Report to Science Committee of the NAC

March 11, 2016

Planetary Protection Subcommittee Meeting – Dec 8-9, 2015

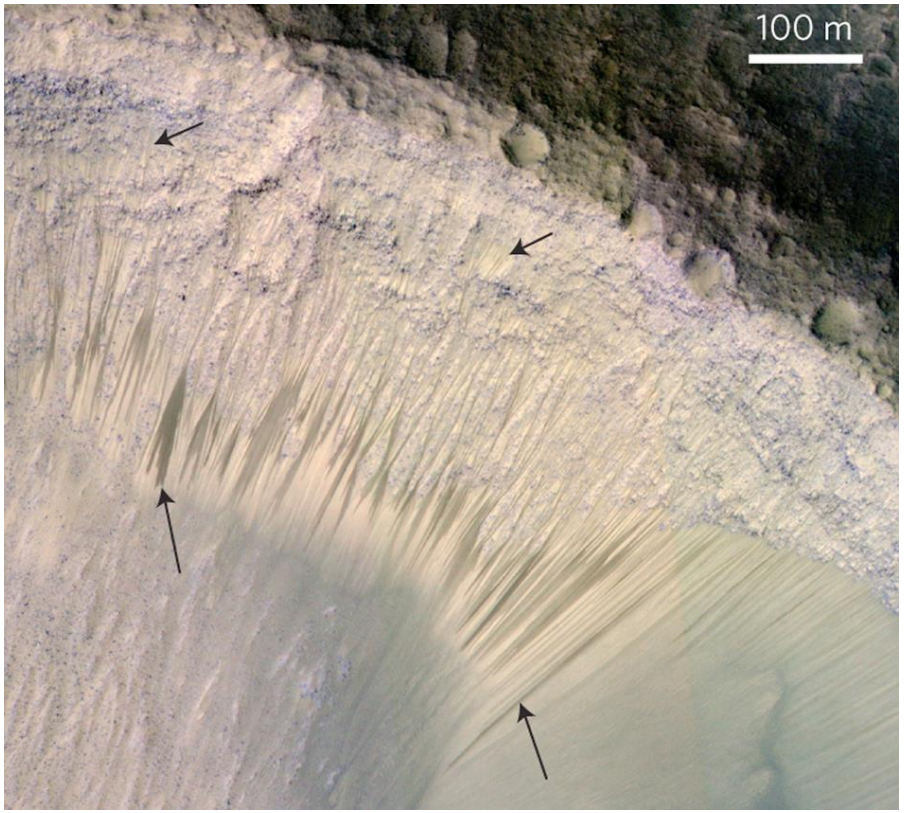
- The primary focus of our meeting was planetary protection status and issues associated with the exploration of Mars

- We noted that we have now entered the era of confirmed liquid water on Mars

- Agenda included:
  - Discussion with SMD AA Dr. John Grunsfeld
  - PSD and Mars Exploration Program Updates
  - Sept 2015 COSPAR Panel Colloquium reports – Mars Special Regions and Icy Moons
  - Oct 2015 ESA PPWG meeting
  - MSL Gale Crater Observations
  - Mars 2020 Planetary Protection Requirements
  - Returned Sample Science Board
  - Mars 2020 Project Briefing from JPL

