MARS HUMAN PRECURSOR SCIENCE/EXPLORATION STEERING GROUP (MHP-SSG)

INTRODUCTION

David Beaty, Noel Hinners

Feb. 17, 2005

The context

A full program of preparing for a human mission to Mars needs to consider the following components:

- Flight missions to Mars
  - –Measurements of the martian environment.
  - –Tech. Demos/Infrastructure Emplacement
- Missions to the Moon
- Laboratory, Field, and Flight test program on Earth
- Flight missions to Earth orbit

This analysis (Flight missions to Mars)

The full job (all components)

Why do Precursor Missions?

Reduce Risk

- Uncertain knowledge of Mars—requires higher design margins than necessary
- Demonstrate flight technology—flight-tested systems are less risky.

Reduce Cost

- Identify the cost drivers, find lower-cost alternatives

Increase Performance

From a starting point of minimum acceptable performance, are there ways performance can be increased at acceptable cost?

Organization of the Study

OVERALL LEADERS: Beaty, Hinners

TECHNOLOGY/ INFRASTRUCTURE
Hinners, Braun

- Transit Team
  Leader = Joosten
- Mars Atmosphere Flight Team
  Leader = Powell
- Surface Operations Team
  Leader = Kohlhasse

HUMAN ACTIVITY AT MARS
Beaty

- 2030 Science Focus Team
  Leaders = Bishop, Heldmann

MEASUREMENTS
Beaty, Snook

- Radiation Haz. Team
  Leader = Zeitlin
- Dust/Soil/ Toxicity/ Focus Team
  Leader = Wagner
- Biohazard/ PP Focus Team
  Leader = Allen
- Atmosphere/ Weather Focus Team
  Leader = Farrell
- Terrain Focus Team
  Leader = Eppler
- Water Resources Focus Team
  Leader = XXX

→ ***INPUTS TO ADVANCE MISSION PLANNING, (Frank Jordan)***

Engaging the Community

NASA System		
Drummond	Mark	ARC
Fishman	Julianna	ARC
Heldmann	Jennifer	ARC
McKay	Chris	ARC
Venkatapath	Ethiraj	ARC
Fincannon	James	GRC
Tyburski	Tim	GRC
Farrell	Bill	GSFC
Glavin	Daniel	GSFC
Houghton	Martin	GSFC
Banerdt	Bruce	JPL
Fuerstenau	Stephen	JPL
Gershman	Robert	JPL
Golombek	Matt	JPL
Hecht	Mike	JPL
Kohlhase	Charley	JPL
Martin	Terry	JPL
Rapp	Don	JPL
Whetsel	Charles	JPL
Winterhalter	Daniel	JPL
Allen,	Carl	JSC
Cucinotta	Francis	JSC
Eppler	Dean	JSC
Graves	Claude	JSC
Hoffman	Steve	JSC
James	John	JSC
Jones	Jeffrey	JSC
Joosten	Kent	JSC
Kennedy	Kriss	JSC
Kosmo	Joseph	JSC
Pearson	Don	JSC
Rush	James	JSC
Sanders	Jerry	JSC
Snook	Kelly	JSC
Tri	Terry	JSC
Wagner	Sandy	JSC
Levine	Joel	LARC
Powell	Richard	LaRC
Metzger	Philip	KSC
Adams	James H.	MSFC
Stephenson	David	MSFC
Bielitzki	Joe	NASA
Connolly	John	NASA HQ
Rush	John	NASA-HQ
Trosper	Jennifer	NASA-HQ

Academia		
Leshin	Laurie	Arizona State Univ.
Rice	Jim	Arizona State Univ.
Head	Jim	Brown University
Mewalt	Richard	Caltech
Ippolito	Jim	Colorado State U.
Banfield	Donald	Cornell University
Cummer	Steven	Duke University
Braun	Bobby	Georgia Tech
Gaier	Jim	Manchester College
Boston	Penny	New Mexico Tech.
Kovacs	Greg	Stanford University
Kraft	Daniel	Stanford University
Lemmon	Mark	Texas A&M
Kounaves	Sam	Tufts University
Arnold	Jim	UC Berkeley
Delory	Greg	UC Berkeley
Withers	Paul	Univ. Arizona
Mazumder	M.K.	Univ. Arkansas
Taylor	Jeff	Univ. Hawaii
Renno	Nilton	Univ. Michigan
Waite	Hunter	Univ. Michigan
Sotin	Christophe	Univ. Nantes, Franc
Newsom	Horton	Univ. New Mexico
Hipkin	Vicky	Univ. of Toronto
Law	Jennifer	Univ. Souther Cal.
Moersch	Jeff	Univ. Tennessee
Townsend	Larry	Univ. Tennessee

