ENABLING HUMAN-COMPATIBLE PLANETARY PROTECTION: A MARS-NEXT-DECADE PATHWAY OPTION. B. Sherwood, Jet Propulsion Laboratory, California Institute of Technology, 301-335, 4800 Oak Grove Drive, Pasadena CA 91109, brent.sherwood@jpl.nasa.gov.

The Mars Next Decade program plan should include a distinct Pathway option focused directly on resolving the forward-contamination paradox that will otherwise preclude human exploration.

Challenge Area: #1, Investigation Approach for a thematic architecture of robotic science missions in the time period from 2018 through the 2030s, that would establish a mutually-dependent partnership among SMD, HEOMD, and OCT.

Introduction and Motivation: Aspirations of human Mars exploration are confounded by a stubborn paradox: a major exploration objective of human crews would be the progressive, detailed investigation of protected microclimates that might host indigenous life; yet all human space flight subsystems shed enormous amounts of biota, likely precluding them from being allowed near such sites – or perhaps even on the planet [1, 2] altogether. Multi-decade planning for a Mars-vectored human program is not viable without resolving this issue; only a deep, focused partnership among SMD, OCT, and HEOMD could resolve it.

Problem: COSPAR defines a Special Region as "a region within which terrestrial organisms are likely to propagate, or a region which is interpreted to have a high potential for the existence of extant Martian life." A decade of Mars exploration has now revealed diverse prospects for Special Regions.

MEPAG Goal IV Investigation 2E [3] focuses on determining Mars Special Region "environmental niches," whether occurring naturally or induced by human activities and systems. It would evaluate their "vulnerability…to terrestrial biological contamination, and the rates and scales of the Martian processes that would allow for the potential transport of viable terrestrial organisms to these special regions. However, through an artifact of its prioritization algorithm MEPAG assesses Investigation 2E as "medium priority" even though humans-to-Mars would be programmatically infeasible until its completion.

Most precursor-planning attention has been focused on validating that Mars would not harm human crews; much less attention is focused on certifying that humans could go there at all, engineering around boundaries on their exploratory activities, or establishing technology and system-development requirements to adequately estimate human-system costs. Contemporary planning for human Mars missions is intrinsically incompatible with the NRC's plan to prevent forward contamination of Mars [2], which is based on differentiating special from nonspecial regions and treating all direct-contact missions as Category IVs *"until measurements are made that permit distinguishing confidently between regions that are special on Mars and those that are not."* There is no system heritage and no body of design engineering to implement a Category-IVs human mission.

Inverting the Science Objective: An integrated robotic-human Mars program could not be organized solely around scientific (terrestrial-planet formation and evolution) priorities, because it is untenable for human-mission planning to wait in limbo while the paradox is unresolved. Programmatic urgency for human exploration would pressure an SMD-HEOMD partnership to address the paradox more expeditiously.

Rather than seeking to determine whether Mars life exists or has existed, and if so how like Earth life it was, a Pathway focused on resolving the paradox would invert this way of thinking. It would seek to prove that Mars does not and could not support life. Success at each step of proof would allow incremental planning for human exploration to proceed as traditionally envisioned. But failure of proof at any step would either stop or significantly change the course of technologies, designs, and costs for human exploration.

Reconnoitering Special Regions Is Just a Start: Finding the Special Regions is Recommendation 10 of [2]. MEPAG-2010 Investigation 2E outlines key measurements: ◆ Map distribution of naturally occurring surface special regions, including via change detection; ◆ Characterize survivability at the surface of terrestrial organisms, including response to oxidation, desiccation, and radiation; ◆ Map distribution of trace gases, as a clue to potential distribution and character of subsurface special regions that cannot be directly observed; ◆ Determine distribution of near-surface ice that could become an induced special region. Orbital and landed measurements (soil probes, heat flow, electromagnetic, ground-penetrating radar) could characterize thermal conductivity, structure, and composition. This is a good start, but a comprehensive program Pathway leading up to and supporting the conduct of human in situ missions is needed.

Example of a Program Pathway: MEPAG Objective IVA Investigation 1B [3] would "determine if extant life is widely present in the Martian near-surface regolith, and if the airborne dust is a mechanism for its

Table 1. Example stepwise program Pathway that could resolve the forward-contamination paradox otherwise precluding human exploration of Mars. (ISRSA = in situ and returned-sample analysis.)