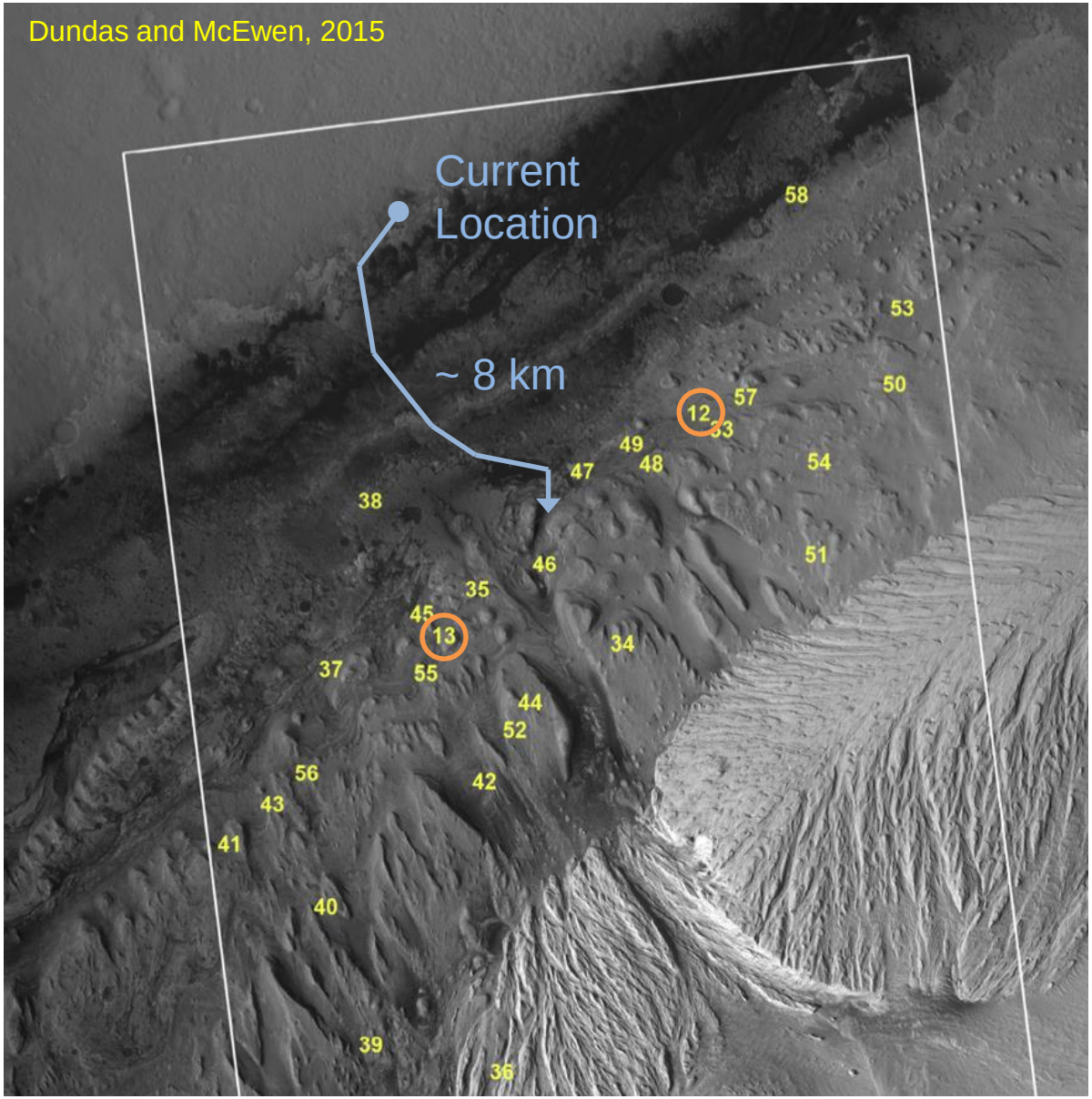
Recurring Slope Lineae

- Recurring Slope Lineae are a class of mass wasting features that:
  - incrementally grow over a period of weeks to months,
  - fade when inactive, and
  - recur annually
- They have been observed at mid and equatorial latitudes
- In September 2015, NASA announced the detection of salts associated with some RSLs, providing strong evidence that brines are involved



RSL on the south-facing slope of a crater on the floor of Melas Chasma. McEwen *et al*., 2014.

