FUTURE HUMAN PRECURSOR MISSION MISSIONS AND ARCHITECTURES TO ACHIEVE HUMANS TO MARS. L.W. Beegle[1] R. Kinnett[1] and E. Klien[1], [1]Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena Ca, 91109-8099, Luther.Beegle@jpl.nasa.gov

Introduction: We have studied a series of payload options that are in response to measurements identified by MEPAG as vital to human precursor activity. These payloads have the ability to make a significant dent in the needed measurements to send humans to Mars, while defining future human spacecraft designs. These precursor mission payloads utilized non-specific instruments including existing Mars program heritage hardware and instruments. Our study was restricted to the initial duel orbiter and stationary lander making simultaneous measurements, and included a series of future missions that led up to human EDL.

Background: The Mars Exploration Program Analysis Group (MEPAG) and the National Research Council, has undertaken studies to determine measurements that are required before a human mission can take place [1]. The measurements defined in these documents are consistent with other recent and preceding studies, except for slight re-ordering of the priorities. In brief the measurements we focused on were (in priority order from MEPAG Goal IV):

1A.a: Make global measurements of the vertical profile of aerosols (dust and water ice) at all local times between the surface and >60 km with a vertical resolution ≤ 5 km.

1A.c: Monitor surface pressure in diverse locales over multiple Martian years to characterize the seasonal cycle, the diurnal cycle (including tidal phenomena) and to quantify the weather perturbations (especially due to dust storms). The selected locations are designed to validate global model extrapolations of surface pressure. The measurements would need to be continuous with a full diurnal sampling rate > 0.01 Hz and a precision of 10^{-2} Pa.

1.A.d: Globally monitor the dust and aerosol activity, especially large dust events, to create a long-term dust activity climatology.

2.A.a (in situ): a higher spatial resolution maps of H-bearing trace gases. Verification of mineral/ice volume abundance and physical properties within approximately the upper 3 meters of the surface.

2.A.b (in situ): Measurement of the energy required to excavate/drill the H-bearing material.

2.A.c (in situ): Measurement of the energy required to extract water from the H-bearing material

2B.b: Measurement of neutrons with directionality. Energy range from ≤10 keV to ≥100 MeV.

2C.a: Assay for chemicals with known toxic effect on humans. Of particular importance are oxidizing species associated with dust-sized particles. Might require a sample returned to Earth.

2C.b: Fully characterize soluble ion distributions, reactions that occur upon humidification and released volatiles from a surface sample and sample

Table 1 Human Precursor notional lander payload.

Objective	Mass	Power	Duration	Operational Requirements/Notes
1A.c	1.3 kg	25 W	15 min	Samples at 1 Hz for 5 mins of each hour, every sol (MSL's plan)
1A.b and d	5.0 kg	10 W	25 min	Doppler shift measurements as well as time gating
2A.c	9.2 kg	65 W	0.1 hr	6 mins per exper cycle, ~0.7 W-hr
2A.e	4.2 kg	66.4 W	3 hour	Would work in conjunction with drill.
2B.b	1.9	4.2 W	10 Hz	Multiple hour integration over mission life time.
2C.a-b	7.8 kg	20W	2 hours	Requires sample acquisition
2D.a-d	.5 kg			Used with a robotic Arm.
2D.a-d	4.2 kg	4 W	1 hour	Used with a robotic Arm.

Table 2 Human Precursor Notional orbiter Payload. Yellow box at bottom is likely a standalone mission.

Objective	Mass	Pwr	Data
1A.a-d 2A.b3	21 kg	44W	Daily pole to pole coverage of temperature, direct measurement of winds, some trace gasses (including H2O)
1A.a-d	11.2 kg	18.4	Temperature, Pressure dust and H2O with 5km vertical resolution between 0-90 km.
2B. C	3.31	7 W	Particle radiation in 15 -500 MeV per nucleon. Needs to have a source on the ground concurrent to fulfill MEPAG measurement goal.
4. a,b	65.10	60 W	High resolution images of landing sites on the surface. Building on the ~1-2% of total surface MRO will map.
2A. b,c	200	450 W	Near surface hydrogen content.

of regolith of similar depth might be affected by human surface operations.

2D.a: Measure the magnitude and dynamics of any quasi-DC electric fields that may be present in the atmosphere as a result of dust transport or other processes, with a dynamic range of 5 V/m-80 kV/m, with a resolution ΔV=1V, over a bandwidth of DC-10 Hz (measurement rate = 20 Hz)

2D.b: Determine if higher frequency (AC) electric fields are present between the surface and the ionosphere, over a dynamic range of 10 uV/m – 10 V/m, over the frequency band 10 Hz-200 MHz. Power levels in this band should be measured at a minimum rate of 20 Hz and also include time domain sampling capability.

2D.c: Determine the electrical conductivity of the Martian atmosphere, covering a range of at least 10^{-15} to 10^{-10} S/m, at a resolution ΔS= 10% of the local ambient value.

2D.d: Determine the electrical conductivity of the ground, measuring at least 10^{-13} S/m or more, at a resolution ΔS of 10% of the local ambient value

3a: A complete analysis of regolith and surface Aeolian fines (dust).

4a: Imaging of selected potential landing sites to sufficient resolution to detect and characterize hazards to both landing and trafficability at the scale of the relevant landed systems.

4b: Determine traction/cohesion in Martian regolith throughout planned landing sites.

4c: Determine vertical variation of *in situ* regolith density within the upper 30 cm for rocky areas, on dust dunes, and in dust pockets to ~ 0.1 g cm^{-3}

Site Selection: Our evaluation of human precursors indicates that early site selection is an important step in the entire human precursor series of measurements. Multiple measurements can be made early but will have to be re-made once the final human landing site is selected. A "most likely" landing site selection with current orbital assets is possible, and would energize the public. It enables in situ resource utilization demonstrations that could be useful to future human exploration as products would be in place for future missions.

Conclusions: Much of the technology currently exists to put together the first few of human precursor missions, which could greatly reduce the uncertainty of sending humans to mars.

Table 3. State of important measurements after 2 (or 3) precursor measurements. Red boxes indicate measurements not addressed, Yellow represents partial address, and Green is complete made measurements. Note the importance of early site selection. (AHLS: Assumes Human Landing Site selection, HLS: Human Landing Site selected)

Investigation	Present SMD work (MSL etc.)	Proposed precursor missions	Mars after SMD and 2 precursor missions	
1A Atmospheric EDL conditions	REMS, MEDLI			
1B BioHazard and life detection	SAM			
2A ISRU	TLS, ChemCam, SAM	AHLS	AHLS	If no HLS
2B Ionization radiation	DAN			
2C Toxicity	SAM, ChemCam			
2D Electrical Atm. Conditions				
2E Special regions		AHLS	AHLS	If no HLS
3 Aeolian particles				
4 Landing site hazards	MAST CAM	AHLS	AHLS	If no HLS

[1] Beaty, D.W., et al (2005). An Analysis of the Precursor Measurements of Mars Needed to Reduce the Risk of the First Human Missions to Mars. Unpublished white paper, 77 p, posted June, 2005 by the Mars Exploration Program Analysis Group (MEPAG); Space Studies Board 2002a. *Safe on Mars: Precursor Measurements Necessary to Support Human Operations on the Martian Surface*. National Research Council, National Academy Press, Washington, DC.