Other		
Turner	Ron	ANSER
Cockell	Charlie	Brit. Antarctic Sur.
Henkel	Richard	CDC-Atlanta
Horneck	Gerda	DLR
Colangeli	Luigi	INAF - Italy
Heilbronn	Lawrence	Lawence Berk. Lab
Zeitlin	Cary	Lawence Berk. Lab
Clark	Benton	Lockheed/Martin
Vaniman	Dave	Los Alamos Nat. La
Clifford	Steve	Lunar & Plan. Inst.
Tolson	Robert	NIA
Lane	Melissa	Plan. Sci. Inst.
Fragola	Joe	SAIC
Murphy	James	San Jose St. Found
Marshall	John	SETI
Race	Margaret	SETI
Bishop	Janice	SETI Institute
Clancy	Todd	Space Sci. Inst.
Rafkin	Scot	SWRI
Peach	Lewis	USRA
Stabekis	Perry	Windermere
Marler	Becca	

Assumptions for this Study

1. The first human mission is scheduled in 2030.
   - goes to the martian surface
   - at least one EVA
2. The series of robotic precursor missions will be designed to reduce risk/cost in the <u>first</u> human mission. For the purpose of this analysis the human program beyond the first mission is undefined.
3. Assume the long-stay and short-stay martian missions are BOTH under active consideration.
4. First dedicated robotic precursor mission in 2011.

This Session

Start	Time	Agenda Item	
8:00	0:20	ESMD update and MHP SSG Introduction	Connolly
8:20	0:45	Proposed revisions to Goal IVa	Beaty et al.
9:05	0:45	Proposed revisions to Goal IVb	Hinners
9:50	0:40	General Discussion:	Group
10:30			

MEASUREMENT SUB-TEAM

INTRODUCTION

David Beaty, Kelly Snook

Risk Analysis

1. Risk analysis process guided by professional risk analysis team (SAIC).
2. Using expert focus teams, probability and consequence of risks that can be reduced by precursor measurement assessed.

Risk Prioritization Criteria

- **a)** **Magnitude of effect** of precursor information on reduction of risk and/or cost of a human mission to Mars.
- b) Perceived degree of viability and cost of available **engineering solutions**
- c) Potential to obtain minimum necessary information in a **less expensive way** than by flying a mission to Mars.

Risk Analysis

All of the risks to the first human mission will need to be dealt with in one of the following ways:

- **Accept the risk**
- **Mitigate the risk** by means of engineering solutions
- **Buy down the risk** by means purchasing advance information
  - reduce uncertainty (so we don't engineer to the upper limit)
  - Establish new (lower-cost) engineering solutions

It is not MHP SSG's job to decide what risks are unacceptable. Our job is to place them in priority order to support future decision-making.

Recommended Revision to Goal IVa

MEPAG (2001)		NRC (2002)		MEPAG (2005)	
		Not listed in priority order	Soil, dust: engineering	1A	Soil, dust: engineering
3	Atmospheric characterization			1B	Atmospheric characterization
			Biohazard–Back PP	1C	Biohazard–Back PP
4	Water-related ISRU			1D	Water-related ISRU
2	Soil, dust: humans		Soil, dust: humans	2	Soil, dust: humans
6	Atmos. electricity			3	Atmos. electricity
				4	Contam.–Forward PP
1	Ionizing radiation		Ionizing radiation	5	Ionizing radiation
5	Traverability hazard		Traverability hazard	6	Traverability hazard
				7	Dust storm meteorology
			3D terrain–landing site safety	8E	3D terrain–landing site safety
			Rocks–landing site safety	8D	Rocks–landing site safety

TEAM DUST

INTRODUCTION

Sandy Wagner, Team Leader

Risks

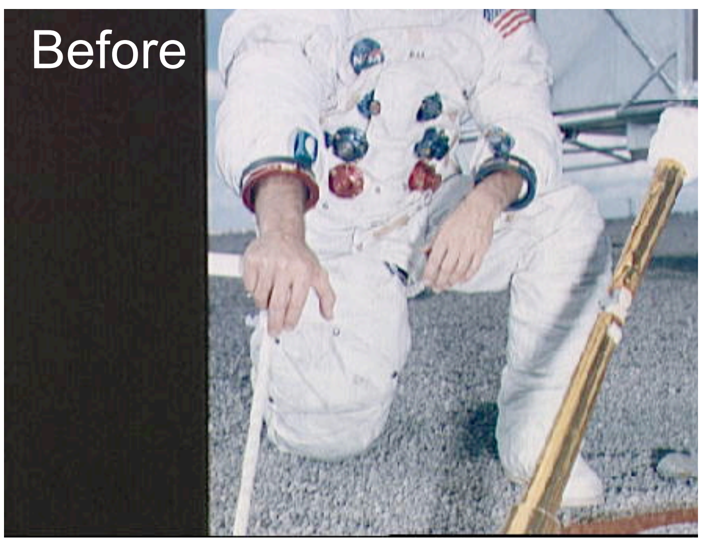
Risk 6A: Failure Due to Abrasion and Accumulation

Risk 6B: Failure of Electrical Systems

Risk 6C: System Failure Due to Corrosive Effects of Dust

Risk 7: If the crew inhales or ingests dust adverse health effects may result.