Step		Example Modality	Result	Collateral Benefit
Clear the dry zones	Verify non-viability of windblown dust zone	• Atmospheric-dust sample return • Planetwide bio-reactivity assay, e.g., using "printable spacecraft"	Aeolian transport not a vector between zones	• First step of sample return as early as 2018 • Mission pull for OCT technologies
	Verify non-viability of dessicated zones	• In situ and returned-sample analysis from dunes, basaltic highlands, etc.	Vast regions of Mars surface OK for human exploration	• EDL for higher elevations • Surface operations for rugged terrain
	Verify absence of endoliths	• ISRSA for photolithotrophs at increasingly likely sites • ISRSA for chemolithotrophs at increasingly likely sites	Most potentially hospitable rock layers OK for human exploration	• Complex selection and return of scientifically selected samples • Complex, extensive in situ life-sign analysis
	Verify non-viability of endolithic microclimates	• Controlled experiments of terrestrial microbial viability in rocks under native conditions	Constraints on biota shedding requirements for human systems in dry zones	• In situ life-introduction experiment techniques for rock
Clear the temperate subsurface ice zones	Verify sterility of protected, episodic melt monolayers associated with large mid-latitude ice deposits	• Deep coring of subsurface ice for paleo or extant life-sign ISRSA • Probing seasonal melt interface as it migrates for life-sign ISRSA • Controlled experiments of terrestrial microbial viability of subsurface ice	• No indigenous ecology in the retrievable reservoirs of ice likely to be used for water, oxygen, and propellant (human ISRU), or… • Constraints on biota shedding requirements for human systems in ice zones • Forward-contamination issue reduced to ethics of terraforming ice deposits	• Drilling operations • Ice-mining technology • In situ life-introduction experiment techniques for subsurface ice
Clear the evident flow zones	Verify gully flows and recurring slope lineations are not caused by liquid water	• Persistent (areosynchronous) or high repeat-frequency, high-resolution spectroscopy from orbit during lineation events • In situ roving neutron spectroscopy at flow aprons and flow sources	Apparent, recent surface flows not caused by liquid water, OK for human exploration	• Higher resolution orbital maps • Surface exploration of known dynamic sites
	If they do, verify sterility of water-flow zones	• Coring of apron deposits for paleo or extant life-sign ISRSA • ISRSA of seep sources for paleo or extant life signs • Controlled experiments of terrestrial microbial viability of episodically moist zones under native conditions	• No indigenous ecology at surface-exposed moist zones or subsurface liquid zones connecting with surface, OK for human exploration • Forward-contamination issue reduced to ethics of terraforming "aquifers" • Constraints on biota shedding requirements for human systems in wet zones	• Technology for complex, moisture-following subsurface sampling • In situ life-introduction experiment techniques for subsurface

transport." This reflects the beginning of a progressive protocol, first outlined in [1], to conclude in stepwise fashion that Mars is sterile, by first mapping and then progressively shrinking the boundaries of zones requiring Category-IVs protection. The protocol begins with robotic missions, allows human activity in incrementally "cleared" zones, and uses sterile robots as probes for human missions to penetrate Special Regions to clear them as well. The end state is either proof of indigenous Mars life, or a sound basis for sequential relaxation of planetary protection restrictions on human exploration at sites of keenest astrobiological interest.

Conclusions: Table 1 shows an example framework for the proposed Pathway. Some important conclusions are immediately apparent: (1) dust sample return in 2018 could be a first critical step; (2) a rich campaign of multiple SMD sample-return and sophisticated in situ analysis missions would have to precede HEOMD development of human systems; (3) OCT would have to develop a diverse suite of advanced technologies, e.g., robotic life-sign analysis, finessed mobile access in rugged terrain and subsurface seeps, deep drilling, in situ human analytical laboratories, and others. Without such a Pathway, much different from traditional plans, human exploration may be precluded.

References: [1] B. Sherwood (2004), Progressive Protocol For Planetary Protection During Joint Human and Robotic Exploration of Mars, IAC-04-IAA.3.7.2.10. [2] NRC (2006), Preventing the Forward Contamination of Mars, ISBN: 978-0-309-09724-6. [3] J.R. Johnson et al. (2010), MEPAG Mars Science Goals, Objectives, Investigations, and Priorities: 2010.