESA contract. Final report due mid 2012.

Small size limit workshop under NASA-PPO responsibility. Expected for end 2011/begin 2012, USA.

US-NRC-SSB study on instrumented containment facility, expected start fall 2011.

NASA-ESA life detection and biohazard assessment instrumentation conference and workshop, February 2012, California, USA.

COSPAR-ESA-NASA workshop on MSR planetary protection requirements, spring 2012, Alpbach, Austria.

ROBOTS

our time unless thorough
qualified. M. L. Barker. 1408 Chap-
man Bldg.

WANTED

for hazardous journey, small wages, bitter cold, long months of complete darkness, constant danger, safe return doubtful, honor and recognition in case of success.

Ernest Shackleton 4 Burlington st.

MEN—Neat-appearing young men of pleasing personality, between ages
and 40 to work