Recurring Slope Lineae



- Numbered locations are dark lineae identified by HiRISE
- These were assessed in successive images to look for RSL behavior. Two sites on northern Aeolis Mons (orange) show possible growth *at the limit of HiRISE resolution*.
- These two are candidate RSLs, pending additional observations.
- The rest do not indicate behavior consistent with RSLs, but may be active slope processes
- "Some of the observed slope features have characteristics similar to RSLs, but none is confirmed to be RSL and most have some characteristics suggesting other origins." (Dundas and McEwen, 2015)

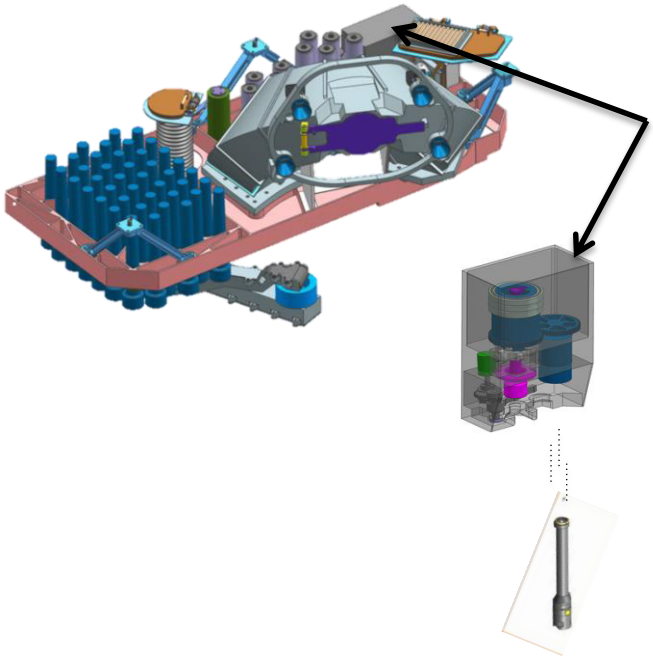
Recurring Slope Lineae

Summary

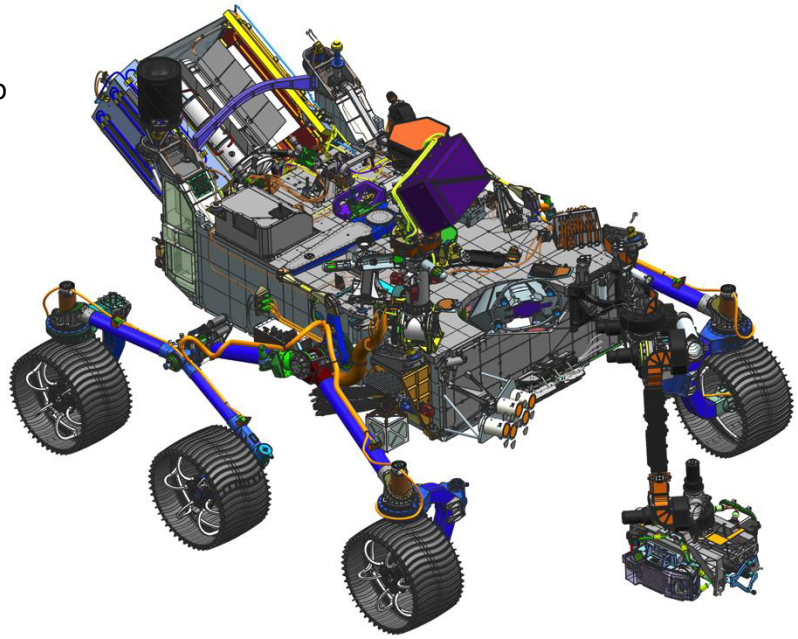
- There are no confirmed RSLs in Gale Crater, but there are two candidates, as well as dozens of dark slope streaks that are not considered RSLs by the HiRISE Team.
- As outlined in the previous slides, a thorough and ongoing search by the MRO HiRISE team has found two candidate RSLs, both poorly resolved by the camera, and neither of which fully demonstrates RSL behavior.
- MSL has updated the PPO on all information that we know from HiRISE and will continue to do so. At quarterly intervals we request an update from the MRO project.
- The planned route up Mount Sharp will keep the rover > 2.5 km from the candidate RSLs. At the closest distance, Curiosity's imaging will be higher resolution than HiRISE and will contribute to the study of these candidate RSLs.

