SCIENTIFIC GOALS AND OBJECTIVES FOR THE HUMAN EXPLORATION OF MARS, 2. GEOLOGY AND GEOPHYSICS. J. B. Garvin[1], J. S. Levine[2], A. D. Anbar[3], D. W. Beaty[4], M. S. Bell[5], R. T. Clancy[6], C. S. Cockell[7], J. E. Connerney[2], P. T. Doran[8], G. Delory[9], J. T. Dickson[10], R. C. Elphic[11], D. B. Eppler[5], D. C. Fernandez-Remolar[12], J. W. Head[10], M. Helper[13], J. E. Gruener[5], J. Heldmann[14], V. Hipkin[15], M. D. Lane[16], J. Levy[10], J. Moersch[17], G. G. Ori[18], L. Peach[19], F. Poulet[20], J. W. Rice[3], K. J. Snook[21], S. W. Squyres[22] and J. R. Zimbelman[23]
[1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, james.b.garvin@nasa.gov, [2]NASA Langley Research Center, [3]Arizona State University, [4]Jet Propulsion Laboratory, [5]NASA Johnson Space Center, [6]Space Science Institute, [7]Open University, UK, [8]University of Illinois, Chicago, [9]University of California, Berkeley, [10]Brown University, [11]Los Alamos National Laboratory, [12]INTA, Spain, [13]University of Texas, [14]NASA Ames Research Center, [15]Canadian Space Agency, [16]Planetary Science Institute, [17]University of Tennessee, [18]University d'Annunzio, Italy, [19]USRA, [20]IAS, CNRS, France, [21]NASA Headquarters, [22]Cornell University, [23]NASM, Smithsonian Institution.

Introduction: To prepare for the exploration of Mars by humans, as outlined in the new national vision for Space Exploration (VSE), the Mars Exploration Program Analysis Group (MEPAG), chartered by NASA's Mars Exploration Program (MEP), formed a Human Exploration of Mars Science Analysis Group (HEM-SAG), in March 2007. HEM-SAG was chartered to develop the scientific goals and objectives for the human exploration of Mars based on the Mars Scientific Goals, Objectives, Investigations, and Priorities.[1] The HEM-SAG is one of several humans to Mars scientific, engineering and mission architecture studies chartered in 2007 to support NASA's plans for the human exploration of Mars. The HEM-SAG is composed of about 30 Mars scientists representing the disciplines of Mars biology, climate/atmosphere, geology and geophysics from the U.S., Canada, England, France, Italy and Spain. MEPAG selected Drs. James B. Garvin (NASA Goddard Space Flight Center) and Joel S. Levine (NASA Langley Research Center) to serve as HEM-SAG co-chairs. The HEM-SAG team conducted 20 telecons and convened three face-to-face meetings from March through October 2007. The management of MEP and MEPAG were briefed on the HEM-SAG interim findings in May. The HEM-SAG final report was presented on-line to the full MEPAG membership and was presented at the MEPAG meeting on February 20-21, 2008.

This presentation will outline the HEM-SAG geology and geophysics goals and objectives. A companion paper will outline the HEM-SAG biology and atmosphere/climate goals and objectives.

Why Mars? Mars is a diverse and complex world. Many of the same processes/mechanisms have operated and still operate on both Earth and Mars, including a period of early heavy bombardment, the formation of impact craters, the existence of a planetary dipole magnetic field, periods of extensive and widespread volcanism, the existence of surface liquid water, the geochemical cycling of elements between the surface and the atmosphere and the condensation of atmospheric gases forming polar caps, etc.

The geological record suggests that the atmosphere and climate of Mars may have changed significantly over its history. Early Mars may have possessed a denser atmosphere, perhaps with a surface pressure approaching or even exceeding 10000 millibars, the surface pressure of the Earth's atmosphere. A denser atmosphere would have permitted liquid water on its surface. Today, Mars has a thin (6 millibars) atmosphere and liquid water is not stable on its surface for any length of time. Why did Mars change so drastically over its history compared to Earth? What can present-day geological features and geophysical measurements tell us about the history and evolution of the interior, surface and atmosphere of Mars? How extensive and widespread are sub-surface volatiles on Mars? How has the habitability of Mars changed over its history? Was early Mars an abode for life? Is present-day Mars an abode for life? Is there a lesson in the history of Mars to better understand the future of the Earth? These are but a very small subset of the questions that humans on Mars can address.