Apollo 12 – Alan Bean's Spacesuit



Investigations and Measurements

Investigation 1A.

Characterize the particulates that could be transported to mission surfaces through the air (including both natural aeolian dust and particulates that could be raised from the martian regolith by ground operations), and that could affect hardware's engineering properties.

Analytic fidelity sufficient to establish credible engineering simulation labs and/or performance prediction/design codes on Earth is required.

Investigations and Measurements

<u>Measurements</u>

a. Complete analysis
   - Shape and size distribution
   - Mineralogy
   - Electrical and thermal conductivity
   - Triboelectric and photoemission properties
   - Chemistry

b. Polarity and magnitude of charge
   - individual dust particles suspended in atmosphere
   - concentration of free atmospheric ions with positive and negative polarities.

c. The same measurements as in a) on a sample of air-borne dust collected during a major dust storm.

d. Subsets of the complete analysis described in a), and measured at different locations on Mars.

Investigations and Measurements

Investigation #2.

Determine the possible toxic effects of martian dust on humans.

Team Dust

Investigations and Measurements

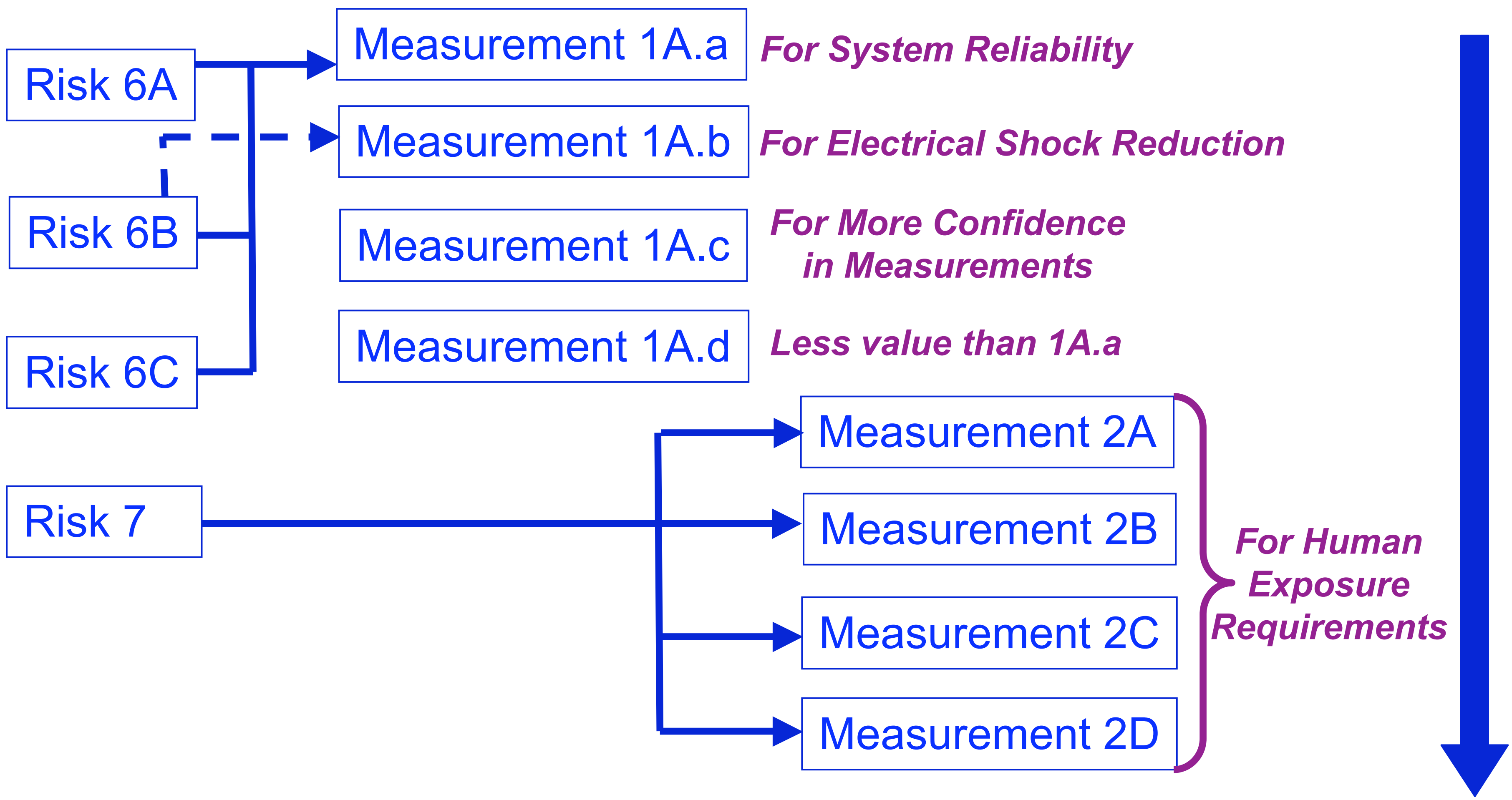
<u>Measurements:</u>

1. For at least one site, assay for chemicals with known toxic effect on humans.
2. Fully characterize:
   - soluble ion distributions
   - reactions that occur upon humidification
   - released volatiles
3. Analyze the shapes of martian dust grains
4. Determine if martian regolith elicits a toxic response in an animal species which is a surrogate for humans.

Team Dust

Risk Mapping

Risk | **Measurements** | **Risk Exposure**



TEAM ATMOSPHERE

INTRODUCTION

Bill Farrell, Team Leader

Team Atmosphere

Risks

Risk #4: Wind shear and turbulence will create unexpected and uncompensatable trajectory anomalies affecting EDL and TAO.

Risk #8: Dust storm electrification may cause arcing, and force human explorers to seek shelter during storms and affect TAO.

Risk #10: During crew occupation and EVA, dust storm may affect visibility to the point where EVA's for regular habitat maintenance becomes compromised.

Risk #15: Photochemical and chemical reactions in the atmosphere have the potential to corrode equipment and/or create a toxic environment for humans.

Investigations and Measurements

<u>Investigation #1B.</u> Determine the fluid variations from ground to >90 km that affect EDL and TAO including both fair-weather and dust storms.

