INTERIM RESULTS FROM THE MEPAG HUMAN EXPLORATION OF MARS SCIENCE ANALYSIS GROUP (HEM-SAG). J. Heldmann[1], J. Levine[2], J. Garvin[3], D. Beaty[4], M.S. Bell[5], T. Clancy[6], C.S. Cockell[7], G. Delory[8], J. Dickson[9], R. Elphic[10], D. Eppler[11], D. Fernandez-Remolar[12], J. Gruener[13], J.W. Head[14], M. Helper[15], V. Hipkin[16], M. Lane[17], J. Levy[18], R. Millikan[19], J. Moersch[20], G. Ori[21], L. Peach[22], F. Poulet[23], J. Rice[24], K. Snook[25], S. Squyres[26], and J. Zimbelman[27], [1]NASA Ames Research Center , [2]NASA Langley Research Center, [3]NASA Goddard Space Flight Center, [4]Jet Propulsion Laboratory, [5]NASA Johnson Space Center, [6]SSI, [7]Open University, [8]UC Berkeley, [9]Brown University, [10]Los Alamos National Laboratory [11]NASA Johnson Space Center, [12]Center for Astrobiology, Spain, [13]NASA Johnson Space Center, [14]Brown University, [15]UT-Austin, [16]Canadian Space Agency, [17]PSI, [18]Brown University, [19]Jet Propulsion Laboratory, [20]University of Tennesee, [21]IRSPS, Italy, [22]USRA, [23]University of Paris, France, [24]Arizona State University, [25]NASA Headquarters, [26]Cornell University, [27]Smithsonian

Introduction: In March 2007, MEPAG (Mars Exploration Program Analysis Group) chartered the Human Exploration of Mars Science Analysis Group (HEM-SAG) to prepare an analysis of the possible science objectives for the human exploration of Mars (HEM). The work of the HEM-SAG feeds into the Mars Architecture Working Group that is tasked with developing integrated program strategies and decision timelines for the initial human exploration of Mars. The possible capabilities that can be provided as part of the Mars surface system are thus iterated with the Flight and Surface Architecture Team as well as the HEM-SAG to develop a most robust human exploration program.

HEM-SAG Assumptions: The HEM-SAG is conducting its work based on several assumptions. HEM-SAG assumes 1) three crewed missions to the martian surface, 2) the earliest human landing is 2030, 3) the scientific objectives for the first human mission to Mars will be set on cumulative knowledge and priorities as of about 5-8 years before launch, 4) a program of robotic missions to Mars will occur between now and the first human mission and thus at the time of the first human mission, our present knowledge of Mars will be incremented by the results of these robotic missions.

Tasks: The HEM-SAG has been chartered with completing the following tasks: 1) Develop a projection of the content of the pre-human Mars robotic program, 2) Analyze the probable/possible evolution of our scientific goals and objectives for Mars up to the time of launch of the human mission in the context of the current MEPAG Goals Document, 3) Analyze the attributes of scientific objectives that would make them appropriate for human explorers, 4) Analyze the options and priorities for program-level scientific goals and objectives, 5) Analyze the scientific options for individual missions within the mission assumed program, 6) Conduct trade studies for key parameters affecting the human mission architecture such as length of stay and number of sites visited by the human missions.

Preliminary Findings: The HEM-SAG here reports on some preliminary findings from work to date. Analysis is still ongoing and these represent only preliminary results of the HEM-SAG efforts.

Context. Science can provide fundamental reasons for humans to explore Mars and to ensure an important and lasting legacy (knowledge, technological capability, etc). Science is a key partner in this overall program. HEM-SAG analysis indicates that humans on Mars can significantly and uniquely advance our understanding of the science of Mars in terms of life, climate, geology, and geophysics, and provide answers to scientific questions that cannot be answered by robotic missions alone. The scientific exploration of Mars should not be driven wholly by engineering considerations; as such, limitations on human exploration access due to altitude, illumination conditions, etc. should be considered in combination with scientific goals and the human activities required to achieve these goals.

Length of Stay and Number of Sites. The HEM-SAG recommends a long stay (500 days) and visits to multiple separate sites to maximize science potential. This scenario provides the highest science yield which requires diversity in both time and space for optimization. The long stay reflects the large amount of work to be performed by humans and robots at each independent site, including adequate time for highly informed sampling, in situ sample reconnaissance, subsurface access, and operation of supporting robotic assistance. It also allows time for maximum utilization of mobility to investigate Mars using well-established field methods already validated on the Earth and Moon. The scientific requirement for three unique human exploration sites reflects the well-established diversity of geological features (and related process histories) on the surface and subsurface of Mars reflecting events from the three primary geological periods of Mars: Noachian, Hesperian, and Amazonian. The second most favored scenario is the short stay (40 days) at multiple sites followed by the long stay at one

individual site for each mission. The least favored scenario is the short stay at one site.

Sampling Diversity. Sampling diversity of Mars is a key variable for human scientific exploration. The projected state of understanding of Mars suggests the highest priority unknowns will likely remained unanswered until the time of human exploration. Therefore human exploration favors multiple, independent sites in order to adequately investigate the Mars "system" in both space and time as well as to understand the chronology.

Mobility. Mobility is an essential capability of any science-optimized human mission to Mars. HEM-SAG concludes that beyond-Apollo-class mobility on the surface of Mars is key to achieving the prioritized scientific goals and objectives of human exploration. Case studies conducted by the HEM-SAG suggest that radial mobility on the order of 100-200 km (minimum) is most desirable.

Interdisciplinary Studies. Human exploration of Mars must optimize scientific objectives and investigation priorities across all major MEPAG Goal areas (Life, Climate, Geology) with an emphasis on interdisciplinary objectives. Many of these studies require sample return to Earth.

Supporting instrumentation/equipment. The HEM-SAG has identified the supporting instrumentation and equipment required to achieve the scientific objectives of HEM. Instrumentation required in a laboratory at the Habitat as well as on field rovers has been identified. As an example, subsurface drilling capability to a depth of several hundred meters is an important technology that needs to be developed prior to HEM because of its significance to multiple science priorities.

Public Engagement. The public, in particular the student population, must be completely engaged in the scientific exploration of Mars. The HEM-SAG believes this will not be a difficult task due to the excitement and interest in exploring new worlds.

Future Work: The HEM-SAG study is a work-in-progress and analysis continues to address several additional issues. These issues include, but are not limited to, 1) tradeoffs between using pressurized rovers versus unpressurized rovers and the various capabilities of each asset, 2) quantifying the level of robotic assistance (and related suborbital sample acquisition and transfer to the human flight systems) for key science activities, 3) projecting 15-20 years ahead to quantify the level of in situ instrumentation required to support HEM missions, 4) outlining specific experiments and investigations to be conducted both inside and outside the Habitat while also providing estimated mass and volume requirements for each case, 5) potential mass fraction of long surface stay mission downmass available for science, 6) assessment of planetary protection protocols likely to be faced in return of Mars samples to Earth on HEM missions, 7) development of several Human Surface Reference Missions (HSRM) to provide detailed activities, instrumentation, and traverse maps for HEM missions, 8) compilation of a comprehensive listing of all relevant HEM science objectives, 9) evaluation of the effectiveness of multiple surface mission architectures proposed by the Mars Architecture Working Group and suggestion of additional options as needed to achieve scientific objectives.

The HEM-SAG continues to work such issues related to the human exploration of Mars and looks forward to sharing the results of this progress with the community.