Analysis of Strategic Knowledge Gaps Associated with Potential Human Missions to the Martian System

Precursor Strategy Analysis Group (P-SAG)

(jointly sponsored by MEPAG and SBAG)

Executive Summary for MEPAG

Oct. 4, 2012

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JPL CL#12-2401

HISTORY

- Last MEPAG meeting: Feb. 27-28
- Chartered March 1 by SMD and HEOMD to produce rapid inputs to MPPG.
- Review copy released May 31.
- Initial findings presented by the MEPAG Chair for public discussion at LPI workshop “Concepts and Approaches for Mars Exploration”, June 12-14.
- Feedback incorporated.
- Refined results accepted by MEPAG Executive Committee, and presented to MPPG June 30
- July: P-SAG dissolved
- This MEPAG meeting: Oct. 4

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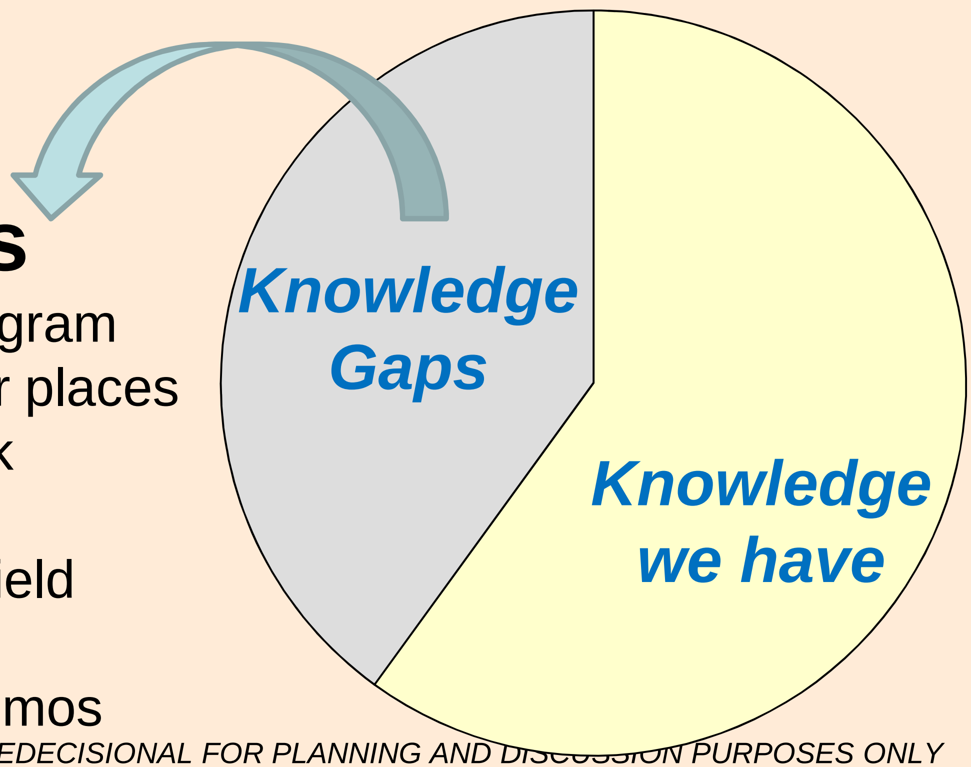
SKG and GFA: Definitions

1. **Strategic Knowledge Gap (SKG): The Gaps in Knowledge Needed to Achieve a Specific Goal.**
2. **Gap-Filling Activity (GFA): Work that contributes to closing an SKG.**

GFA areas

- Mars flight program
- Flights to other places
- Non-flight work (models, lab experiments, field analogs, etc.)
- Technology demos



Total knowledge needed to achieve a goal

Process Summary

1. The Strategic Knowledge Gaps (SKGs) associated with each of the following goals have been defined:
   - First human mission to martian orbit (**Goal IV-**).
   - First human mission to land on either Phobos or Deimos
   - First human mission to the martian surface (**Goal IV**).
   - Sustained human presence on Mars (**Goal IV+**)
2. The SKGs have been broken down into Gap-Filling Activities (GFAs), and each has been evaluated for priority, required timing, and platform.
3. The relationship of the above to the science objectives for the martian system (using existing MEPAG, SBAG, and NRC scientific planning), has been evaluated.
   - Five areas of significant overlap have been identified. Within these areas it would be possible to develop exciting mission concepts with dual purpose.
4. The priorities relating to the Mars flight program have been organized by mission type, as an aid to future mission planners: orbiter, lander/rover, Mars Sample Return (MSR), and Phobos/Deimos.