Investigations and Measurements

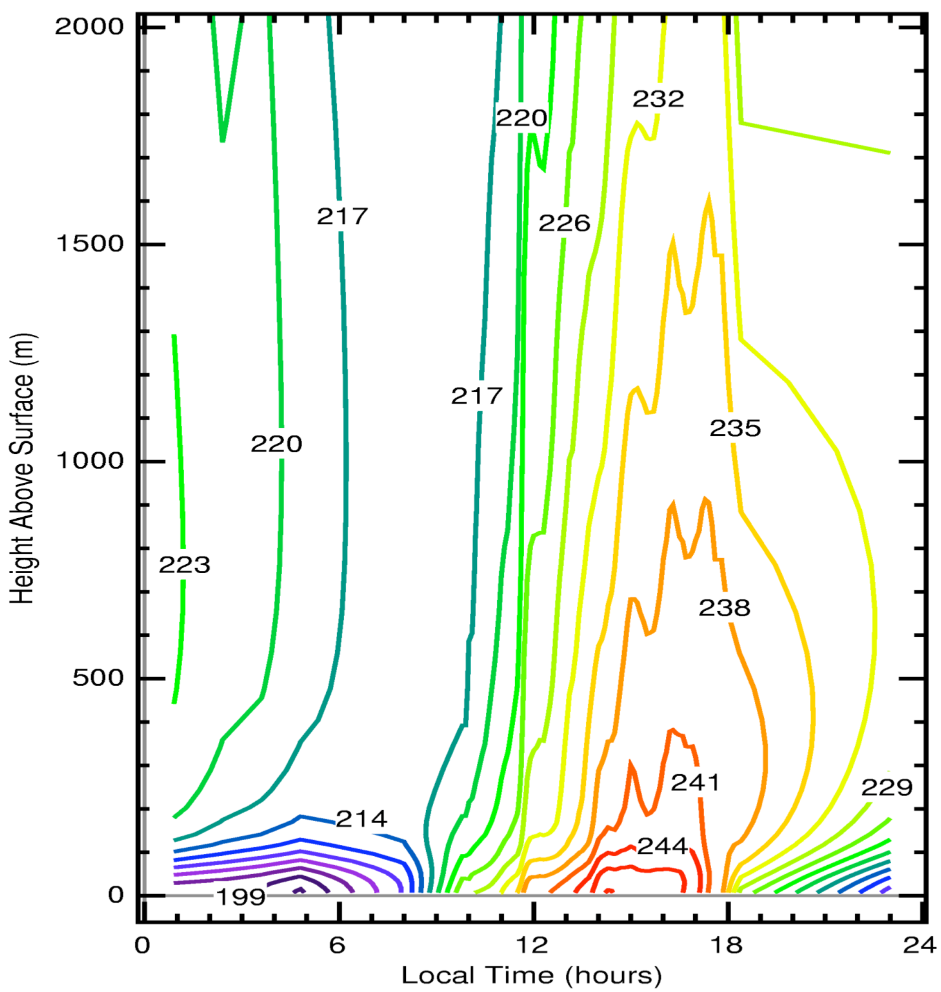
<u>Measurements</u>

– Measure v, P/ ρ, and T in the atmosphere **during EDL** with as many profiles/locations as possible. Quantify turbulent layers.
– Monitor **surface/near-surface** v, P/ ρ, and T, as a function of time, as many locations as possible.
– Make **long-term observations** of the weather from orbit (aeolian cloud frequency size and occurrence, temperature & density profiles, winds as a function of altitude, with profiles obtained globally).
– During human EDL and TAO, pre-deploy ascent/descent probes to obtain P, V, and T along assumed trajectory.

Measurements needed globally with special emphasis on 0-20 km to quantify boundary layer turbulence and 30-60 km where vehicle dynamic pressures are large

Example: BL Atmosphere Dynamics

Temperature profile vs Local Time



Smith et al, 2004 Multi-sol composite

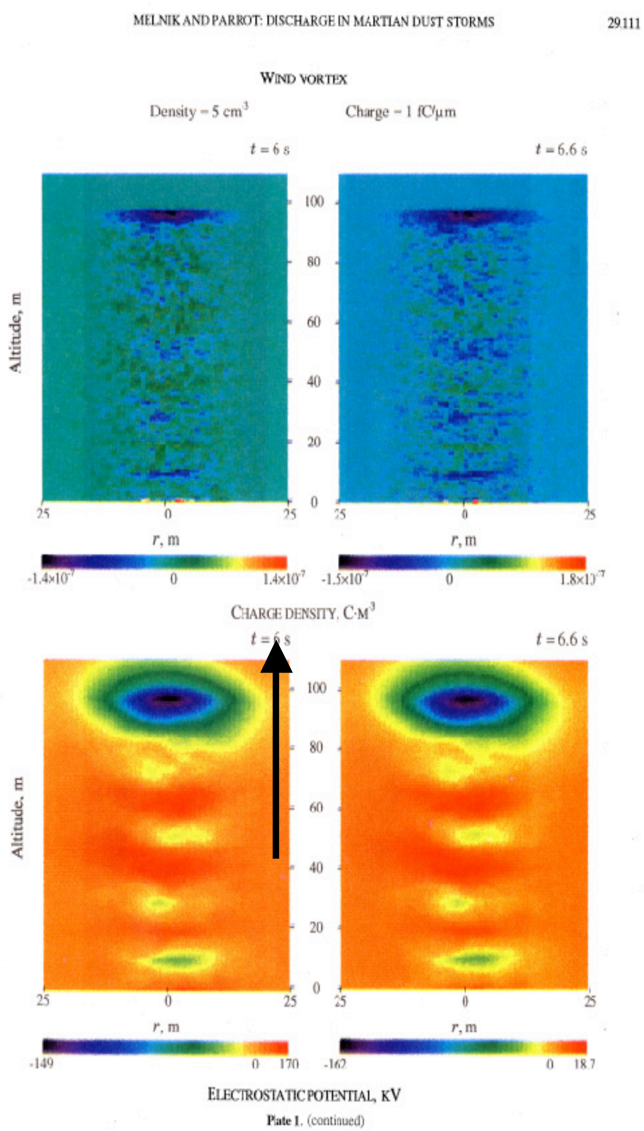
- Models indicate that boundary layer very dynamic and unstable in afternoon via solar heated surface
- MER Mini-TES obtained atmospheric temperature vs height profiles via radiative transfer inversion model
- Observed a super-adiabatic layer in the afternoon resulting in turbulent motion
- High time resolution shows the passage of thermal plumbs extending to high altitudes over MER… temperature changes on order of 5^{o}C.
- What are the winds during unstable period? Don't know because a surface MET package was not included
- Some of the plumbs may even be hot-cored vortices [Ryan and Lucich, 1983] with substantial wind shifts

Investigations and Measurements

Measurements

- Derive the basic measurements of atmospheric electricity that affects TAO and human occupation.
  - DC E-fields (electrostatic fields), AC E-fields (RF from discharges & RF contamination assessment), atmospheric conductivity probe, surface conductivity probe, and grain radius and charge
  - Combine with surface MET package to correlate electric and its causative meteorological source over a Martian year, both in dust devils and large dust storms.
- *Measurements needed on at least one landed mission.*

