FORWARD PLANETARY PROTECTION ISSUES AND CONSTRAINTS RELATED TO PLANNING FOR THE POTENTIAL HUMAN EXPLORATION OF MARS. D. W. Beaty[1], R. M. Davis[2], V. E. Hamilton[3], L. E. Hays[1], M. A. Jones[1], D. S. S. Lim[4,5], J. D. Rummel[6], and R. Whitley[7]. [1]Mars Program Office, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 (dwbeaty@jpl.nasa.gov), [2]NASA HQ, Washington, DC, [3]NASA Ames Research Center, Mountain View, CA 94035, [4]BAER Institute, Petaluma, CA 94043; [6]East Carolina University, Greenville, NC 27858, [7]NASA Johnson Space Center, Houston, TX 77058.

Introduction: A human mission to the martian surface would potentially constitute a large biological contamination event for at least one location on Mars, and depending on the design of the mission, possibly more than one. In order for such a mission to be accomplished in an acceptable manner, the planetary science community needs to debate and consider the best answers to the following broad questions:

1) How can a human mission to Mars limit its potential contamination of the planet?
2) Where are the places on Mars where a large biological contamination event would be acceptable, if it were to occur?
3) Would a human mission entail a lifting, either partially or entirely, of the restrictions on the biological contamination of Mars?

At the present time, a primary driver behind the restrictions on "forward" contamination is that the exploration of Mars is in an active phase of the search for evidence of indigenous life (both past and present). As we look ahead to a possible human exploration program focused on Mars, there are three logical ways the future could unfold: At the time of human landings on Mars, 1) Mars is still in a period of biological exploration, and restrictions on Earth-sourced biological contamination are still essential to scientific success; 2) Biological exploration of Mars has been completed without detecting life, and restrictions on biological contamination are no longer necessary for that purpose; and 3) (which can be paired with either of the other two) Restrictions on biological contamination are essential to prevent damage to resources on Mars capable of supporting human colonists.

The Concept of Special Regions: Special Regions on Mars are defined as places (3D volumes) within which terrestrial microbial life could take a foothold, prosper, and reproduce. Because this would have the potential to confound the scientific exploration for indigenous life on Mars, a high priority requirement for spaceflight missions is to avoid such contamination, keeping the Special Regions safe (for additional details, see Rummel et al., 2014, and references therein).

Locational Constraints on a Human Landing Site: We anticipate that a human landing site will need to have some degree of spatial separation from Special Regions in order to avoid deleterious contamination effects. Currently, however, we don't yet have a good way to establish the scale of that separation, taking into account wind, dust storms, and potential subsurface connectivity. Until this separation can be quantified for a particular landing site/Special Region combination, it is not known how close a source of contamination can be allowed to get to a previously identified Special Region. This issue has previously been recognized by MEPAG, and it is discussed in the MEPAG Goals Document (most recent version: MEPAG, 2014).

Relationship to MEPAG Goal IV: In the MEPAG Goals Document, the importance of protecting Special Regions from human-sourced contamination is described in Investigation IV-2B. MEPAG points out that it is logically necessary to know, in advance of human missions, not only where the Special Regions are located (including those formed by natural processes, but also those that could be induced by some element of the human mission), but also the pathways and probabilities for the transport of contaminants to a nearby Special Region. Investigation IV-2B specifically calls for "understanding the rates and scales of the martian processes that would allow for the potential transport of viable terrestrial organisms to Special Regions." ". Once the Special Regions are located, we would need this to determine how close, and under what circumstances, human-related contamination could be allowed.

A practical question that needs discussion is what are the necessary informational inputs to determining the rates and scales of the various processes that would be relevant to the contamination of Special Regions? . This would need to include assessments of the form and probable quantities of the biological contaminants associated with human surface operations, such as that:

- discharged into the air,
- deliberately buried (either encapsulated or not),
- adhering to the surface of equipment/spacesuits that are exposed to the martian environment
- other.

We would then need to assess the factors that relate to the mechanical dispersal of these biological contaminants, including speed, direction, and duration of the winds, adhesion coefficients of microbes/particles under martian conditions, etc.

Finally, we would need to understand the lethality of the martian environment to Earth-sourced microbes as a function of time and space. As the contaminant plume spreads, the live organisms would be affected by UV radiation, dessication, oxidation, lack of nutrients, etc., which would cause the live organisms to die (but not disappear—the dead remains would still be part of the contaminant plume).

What do we need to measure or model to reach a community-acceptable solution to the above questions? At least some of these inputs can be obtained from experiments and models here on Earth, but are there also data sets that would need to be collected from Mars? If so, this requires careful planning through NASA's robotic Mars Exploration Program.

The inverse of Special Regions: If we presume that future exploration of Mars leads—at some point—to relaxing the restrictions on biological contamination carried by spacecraft—in particular regarding the allowable level of risk with respect to the contamination of at least parts of Mars—there may be in the future identifiable portions of Mars that are functionally the inverse of Special Regions. Instead of places where less than the current levels of spacecraft contamination (which have heretofore applied only to robotic missions) are allowed, there could be places on Mars where the additional contamination associated with human habitats and spacecraft would be allowed. Two key questions about implementing this potential future would be 1). What is the process whereby these places are identified and vetted, and 2). What is the timing wherein this process takes place?

Whatever the case, it is not within the planning horizon that we will remove all restrictions on biological contamination on Mars. In fact, there are many restrictions in place (but less than fully adequate) on the transport of biological contamination on Earth [e.g., 4]. We can envision that Mars will have certain sites (such as Special Regions and other areas where Earth organisms are not allowed) far into the future, and we can hope that the process and timing by which international PP policy would be revised relative to human missions will consider the situation carefully as the exploration of Mars continues.

Conclusions: The above issues are significant input to planning for the specific location (or locations) to be considered for human exploration activities on the surface of Mars. As of this writing, momentum seems to be increasing, in more than one sector here on Earth, for crewed missions to the Red Planet, both for exploration and for long-term habitation. It would be prudent to start now in discussing a process whereby the technical needs and timing associated with the biological exploration of Mars, human exploration interests, and our internationally basedother international planetary protection provisions can be simultaneously satisfied.

References: [1] Rummel, J. D., Beaty, D. W., Jones, M. A., Bakermans, C., Barlow, N. G., Boston, P. J., ... & Wray, J. J. (2014). A New Analysis of Mars "Special Regions": Findings of the Second MEPAG Special Regions Science Analysis Group (SR-SAG2). *Astrobiology, 14, 887-968*. [2] MEPAG (2014), Mars Scientific Goals, Objectives, Investigations, and Priorities: 2012 V. Hamilton, ed., 52 p. white paper posted September, 2014 by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.nasa.gov/reports.cfm. [3] COSPAR. (2011) COSPAR Planetary Protection Policy (20 October 2002, amended 24 March 2011). COSPAR, Paris. [4] Becker, R. (1997). MARPOL 73/78: An Overview in International Environmental Enforcement. *Geo. Int'l Envtl. L. Rev., 10, 625*.