Why Humans? Humans are unique scientific explorers. Humans can obtain previously unobtainable measurements while on the surface of Mars. Humans possess the abilities and intelligence to adapt to new and unexpected situations in new and alien environments. Human explorers can make real-time decisions. Human explorers have strong recognition abilities. Human explorers can perform detailed and precise measurements of the surface, sub-surface and atmosphere of Mars with state-of-the art scientific equipment and instrumentation. Human explorers can perform detailed and precise in situ analysis on the surface of Mars. The HEM-SAG envisions that the scientific exploration of Mars will be performed as a synergistic partnership between humans and robotic probes, controlled by humans on the surface of Mars. Robotic probes can travel great distances and explore terrains and geologic features not suitable or too risky for human exploration. For example, under human control, robotic probes can traverse great distances from the human landing site and collect and return rock samples to the human base from great distances. At the human landing site, these rock samples can be analyzed and studied on the surface of Mars.

Single vs. Multiple Site Missions: There is no site on Mars that spans the diverse range of surface processes or mineralogy that Mars exhibits. Therefore, it would be necessary to study a multitude of sites to provide context and form conclusions about the geologic history of the planet. Strategic planning of exploration sites could potentially reveal deposits that are consistent over regional and potentially global scales. Several of our fundamental questions *require* multiple sites; crustal magnetism in the Noachian cannot be studied in the same region as Amazonian lava flows, for instance. While any one site would be interesting, no individual site would provide the necessary data to make firm conclusions about the geologic history of Mars.

Mission Surface Stay Time: Members of the HEM-SAG team have multiple field seasons of experience in harsh climates on Earth, from the bottom of the ocean, to the Canadian arctic, to the Dry Valleys of Antarctica. The overwhelming consensus is that a long-duration (500 day mission) is not only recommended but required to yield significant science return worthy of the time and effort needed to get to Mars. The first week of any human mission to Mars would be occupied by setting up a base camp, establishing communication systems, initial exploration of science targets, and general acclimation to the environment. If this were a 30-day short-stay mission, little time would be left for scientific analysis before preparing to depart. Astronauts will encounter unexpected features on the surface and time must be allotted in the mission to allow them to explore and design experiments at the exploration site.

Human and Robotic Operations: Despite the remarkable accomplishments of the Mars Exploration Rovers, automated rovers are severely limited in the harsh Martian climate. Robots on Mars are heavily constrained by the low-temperature and high-dust conditions on the Martian surface. Remote programming from Earth also influences less-than-efficient mobility and on-station activity for rovers. These problems would all be mitigated by human presence on Mars, where decisions can be made in real-time and routine maintenance of equipment can be performed. Rovers are traditionally designed with a limited instrument payload that is designed to answer certain scientific questions, whereas humans have the capacity to adapt to the environment and design hypotheses and experiments in the field that can yield data and results that otherwise would be unavailable.

Humans and rovers should have a symbiotic relationship on Mars. Analogous to terrestrial geologists using submersibles to study the ocean floor, there will be locations on Mars that are unsafe for humans to explore. For this reason there should be rovers with the astronauts that can traverse steep slopes and enter craters that humans might not be able to get out of. Robots should be used to extend, interpolate and scout human observations and traverses. Focus on how the human/robots partnership can be optimized should be a priority for mission architecture from the outset of any human mission to Mars.

Roving Distance Scales: As exhibited by the Apollo missions, traverse capacity in planetary missions is greatly enhanced by human presence. A critical component of any field investigation is the mapping of various rock types, and the greater the distance traveled, the more surface context is provided for the analysis. At all of our reference mission sites, human missions would allow for the study of units of different mineralogical composition and surface age, permitting a detailed description of the local, regional and potentially global geologic history.

Drilling: Geology Implications: Our understanding of Mars is currently limited to the top centimeters to meter of the surface. Drilling at any site on Mars would yield unprecedented data, but there are several specific questions that could be solved by targeted drilling. Among others, 1) Drilling into the northern lowlands can test the hypothesis that there was once a vast ocean on Mars; 2) Drilling into either of the polar caps will reveal the record of recent climate change on Mars; 3) Drilling in a site with known gullies can test the hypothesis that deep groundwater aquifers (> 200m below the surface) have supplied the water that carved recent channels on Mars; 4) Drilling into an assortment of lava flows can yield the evolution of the Martian interior through time, and perhaps its paleomagnetic field; 5) Drilling through known sedimentary structures like deltas can reveal the climatic conditions when deposited. Several drilling projects performed in conjunction can reveal patterns in the history of Mars that are currently unknown. Drilling is also of extreme importance in the search for sub-surface life.

References: [1] MEPAG, 2006. Mars Scientific Goals, Objectives, Investigations, and Priorities: 2006, J. Grant, ed., 31 p. white paper posted February, 2006 by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports/index.html.