Sample Caching

- The Mars 2020 project will cache the final collection of tubes on the Mars surface for later retrieval
  - Each tube is labeled for identification and sealed to protect sample
  - Cache is located for ease of retrieval by future mission

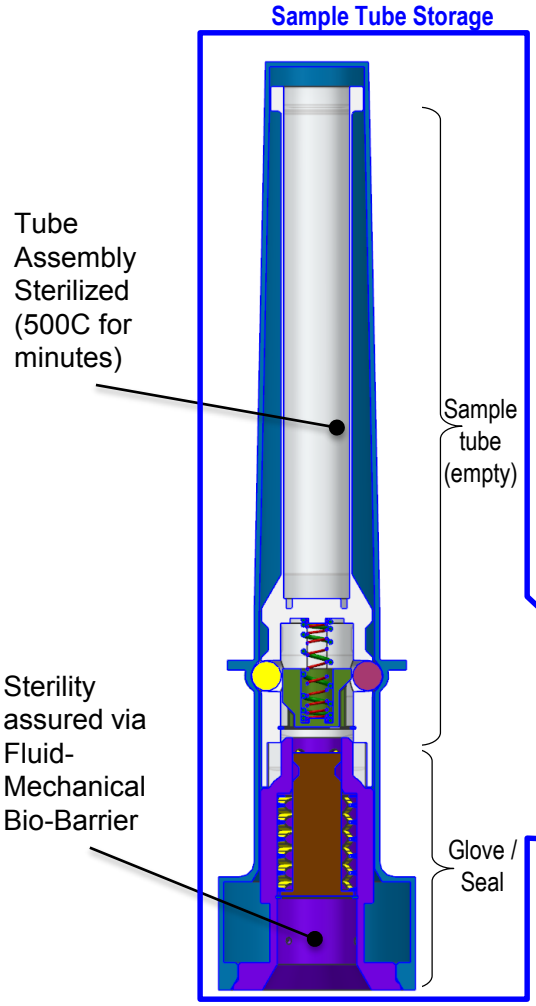


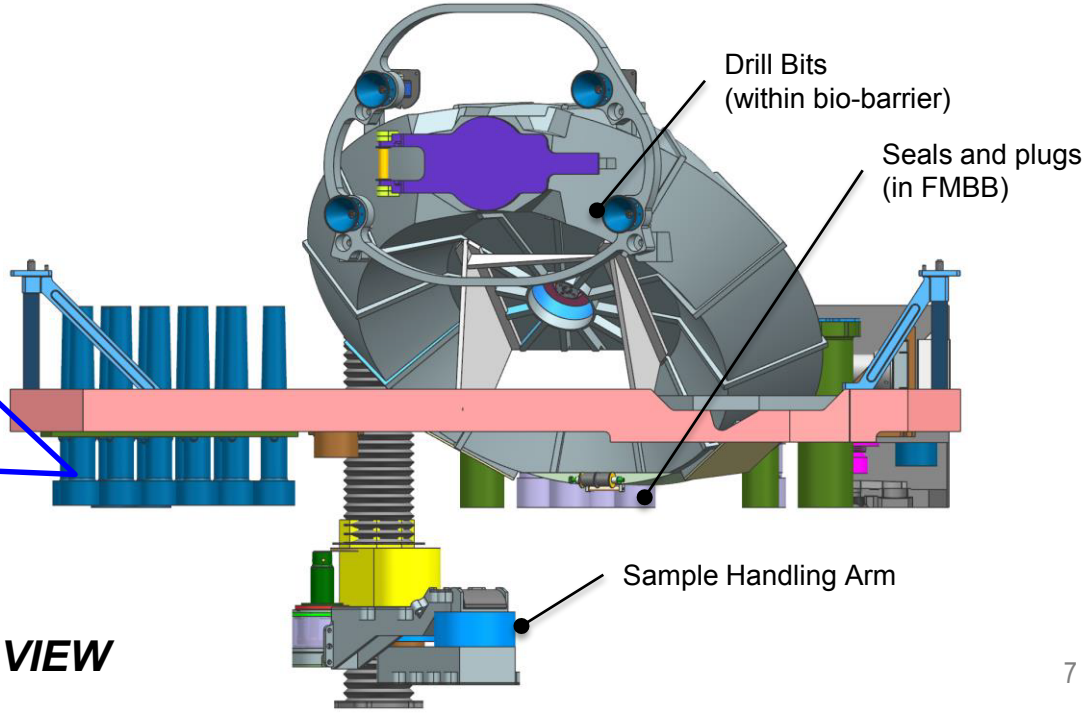
Sealing / Drop-off
- Axial load to seal tub
- Tube gripper acts to drop sealed tubes