GFA Analysis (1 of 2)

SKG		Gap-Filling Activity	Priority	Timing	Location
A1	Upper Atmosphere	A1-1. Global temperature field.	H	IV-	Mars Orbit
		A1-2. Global aerosol profiles and properties	H	IV-	Mars Orbit
		A1-3. Global winds and wind profiles	M	IV-	Mars Orbit
A2	Atm. Modeling	A2-1. Atm. Modeling.	H	IV-	Earth
A3	Orbital Particulates	A3-1. Orbital particulate environment	M	IV-	Mars Orbit
A4	Technology: To/from Mars System	A4-1. Autonomous rendezvous and docking demo	H	IV-	Earth or Mars Orbit
		A4-2. Optical Comm. Tech demo	H	IV-	Earth or Mars Orbit
		A4-3. Aerocapture demo	M	IV-	Earth or Mars Orbit
		A4-4. Auto systems tech demo	L	IV-	Earth
		A4-5. In space prop tech demo	H	IV-	Earth
		A4-6. Life support tech demo	H	IV-	Earth
		A4-7. Mechanisms tech demo	L	IV-	Earth
B1	Lower Atmosphere	B1-1. Dust Climatology	H	IV Late	Mars Orbit
		B1-2. Global surface pressure; local weather	H	IV Early	Mars surface
		B1-3. Surface winds	M	IV Early	Mars surface
		B1-4. EDL profiles	M	IV Early	Mars EDL
		B1-5. Atmospheric Electricity conditions	L	IV Late	Mars surface
		B1-6. EDL demo	H	IV Early	Mars EDL
		B1-7. Ascent demo	H	IV Early	Earth or Mars Surface
B2	Back Contamination	B2-1. Biohazards	H	IV Early	Sample return
B3	Crew Health & Performance	B3-1. Neutrons with directionality	M	IV Late	Mars surface
		B3-2. Simultaneous spectra of solar energetic particles in space and in the surface.	M	IV Late	Mars surface and Mars orbit
		B3-3. Spectra of galactic cosmic rays in space.	L	IV Late	NEAR EARTH
		B3-4. Spectra of galactic cosmic rays on surface.	M	IV Late	Mars surface
		B3-5. Toxicity of dust to crew	M	IV Late	Sample return
		B3-6. Radiation protection demo	H	IV Late	Earth or Mars Surface
B4	Dust Effects on Surface Systems	B4-1. Electricity	L	IV Late	Mars surface
		B4-2. Dust physical, chemical and electrical properties	H	IV Late	Mars Surface or Sample return
		B4-3. Regolith physical properties and structure	M	IV Late	Mars Surface or Sample return

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See notes on page 10. For full statements of SKGs, see Appendix 1.

GFA Analysis (2 of 2)