Example: Melnik and Parrot [1998]



- Simulated Martian dust cloud dynamics
- Charged grains via contact electrification
- Allowed large and small grains to separate via gravitational filtration
- Used Poisson solver to monitor ES fields
- Found inter-cloud potential differences of 300 kV over 100 m dust devil and E-field values near local breakdown levels
- Rocket launch could cause a discharge from cloud top-to-bottom
- Parallel to KSC field mill system

Investigations and Measurements

Measurements

- Determine the meteorological properties of dust storms at ground level that affect human occupation and EVA.
  - P (or ρ), V, T, and dust density (opacity) as a function of time at the surface, for at least a Martian year, to obtain an understanding of the possible MET hazards inside dust storms. Dust particle properties should be quantified (see Soil/Dust FT).
  - Orbiting weather station: optical and IR measurements to monitor the dust storm frequency, size and occurrence over a year, & measure terrain roughness and thermal inertia. Obtain temperature & density profiles, winds as a function of altitude, with profiles obtained globally.

TEAM BIOHAZARD

INTRODUCTION

Carl Allen, Team Leader

Risks

Risk #5: Martian life transported to Earth

Hazards to Earth's biota and ecosystems

Risk #9: Terrestrial life transported to Mars

Local / widespread contamination

False positive indication of life on Mars

Hybridization with Martian life

Risk #11: Martian life released in surface habitat

Health hazard to crew

Potential for mixing ecologies

Interference with biological life support systems

Team Biohazard

Investigations – High Risk

<u>Investigation #1C.</u> Determine if each Martian site to be visited by humans is free, to within acceptable risk standards, of replicating biohazards which may have adverse effects on humans and other terrestrial species.

Sampling into the subsurface for this investigation must extend to the maximum depth to which the human mission may come into contact with uncontained Martian material.

Measurements

Phase 1. Is life 'everywhere'?

- Return and analyze samples in terrestrial laboratories.
- Test for evidence of Martian life in representative samples of the atmosphere, dust, near-surface soil, deep soil, rock and ice
- Fully characterize Martian life (if found)
- Test for biohazards

Phase 2. Landing site screening

- At the site of the planned first human landing, conduct biologic assays using in-situ methods.
- At the site of the planned first human landing, conduct biologic assays using in-situ methods
- Measurements and instruments specific to Martian life found by previous investigations

Investigations – High Risk

Investigation #4. Determine the processes by which terrestrial microbial life, or its remains, is dispersed and/or destroyed on Mars, the rates and scale of these processes, and the potential impact on future scientific investigations.

Measurements

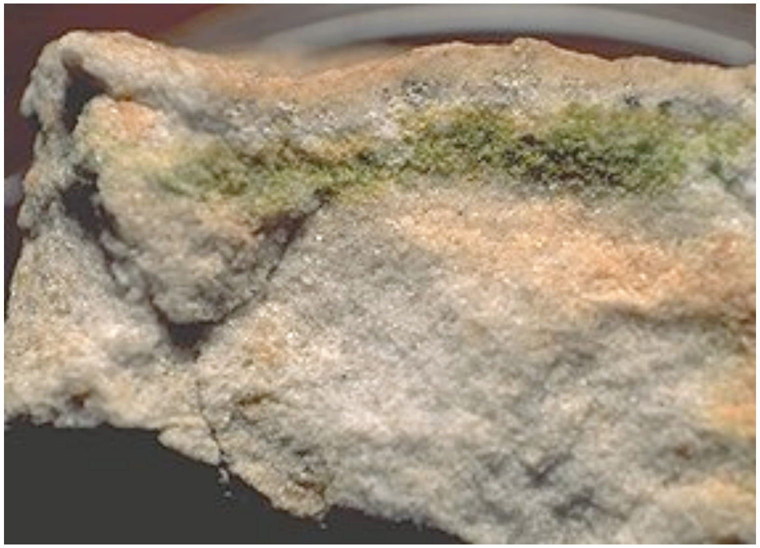
- Survival and reproduction under Martian conditions
- Destruction or organics at the Martian surface
- Mechanisms / rates of aeolian processes which disburse contaminants
- Mechanisms of contaminant transport into the Martian subsurface
- Adhesion characteristics of contaminants on landed mission elements

Measurements

Simulated Mars Environments

Test for survival and genetic adaptation of terrestrial life under Martian conditions

Assess rates, scales and methods of contamination dispersal under Martian conditions



