SCIENTIFIC INVESTIGATIONS ASSOCIATED WITH THE HUMAN EXPLORATION OF MARS IN THE NEXT 35 YEARS

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Introduction

A human mission to Mars would present an unprecedented opportunity to investigate the earliest history of the solar system. This history that has largely been overwritten on Earth by active geological processing throughout its history, but on Mars, large swaths of the ancient crust remain exposed at the surface, allowing us to investigate martian processes at the earliest time periods when life first appeared on the Earth. Mars' surface has been largely frozen in place for 4 billion years, and after losing its atmosphere and magnetic field what remains is an ancient landscape of fomer hydrothermal systems, river beds, volcanic eruptions, and impact craters. This allows us to investigate scientific questions ranging from the nature of the impact history of the solar system to the origins of life.

We present here a summary of the findings of the Human Science Objectives Science Analysis Group, or HSO-SAG chartered by MEPAG in 2015 to address science objectives and landing site criteria for future human missions to Mars (Niles, Beaty et al. 2015). Currently, NASA's plan to land astronauts on Mars in the mid 2030's would allow for robust human exploration of the surface in the next 35 years. We expect that crews would be able to traverse to sites up to 100 km away from the original landing site using robust rovers. A habitat outfitted with state of the art laboratory facilities that could enable the astronauts to perform cutting edge science on the surface of Mars. Robotic/human partnership during exploration would further enhance the science return of the mission.

The Benefits of Human-Robot Exploration

The essential feature, from the point of view of science planning, of a potential human mission to Mars would be the presence of humans on the surface. However, we do not envision the scientific content of a human mission to Mars as only the science that would be done by astronauts' hands. Science efficiency during a crewed mission could be substantially enhanced by complementary operation between humans and robots on the surface of Mars. This would include work directly done by astronaut-explorers, human supervision and control of robotic assets around the habitat, and human supervision and control of robotic assets well outside the exploration zone (>100 km away).

The key question then is what are the kinds of scientific activities that would either be enabled or significantly enhanced by humans on the surface of Mars? Our analysis concluded that while humans can do many tasks that could also be performed by robots controlled from Earth, humans provide exceptional abilities in performing the following:

Establishing geologic context:

Humans in the field can rapidly collect and process visual data to determine stratigraphic relationships, superposition relationships, rock types, structures, and landforms.

Sampling

Human situational awareness improves the likelihood of identifying important samples of opportunity using judgment and experience to combine multiple streams of data to build a conceptual model of the site to test multiple working hypotheses.

Sample preparation and analysis in a habitat-based laboratory

Humans can manipulate and prepare samples in an unlimited variety of ways, ensuring that the right kinds of measurements are made on the most important part(s) of the sample to address the investigation.

Performing field investigations and analyses

Many field instruments and sensor systems benefit from troubleshooting and optimization in order to improve the targeting or data collection parameters of the sensor. Humans both speed up

the rate of measurement as well as improve its quality.

Robotic assets working along side astronauts would also provide several important advantages to a human mission. For example, sterilized robots may be able to explore special regions (areas where liquid water may be present) in order to minimize contamination and collect essential samples in the search for life. Robots could also provide long term autonomous monitoring at a fixed station allowing for the crew to perform other tasks. Finally robots could provide effective reconnaissance that could be utilized to maximize the time of the crew on the surface and identify important sites for more intensive study. Robots operating beyond line of sight of crew could extend the human presence beyond the edge of the Exploration Zone (telepresence) including exploring other regions on Mars.

Much of this will be important during human exploration of other solar system bodies as well, and human exploration has the potential to provide substantial science return at a wide variety of destinations.

High Priority Science Objectives

Many different scientific objectives could be pursued that would be appropriate for the capabilities of a crewed mission. However, a potential human mission would be constrained in mass, power, volume, cost, mission risk, astronaut risk, and other factors. The high priority science objective set will need to be continually adjusted within these constraints and limited resources. In addition, while priorities can be more easily defined within a particular scientific discipline, consensus priorities that cut across different disciplines will require much more work within the scientific community. Given those caveats, high priority scientific objectives have been mapped out in three general areas: Astrobiology, Climate/Atmospheric Sciences, and Geological Sciences.

Past habitable environments with high preservation potential for ancient biosignatures are the primary target for our understanding of the history of habitability of the Planet. Robotic missions have identified some past habitable environments, and based on results collected thus far, we expect past habitable environments to be preserved in many locations across the surface of Mars. These include

sediments derived from lakes, rivers, and peri-glacial environments, as well as igneous rocks that preserve evidence for ancient hydrothermal environments. Biosignatures indicating the existence of past life can be identified through morphological, chemical, and mineralogical analyses of the geological materials. These analyses can be performed at the rock outcrop, in a laboratory on the Mars surface, or by laboratories on Earth examining returned samples.

Discovering evidence for existing life on Mars would be an extraordinary discovery and would allow us to study the biology that is likely to be completely alien from our own. Locations on Mars that allow for the presence of liquid water would be the primary target for this search which would have to be conducted carefully under strict planetary protection protocols.

While we have been able to study the martian atmosphere from orbit and at the surface in a few locations, much uncertainty remains about the atmospheric state and forcings near the surface. Robust measurements by meteorological stations distributed across the human exploration zone would provide new insights into how the martian atmosphere behaves. Additional measurements of surface materials and atmospheric properties would allow us to better understand sources and sinks for dust, water, and CO_2 and the cycling of these materials. Furthermore, geological investigations will yield insight into past climate states and the evolution of the martian atmosphere over time and under different orbital configurations.

The origin and geological evolution of the planet would be pursued through the characterization of surface units to evaluate the diverse geologic processes and paleo-environments that have affected the martian crust. Geologic mapping and sample analysis would allow us to determine the sequence and duration of geological events, and establish their context within the geologic history of Mars to answer larger questions about planetary evolution.

References:
Niles, P. B., D. W. Beaty, et al. (2015). Candidate Scientific Objectives for the Human Exploration of Mars, and Implications for the Identification of Martian Exploration Zones. Report of the Human Science Objectives Science Analysis Group (HSO-SAG), Mars Exploration Analysis Group (MEPAG).