SKG		Gap-Filling Activity	Priority	Timing	Location
B5	Forward Contamination	B5-1. Identify and map special regions	H	IV Late	Mars surface and Mars orbit
		B5-2. Model induced special regions	L	IV Late	Earth
		B5-3. Microbial survival, Mars conditions	M	IV Late	Earth
		B5-4. Develop contaminant dispersal model	M	IV Late	Earth
		B5-5. Forward Contamination Tech demo	M	IV Late	Earth or Mars Surface
B6	Atmospheric ISRU	B6-1. Dust physical, chemical and electrical properties	H	IV Late	Mars Surface or Sample return
		B6-2. Dust column abundances	L	IV Late	Mars surface
		B6-3. Trace gas abundances	L	IV Late	Mars Orbit
B7	Landing Site and Hazards	B7-1. Regolith physical properties and structure	M	IV Late	Mars Surface and Sample return
		B7-2. Landing site selection	M	IV Late	Mars surface and Mars orbit
		B7-3. Trafficability	L	IV Late	Mars surface
		B7-4. Auto rover tech demo	L	IV Late	Earth or Mars Surface
		B7-5. Env exposure tech demo	H	IV Late	Mars surface
		B7-6. Sample handling tech demo	L	IV Late	Earth or Mars Surface
B8	Tech: Mars Surface	B8-1. Fission power tech demo	H	IV Late	Earth
C1	Phobos/Deimos surface science	C1-1. Surface composition	H	IV- P/D	Phobos/Deimos rendezvous and lander
C2	Phobos/Deimos surface Ops	C2-1. P/D electric and plasma environments	L	IV- P/D	Phobos/Deimos rendezvous
		C2-2. P/D Gravitational field	M	IV- P/D	Phobos/Deimos rendezvous
		C2-3. P/D regolith properties	H	IV- P/D	Phobos/Deimos rendezvous and lander
		C2-4. P/D thermal environment	L	IV- P/D	Phobos/Deimos rendezvous and lander
C3	Technology P/D	C3-1. Anchoring and surface mobility demo	H	IV- P/D	Phobos/Deimos rendezvous and lander
D1	Water Resources	D1-1. Cryo storage demo	M	IV+	Earth
		D1-2. Water ISRU demo	M	IV+	Earth or Mars Surface
		D1-3. Hydrated mineral compositions	H	IV+	Sample return
		D1-4. Hydrated mineral occurrences	H	IV+	Mars Orbit
		D1-5. Shallow water ice composition and properties	M	IV+	Mars surface
		D1-6. Shallow water ice occurrences	M	IV+	Mars surface and Mars orbit
D2	Tech: Sustained Presence	D2-1. Repeatedly land	H	IV+	Earth
		D2-2. Sustain humans	H	IV+	Earth
		D2-3. Reduce logistical support	H	IV+	Earth

See notes on page 10. For full statements of SKGs, see Appendix 1.

GFA: Priority vs. Timing & Location
(Humans to the Martian Surface)

Priority \ Timing	IV-	IV early	IV late	IV+
H	• A1-1. Global T • A1-2. Aerosols • A2-1. Atm models • A4-1. Auto Rendez. • A4-2. Optical Comm • A4-5. Propul. demo • A4-6. Life supp. Demo	• B1-2. Surf Pressure • B2-1. Biohazards • B1-6. EDL demo • B1-7. Ascent demo	• B1-1. Dust clim. • B3-6. Rad. protect • B4-2. Dust prop. • B5-1. Special reg. • B6-1. Dust prop. • B7-5. Env expos • B8-1. Fission pwr	• D1-3. Hyd mins • D1-4. Min occur • D2-1. Land x N • D2-2. Sustain • D2-3. Logistics
M	• A1-3. Global wind • A3-1. Orb Partic. • A4-3. Aerocapture	• B1-3. Surf winds • B1-4. EDL profile	• B3-1. Neutrons • B3-2. SEPs • B3-4. Cosmic rays • B3-5. Toxicity • B4-3. Regolith • B5-3. Microbe • B5-4. Disprs model • B5-5. FPP • B7-1. Regolith • B7-2. Landng site	• D1-1. Cryo • D1-2. water ISRU • D1-5. Ice comp • D1-6. Ice occur
L	• A4-4. Auto sys • A4-7. Mech.		• B1-5. Atm elec • B3-3. Cosmic ray • B4-1. Elec • B4-4. Dust mit • B5-2. Model SpR • B6-2. Dust column • B6-3. Trace gas • B7-3. Trafficability • B7-4. Auto rover • B7-6. Samp handling	

Color Key:
Mars Orbiter
Earth
MSR
Technology demo
Mars Lander (Could be MSR landers)

Relationship of SKGs to Science

If the SKG is addressed, how well is the science question answered.