Planetary Protection Specific Hardware

- The planetary protection *subsystem* is the sample tube
  - Tubes experience 12 log overkill microbial reduction at 500C
  - Plugs and seals experience a 4-6 log microbial reduction through standard DHMR
  - Drill bits receive a 4 log reduction via DHMR and are sealed until used on Mars
- The cleanliness is maintained
  - Stored in sterile bio-barrier enclosure until use
  - Inserted into sterile drill bit for sample acquisition
  - Tube is sealed after sample acquisition





FRONT VIEW

Planetary Protection Report to SC

Recommendation to NASA Science Directorate
COSPAR Colloquium Reports

Recommendation

The Subcommittee heard summary briefings on two reports generated at the recent COSPAR Colloquium on Mars Special Regions and Icy Moons. The purpose of the colloquium was two-fold: to prepare an update to the COSPAR Bureau and Council on the COSPAR Planetary Protection Policy for Mars Special Regions, and to provide input for a position paper on planetary protection requirements for sample return from icy bodies.

The recommendations from the two colloquium reports will be formally addressed during the 41st COSPAR Scientific Assembly to be held in Istanbul from 30 July - 7 August 2016. Based on the sound merit of the recommendations and their anticipated adoption by COSPAR, the Subcommittee recommends that NASA's Office of Planetary Protection embrace these new recommendations immediately.

Major Reasons for the Recommendation

The COSPAR Colloquium recommendations were prompted by new scientific discoveries (regarding Mars Special Regions) and by recent mission planning activities (Icy Worlds). The distribution of these recommendations provides NASA the opportunity to plan for their anticipated adoption at the COSPAR assembly in July. The ESA Planetary Protection Working Group has already recommended that ESA embrace the new recommendations.

Consequences of No Action on the Recommendation

NASA would be at risk of proceeding with planning that will have to be changed once the recommendations are formally adopted by COSPAR in July 2016.

Planetary Protection Report to SC

Recommendation to NAC/Science Committee
NASA Planning for Full System Level Sterilization

Recommendation

In order to ensure that future scientific instruments can meet the challenges of planetary protection implementations for missions to worlds that could support Earth life, the Subcommittee recommends that NASA provide support to enable instrument developers to qualify and employ construction methods that will be compatible with the use of system-level dry heat microbial reduction (DHMR) over the appropriate time/temperature range.

Concomitantly, the Subcommittee recommends that NASA benchmark or consider engaging the SSB to conduct a study to identify successful approaches by which modern instruments can be subjected to the current suite of commercially available microbial-reduction methods, including the use of DHMR. Approaches from other fields (including medical, military, and food-industry practitioners) would be particularly important to evaluate. Methods identified for use should be compatible with implementation strategies capable of complying with the regulatory framework for planetary protection currently in use by NASA and COSPAR.