TEAM RADIATION

INTRODUCTION

Cary Zeitlin, Team Leader

Team Radiation

Particles and Risks

- Galactic Cosmic Rays (GCRs)
  - Continuous
  - Low dose-rate
  - Predictable
  - Same at Earth and Mars
  - Risk is to long-term health, "late effects," principally cancer.
  - Cannot be stopped by practical depths of shielding
  - Not stopped by Martian atmosphere
  - Include heavy ions which may be important biologically.
- Solar Energetic Particles (SEPs)
  - Sporadic
  - Sometimes v. high dose-rates
  - Not predictable at present
  - Not same at Earth and Mars
  - Can present risk of immediate and severe illness, even death.
  - Can be stopped by practical depths of shielding*
  - Stopped by Martian atmosphere*
  - Very rare events produce highly energetic heavy ions.

* True in the vast majority of cases but not 100%

Radiation Hazard Summary

$$H_{GCR} = (2.5 \pm 0.8)t_{transit} + (1.1 \pm 0.5)t_{surface} \text{ with } H_{GCR} \text{ in milliSieverts and } t \text{ in days.}$$

GCR Dose for two scenarios with NO shielding

- Note LEO career limits: 0.5 to 4.0 Sv depending on age & gender.
- 6 month transit each way → 0.6 – 1.1 Sv total
- 30-day surface stay: .02 – .05 Sv total → < 10% of total.
- 500-day surface stay: 0.3 – 0.8 Sv total
  - 0.3 – 0.8 Sv could be significant depending on definition of career limits
  - Shielding of habitats on surface may help considerably
- A KEY CONCLUSION: The GCR radiation risk for the entire mission is significant, but the contribution from the time on Mars is small for a short-stay scenario.

SEP considerations on Martian surface

- Atmosphere provides significant shielding against primaries.
- Large fluxes of secondary neutrons are possible, give dose comparable to several months of exposure to GCR.

Risks

Risk #13: Risk of chronic radiation exposure exceeding career limits.

Mitigations:

- Precise knowledge of GCR flux and an accurate transport model.
- Relax "acceptable" standard with informed consent.

Risk #14: Risk of acute radiation exposure: Inadequate shielding against a severe solar event - crew members on surface EVAs especially at risk.

Mitigations:

- Early warning system.
- Accurate modeling of transport of solar energetic particles through atmosphere.
- In vast majority of cases, shielding from Martian atmosphere is enough.

Team Radiation

Investigations, and Measurements

- Like “Safe on Mars”, we recommend measurements needed to validate radiation transport models.
- Measure ionizing radiation on Martian surface:
  - Distinguish contributions from charged particles vs. neutrons, with coarse directionality (up vs. down vs. sideways).
  - Neutron fluxes will vary with location.
  - Difficult to measure low-energy neutrons if an RTG is used.
- Simultaneously, make orbital measurements of the charged particle flux at the top of the atmosphere to test transport models for SEPs and secondaries.
- *Measurements needed once (preferably twice) and over length of time sufficient to see multiple solar particle events.*

Why has the priority been reduced?

- Radiation risk for entire mission remains significant.
  - Very rare high-flux "hard spectrum" solar event is potentially dangerous and mitigation may not be possible.
- For long-cruise, short-stay mission, dose equivalent received on surface is a small part of the total (< 10%).
- Accuracy of risk assessment is incrementally advanced by measurements on the surface.
  - State of knowledge of particle fluxes & transport is relatively good, with some minor weaknesses.
  - Improved knowledge likely to have little effect on risk mitigation strategies.

