ASTROBIOLOGY AND THE HUMAN EXPLORATION OF MARS J. S. Levine[1], J. B. Garvin[2], B. G. Drake[3], D. W. Beaty[4], and the HEM-SAG Team, [1]NASA Langley Research Center, Hampton, VA 23681, joel.s.levine@nasa.gov, [2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [3]NASA Johnson Space Center, Houston, TX 77058, [4]Jet Propulsion Laboratory, Pasadena, CA 91109.

Introduction: In March 2007, the Mars Exploration Program Analysis Group (MEPAG) charterd the Human Exploration of Mars Science Analysis Group (HEM-SAG), co-chaired by J. B. Garvin and J. S. Levine and consisting of about 30 Mars scientists from the U.S. and Europe. HEM-SAG was one of a half dozen teams charted by NASA to consider the human exploration of Mars. Other teams included: Mars Entry, Descent and Landing, Human Health and Performance, Flight and Surface Systems, and Heliospheric/Astrophysics. The results of these Mars teams and the development of an architecture for the human exploration of Mars were summarized in two recent publications: Human Exploration of Mars Design Reference Architecture 5.0, NASA Special Publication-2009-566 (B. G. Drake, Editor), 100 pages, July 2009 and Human Exploration of Mars Design Reference Architecture 5.0, NASA Special Publication-2009-566 Addendum (B. G. Drake, Editor), 406 pages, July 2009. This presentation summarizes the HEM-SAG conclusions on astrobiology and the search for life on Mars by humans.

The Unique Attributes of Humans in Scientific Exploration: It is important to consider the unique capabilities that humans bring to the process of exploring Mars. As a result, a common set of human traits emerged that apply to exploration relating to the MEPAG science disciplines, which include geology, geophysics, life, and climate. These characteristics include: speed and efficiency to optimize field work; agility and dexterity to go places that are difficult for robotic access and to exceed currently limited degrees-of-freedom robotic manipulation capabilities; and, most importantly, the innate intelligence, ingenuity, and adaptability to evaluate in real time and improvise to overcome surprises while ensuring that the correct sampling strategy is in place to acquire the appropriate sample set. Real-time evaluation and adaptability especially would be a significant new tool that humans on Mars would bring to surface exploration. There are limitations to the autonomous operations that are possible with current robotic systems, with fundamental limitations to direct commanding from Earth being the time difference imposed by the 6- to 20-minute communications transit time and the small number of daily uplink and downlink communications passes.

Humans are unique scientific explorers that could obtain previously unobtainable scientific measurements on the surface of Mars. Humans also possess the ability to adapt to new and unexpected situations in new and strange environments. They can make real-time decisions, have strong recognition abilities, and are intelligent. Humans also can perform detailed and precise measurements of the surface, subsurface, and atmosphere while on the surface of Mars using state-of-the-art scientific equipment and instrumentation brought from Earth. The scientific exploration of Mars by humans would presumably be performed as a synergistic partnership between humans and robotic probes – a partnership that is controlled by the human explorers on the surface of Mars. Robotic probes could explore terrains and features not suitable or too risky for human exploration. Under real-time human control, robotic probes could traverse great distances from the human habitat, covering distances/terrain too risky for human exploration; undertake sensitive, delicate sample handling operations; and return rock and dust samples to the habitat for triage and laboratory analyses.

Determine Whether Life Ever Arose on Mars: By 2025, our assessments of habitability potential will be well advanced for some environments, particularly those that have been visited by the MSR or by major in-situ rovers with life-related experiments. However, it is likely that the habitability of the martian subsurface will be almost completely unexplored other than by geophysical methods. The objective relating to carbon cycling is likely to be partially complete, but in particular as related to subsurface environments. For the purpose of this planning, we assume that the investigations through 2025 have made one or more discoveries that are hypothesized as being related to ancient life (by analogy with the Allen Hills meteorite story, this is a particularly likely outcome of MSR). We should then be prepared for the following new objectives:

1. Characterize the full suite of biosignatures for ancient life to confirm the past presence of life. Interpret its life processes and the origin of such life.

2. Assess protected environmental niches that may serve as refugia for extant life forms that may

havesurvived to the present. Find the life, measure its life processes.

3. In earliest martian rocks, characterize the prebiotic chemistry.

Biology/Life Scientific Objectives for the Initial Human Exploration of Mars: Human-enabled biological investigations on Mars would focus on taking samples and making measurements to determine whether life ever arose on Mars. This goal is consistent with the 2006 MEPAG goals and priorities, and we do not see this goal changing within the next 30 years. The search for life on Mars can be generally broken into two broad categories: (1) the search for evidence of past life on Mars, which may or may not still be alive; and (2) the search for present (extant) life. Both have been, and will continue to be, based on a search for H_2O, since all life on Earth requires H_2O for survival. Abundant evidence on the martian surface of past H_2O activity (e.g., rivers, lakes, groundwater discharge) has led to Mars becoming a strong candidate as a second planet in the Solar System with a history of life. With our increasing knowledge of the extremes under which organisms can survive on Earth, especially in the deep subsurface, whether martian life is still present today has become a compelling and legitimate scientific question. The NRC was recently commissioned to do a study to develop "an up-to-date integrated astrobiology strategy for Mars exploration that brings together all the threads of this diverse topic into a single source for science mission planning." This NRC report, which was published in 2007, is entitled An Astrobiology Strategy for the Exploration of Mars (NRC, 2007). Although this report did not consider how to do science with humans, we rely heavily on it and earlier MEPAG documents here to provide snapshots of the current community thinking on astrobiological investigations on Mars.

As pointed out by the NRC (2007), the search for life on Mars requires a very broad understanding of Mars as an integrated planetary system. Such an integrated understanding requires investigation of the following:

1. The geological and geophysical evolution of Mars;
2. The history of Mars' volatiles and climate;
3. The nature of the surface and the subsurface martian environments;
4. The temporal and geographical distribution of H_2O;
5. The availability of other resources (e.g., energy) that are necessary to support life; and
6. An understanding of the processes that control each of the factors listed above.

Many of these investigations are well under way robotically and will be much further advanced through future robotic missions and sample return missions.

The Search for Extant Life

The NRC (2007) suggests a number of high-priority targets based on evidence for present-day or geologically recent H_2O near the surface. These targets are

1. The surface, interior, and margins of the polar caps;
2. Cold, warm, or hot springs or underground hydrothermal systems; and
3. Source or outflow regions that are associated with near-surface aquifers that might be responsible for the "gullies" that have been observed on the martian surface.

The MEPAG Special Regions Science Analysis Group (2006) noted that the sites where recent H_2O may have occurred might also include some mid-latitude deposits that are indicative of shallow ground ice. Conditions in the top 5 m of the martian surface are considered extremely limiting for life. Limiting conditions include high levels of ultraviolet radiation and purported oxidants as well as most of the surface being below the limits of H_2O activity and temperature for life on Earth. For these reasons, finding evidence of extant life near the martian surface will likely be difficult, and the search will almost certainly require subsurface access. This was also a key recommendation of the NRC (2007).

The Search for Past Life

The NRC (2007) lists sites that are pertinent to geologically ancient H_2O (and, by association, the possibility of past life), including the following:

1. Source or outflow regions for the catastrophic flood channels;
2. Ancient highlands that formed at a time when surface H_2O might have been widespread (e.g., in theNoachian); and
3. Deposits of minerals that are associated with surface or subsurface H_2O or with ancient hydrothermal systems or cold, warm, or hot springs.