These recommendations will provide the technologies needed to explore special regions

Major Reasons for the Recommendation

In the past, the Space Studies Board (SSB) has made recommendations about the measures that should be taken to protect potentially habitable worlds (e.g., Mars, Europa, and Enceladus) from terrestrial contamination, often reflecting the rigor with which the Viking landers and orbiters of the mid-1970s were treated to reduce biological contamination. Based on SSB recommendations, knowledge of Earth organisms, and ongoing scientific discoveries regarding these potentially habitable worlds, it is clear that methods to reduce or eliminate biological contamination on outbound and inbound space missions (and preventing recontamination) will continue to be necessary for the most compelling targets.

Consequences of No Action on the Recommendation

Future NASA science, particularly life detection efforts and in-situ exploration of special regions, may not be possible without the development of new instruments amenable to dry heat microbial reduction (DHMR) or other commercially available microbial reduction methods.

Planetary Protection Report to SC

Finding on the Full Support of the SMD AA

Finding

The Subcommittee heard from SMD Associate Administrator, Dr. Grunsfeld and was exceptionally pleased to hear both his full commitment to the NASA planetary protection activity, which he leads as described in NPD 8020.7G, and the knowledge and insights that he brings to that role. We support Dr. Grunsfeld's recent guidance to the Mars Exploration Program, the Curiosity Science Operations Working Group, the MSL Science Team and the Planetary Protection Officer on the immediate need for a process to incorporate planetary protection considerations in daily surface operations as well as the need to develop a plan of action for encountering any potential Special Regions. We also support Dr. Grunsfeld's plan to convene a workshop on the potential for finding Special Regions within Gale Crater.

Planetary Protection Report to SC

Observation Regarding Mars 2020's Planetary Protection Design and Implementation

Observation

A major focus of the December 8-9th Planetary Protection Subcommittee meeting was the planetary protection implementation strategy for the Mars 2020 Project, particularly with respect to the Mars 2020 sample caching system (SCS). The Subcommittee was impressed with the detailed presentations provided by JPL and the Mars 2020 team on the SCS design. The Subcommittee also appreciated the detailed presentation by JPL on the current status of the SCS implementation as part of the overall mission planetary protection implementation (which was not presented). The Subcommittee makes the following observations:

- Current Mars 2020 Project plans are now closer, both theoretically and practically, to the planetary protection requirements given in NPR 8020.12D for a subsystem level planetary protection implementation of a Category V, restricted Earth return, mission; …

Planetary Protection Report to SC

- No technical showstoppers appear to be present that should prevent the Mars 2020 Project from implementing a successful planetary protection strategy. However, many details remain unresolved, and the overall plans, schedule, and costs for the planetary protection implementation were not presented;
- Although Mars 2020 has been creative in pursuing new approaches to planetary protection implementation and adapting new concepts based on the nature of science anticipated, it remains the responsibility of the Mars 2020 Project to demonstrate that their approach meets the current, published planetary protection requirements;
- Consistent with NASA policy , if the Mars 2020 Project cannot meet the stated requirements then it will need to seek a waiver for implementation strategies that still comply with overall planetary protection objectives, while maintaining design options for their implementation in case such a waiver is denied; and
- Continued active engagement with the Planetary Protection Office will be critical to the Mars 2020 Project's success in planetary protection implementation.

Status of Open Recommendations from Previous Meetings

Jan. 2015

- That NASA's internal review of proposed licenses for launches and reentries by non-governmental entities include an assessment by the NASA Science Mission Directorate/Planetary Protection Office – **Recommendation reiterated at January 2015 SC meeting**

July 2015

- Categorization of the Mars 2020 Mission as Category V, restricted Earth return **– Tabled by the NAC; categorization letter has been issued by the Planetary Protection Officer**

- Planetary Protection Contingency Action Plan for ongoing surface operations **– Tabled by the NAC; recent SMD/AA action is consistent with the subcommittee's recommendation**

Backup

2.1 Mars Special Regions parameter definitions

The current parameters defining Mars Special Regions are:
Temperature: > -25°C
Water activity: > 0.5

Timescale of astronomical or geological events that could affect the environment: 500 years

Determining the lower temperature limit for the replication of terrestrial microorganisms is challenging mainly because the time required for replication increases nonlinearly with decreasing temperatures. A margin was added to the lowest published temperature in which experts had confidence that replication of terrestrial microorganisms had been observed. Based on the 2007 COSPAR Panel on Planetary Protection Colloquium, this margin is currently set at a conservative value of 10°C. Since the last update of the requirements for Mars Special Regions in 2007 more data have confirmed cell division at -15°C and literature not identified in the 2006-2007 review demonstrates cell division can occur down to -18°C (ref. in [6]).