RECOMMENDED REVISIONS TO MEPAG'S GOAL IVa

Recommended Revision to Goal IVa

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Possible Follow-up Studies

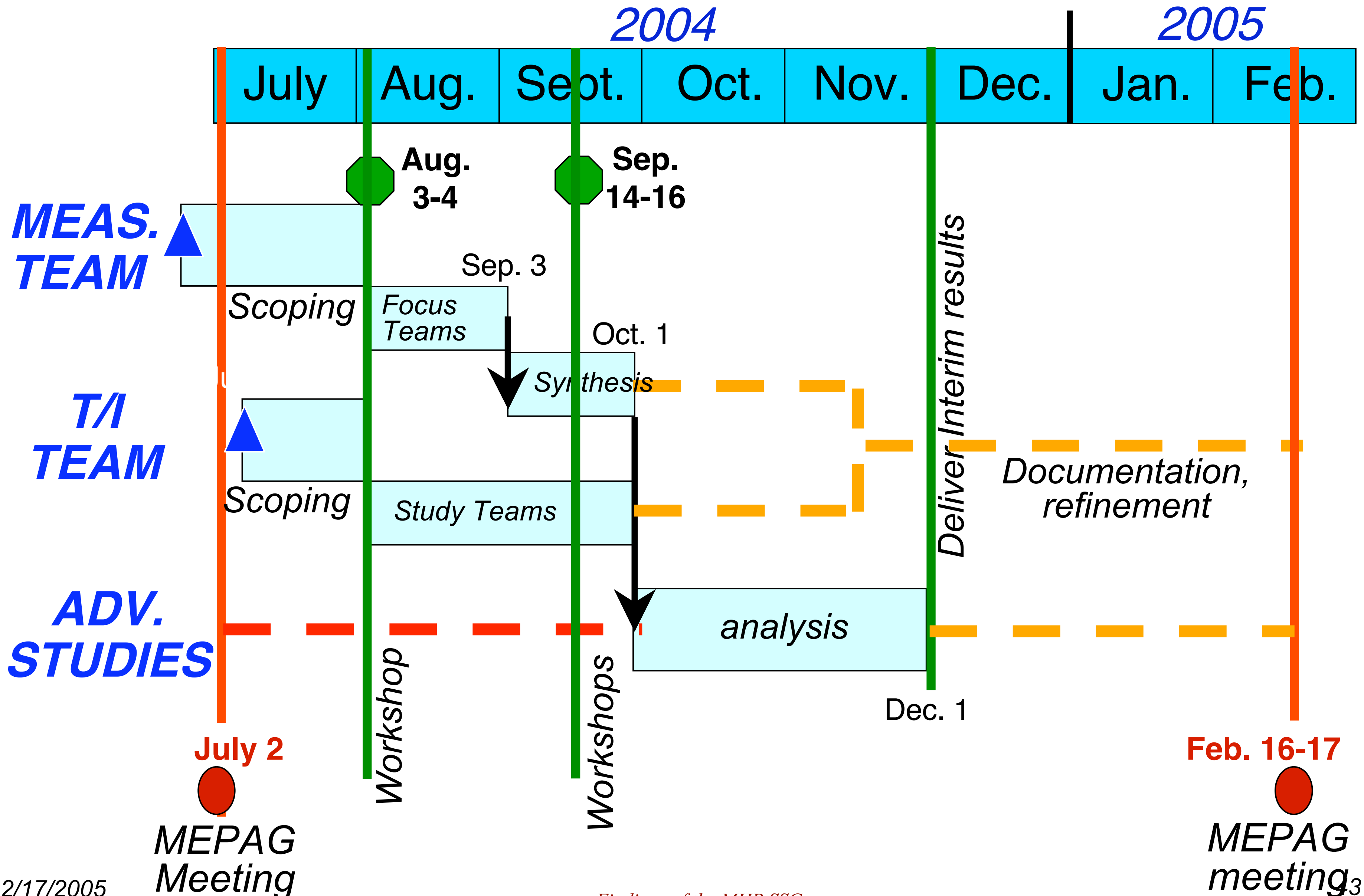
The MHP SSG sees a need/opportunity for further studies in the following areas:

- Optimal configuration for human aeroassist landing vehicle
- ISRU Trade Space
- Systems-level landing site constraints (other than ISRU)
- Science priorities for the first human mission

Backup Slides

Appendices

MHP SSG Timeline



Define Investigations, Measurements

Define the investigations and measurements that will address the high priority risks.

For all Measurements:

- Required precision and detection limit
- How many places or times?
- Sequential relationships

Definitions

Hazard - A state or condition that could potentially lead to undesirable consequences.

Risk - The combination of 1) the probability (qualitative or quantitative) and associated uncertainty that a program or project will experience an undesired event; and 2) the consequences, impact, severity and/or associated uncertainty of the undesired event were it to occur.

Opportunity - A state or condition that could potentially lead to desirable consequences.

Condition: The key circumstances, situations, etc., that are causing concern, doubt, anxiety, or uncertainty. In a risk statement, the condition phrase is the phrase at the beginning of the statement.

Consequence: The possible negative out comes of the current conditions that are creating uncertainty. In a risk statement, the consequence phrase is the phrase at the end of the statement.

Context: Context provides additional detail regarding the events, circumstances, and interrelationships within the project that may affect the risk. This description is more detailed than can be captured in the basic statement of risk.

Impact: The loss or effect on the project if the risk occurs. Impact is one of the three attributes of a risk. A risk that does not impact an objective is not particularly important to a project manager. A risk that can affect the objective should be assessed and, if possible, it's impact quantified. Qualitative judgments such as low, moderate and high-risk impacts are useful in some cases. The impact is traditionally described in two dimensions, it's likelihood of occurring and the impact on an objective should it occur.