COSPAR Panel Colloquium – Mars Special Regions Planetary Protection Requirements

It is **recommended** that a margin of 10°C on the threshold for the low-temperature limit that constitutes a Mars Special Region be maintained. As a consequence, it is **recommended** that the new low-temperature limit for parameters that defines Mars Special Regions be set to -28°C.

As more experiments are published and knowledge and confidence improves, the margin of 10°C may be relaxed in the future, if deemed appropriate by expert review.

In line with the MEPAG-SR-SAG2 report and the Academies/ESF Joint Committee report, it is **recommended** that the current lower limit for water activity of 0.5 be maintained.

In line with the MEPAG-SR-SAG2 report and the Academies/ESF Joint Committee report, it is **recommended** that the current long-term time limit for changes in the environmental conditions of 500 years be maintained.

2.2 Features that must be treated as Special Region

No Special Regions have been directly detected on Mars. However, current features that suggest the existence of environmental conditions that would qualify them as Special Regions, and that therefore must be treated as Mars Special Regions are:

- Gullies, and bright streaks associated with gullies
- Pasted-on terrain
- Subsurface below 5 m
- Others TBD (including dark streaks, possible geothermal sites, fresh craters with hydrothermal activity, modern outflow channels, or sites of recent seismic activity)

Since the last 2006-2007 review, the understanding of gullies has evolved and discoveries of new features such as Recurrent Slope Lineae (RSL) [8] and near-surface atmospheric methane [9] have been made.

COSPAR Panel Colloquium – Mars Special Regions Planetary Protection Requirements

In line with the MEPAG-SR-SAG2 report and the Academies/ESF Joint Committee report, it is **recommended** that gullies of taxon 2 through 4 be treated as Special Regions until proven otherwise. The definition of the various taxons is based on the MEPAG-SR-SAG2 report.

In line with the MEPAG-SR-SAG2 report and the Academies/ESF Joint Committee report, it is **recommended** that confirmed and partially confirmed Recurrent Slope Lineae (RSL) be treated as Special Regions until demonstrated otherwise.

Due to an artificial observational bias it is **recommended** that candidate Recurrent Slope Lineae (RSL) be evaluated on a case-by-case basis.

It is **recommended** that the following definition of observational evidence for Recurrent Slope Lineae (RSL), adapted from [10], be used:

- Confirmed: observed simultaneous incremental growth of flows on a warm slope, fading, and recurrence of this sequence in multiple Mars years
- Partially confirmed: observed either incremental growth or recurrence
- Candidate: slope lineae that resemble RSL but observations needed for partial confirmation are lacking

COSPAR Panel Colloquium – Mars Special Regions Planetary Protection Requirements

In line with the MEPAG –SR-SAG2 report and the Academies/ESF Joint Committee report, it is **recommended** that caves and subsurface cavities be treated as Special Regions until demonstrated otherwise.

The colloquium participants agreed that it is appropriate that special consideration be given to the presence of methane, recently detected near the surface of Mars [9]. Methane is considered to be an organic compound of special interest. The lack of knowledge about the source(s) and sink(s) of methane requires that its sources, if identified, be evaluated to determine whether they should be designated as non-special, uncertain, or special regions.

In line with the Academies/ESF Joint Committee report, it is **recommended** that localized "sources of methane" be added to the list of sites that must be treated as Special Regions until demonstrated otherwise.

The MEPAG-SR-SAG2 report classified dark slope streaks as non-special (Table 11 in the MEPAG report, supported by finding 4-8 in the same report). The Academies/ESF Joint Committee report describes recent publications suggesting that not all dark slope streaks can be explained by dry granular flow, and therefore aqueous processes cannot be definitely excluded for all dark slope streaks. As a consequence, the Academies/ESF Joint Committee advised, and the colloquium attendees have **recommended** that dark slope streaks be evaluated on a case-by-case basis.

2.3 Maps, landing and operational sites

The concern of the Academies/ESF Joint Committee with respect to the use of large-scale maps is supported by the participants of the colloquium. It is **recommended** that maps be dated and only used to illustrate the general concept of Special Regions but not be used to delineate their exact location because many relevant features and processes are likely to be sub-grid scale for such maps.

Until now it has been common understanding and practice that the temperature and water activity thresholds have to be exceeded at the same time for a location to qualify as Mars Special Region.

The MEPAG-SR-SAG2 has critically reviewed the timing of available liquid water and sufficiently high temperatures needed to allow replication and identified this as one of the knowledge gaps. Taking into account the precautionary approach for planetary protection, the colloquium attendees expressed their concern about this aspect, mainly due to the lack of experimental data, the limited understanding of microenvironments and disequilibrium conditions, and known abiotic and biotic processes to capture and retain liquid water.

COSPAR Panel Colloquium – Mars Special Regions Planetary Protection Requirements

In line with the Academies/ESF Joint Committee report and taking into account the critical review of the MEPAG-SR-SAG2 report regarding the timing of available water and sufficiently high temperatures, it is **recommended** that the following requirement to the current requirements for Mars Special Regions be added:

> Planned 3-sigma pre-launch landing ellipses must be evaluated on a case-by-case basis as part of the (landing) site selection process, to determine whether the mission would land or come within contamination range of areas or volumes meeting the parameter definition for Mars Special Regions or would impinge on already described features that must be treated as Mars Special Regions. The evaluation must be based on the latest scientific evidence and in particular include an assessment of the extent to which the temperature and water activity values specified for Mars Special Regions are separated in time. The evaluation must be updated during the mission whenever new evidence indicates that the landing ellipse and/or the operational environment contain or are in contamination range to areas or volumes meeting the parameter definition for Mars Special Regions or already described features that must be treated as Mars Special Regions.

2.4 Planetary protection and human missions to Mars

The current COSPAR Planetary Protection Policy contains principles and guidelines for human missions to Mars.

In line with the concerns raised in the Academies/ESF Joint Committee to avoid misunderstandings and to ensure that the primary COSPAR Planetary Protection Policy statement is properly reflected in the current guidelines and future requirements, it is **recommended** that the clarification of the principles be extended to read:

> The intent of this planetary protection policy is the same whether a mission to Mars is conducted robotically or with human explorers. Accordingly, the stated COSPAR Planetary Protection Policy must not be compromised to accommodate a human mission to Mars.

In addition, it is **recommended** that the following implementation guideline be deleted:

> *"Neither robotic systems nor human activities should contaminate "Special Regions" on Mars, as defined by this COSPAR policy."*

And replaced with the following statement:

> Requirements for human activities must be imposed to control the contamination of Mars in general and of Mars Special Regions, specifically, in line with the COSPAR Planetary Protection Policy.

COSPAR Panel Colloquium – Icy Moons Conclusions

The following **policy updates** to the current COSPAR Planetary Protection Policy are **recommended**:

- Addition of Enceladus to the list of target bodies for a Planetary Protection Category V, restricted Earth return
- Extension of the current Planetary Protection Category III/IV/V Requirements for Europa also to Enceladus
- Specific updates to individual requirements

Further development of the COSPAR Planetary Protection Policy is **recommended** to address the level of biological contamination requirement for Europa (and Enceladus) *in-situ* life-detection and sample return missions.

Further research and guidance are **recommended** on the following aspects:

- Response of organisms to the conditions of high velocity impacts
- Physical exchange processes for transport from the surface to the sub-surface
- Survival of organisms during transport from the surface to the sub-surface