SKGs

Scientific Objectives, Martian System

Objective		#	Investigation (from 2010 MEPAG Goals Document)	A1 Upper Atmosphere	A2 Atm. Modeling	A3 Orbital Particulates	A4 Technology: To/from Mars System	B1 Lower Atmosphere	B2 Back PP	B3 Crew Health and Performance	B4 Dust Effects	B5 Forward PP	B6 Atmospheric ISRU	B7 Landing Site and Surface Hazards	B8 Technology: Mars Surface	C1 Phobos/Deimos Science	C2 Phobos/Deimos surface Ops	C3 Technology: Phobo/Deimos	D1 Water Resources	D2 Technology: Sustained Presence
I. Life	A. Past habitability /life	1	PRIOR HABITABILITY OF SURFACE ENVIRONMENTS																S	
		2	PRESERVATION POTENTIAL																	
		3	EVIDENCE OF PRIOR HABITABILITY OR BIOSIGNATURES																	
	B. Present habitability/life	1	PRESENTLY HABITABLE ENVIRONMENTS						E			E							S	
		2	DEGRADATION OF LIFE SIGNATURES						S			E								
		3	SEARCH FOR EXTANT LIFE						E			S								
	C. Evolution of habitability	1	CHARACTERIZE HYDROLOGICAL CYCLE																S	
		2	BIOESSENTIAL ELEMENTS																	
		3	POTENTIAL ENERGY SOURCES																	
		4	OXIDATIVE / RADIATION HAZARDS						E	E	S			S						
II. Climate	A. Present	1	WATER, CO2, AND DUST PROCESSES	E	E			E		S	S		E	S					S	
		2	PHOTOCHEMICAL SPECIES	S	S			S	E		S		E							
		3	VOLATILE AND DUST EXCHANGE	S	S			S			S		E							
		4	SEARCH FOR MICROCLIMATES						S		S	S	S							
	B. Recent	1	ISOTOPIC, NOBLE, & TRACE GAS CHANGES W/ OBLIQUITY																	
		2	STRATIGRAPHIC RECORD--PLD																	
		3	PERIGLACIAL PROCESSES																	
	C. Ancient	1	RATES OF ESCAPE OF KEY SPECIES				Not addressed.								Not addressed.			Not addressed.		Not addressed.
		2	PHYS AND CHEM RECORDS																S	
		3	ISOTOPIC, NOBLE, AND TRACE GAS EVOLUTION																	
III. Geology/ Geophysics	A. Crust	1	MINERALOGY OF GEOLOGIC UNITS							S	E			E					E	
		2	SEDIMENTARY PROCESSES AND EVOLUTION							S	S			S					S	
		3	ABSOLUTE AGES																	
		4	HYDROTHERMAL ENVIRONMENTS						E										S	
		5	IGNEOUS PROCESSES AND EVOLUTION																	
		6	SURFACE-ATM INTERACTIONS								S			S					S	
		7	TECTONIC HISTORY OF CRUST																	
		8	PRESENT STATE AND CYCLING OF WATER																E	
		9	CRUSTAL MAGNETIZATION																	
		10	EFFECTS OF IMPACTS																	
	B. Interior	1	STRUCTURE AND DYNAMICS OF INTERIOR																	
		2	ORIGIN AND HISTORY OF MAGNETIC FIELD																	
		3	CHEMICAL AND THERMAL EVOLUTION																	
	C. Phobos / Deimos	1	ORIGIN													E	S			
		2	COMPOSITION													E	E			
		3	INTERNAL STRUCTURE													E	E			

NO OVERLAP | EXCELLENT OVERLAP | SOME OVERLAP

Summary of Findings (1 of 2)

Finding #1	The high-priority gaps for a human mission to Mars orbit relate to a) atmospheric data and models for evaluation of aerocapture, and b) technology demonstrations.
Finding #2	A human mission to the Phobos/Deimos surface would require a precursor mission that would land on one or both moons.
Finding #3	The early robotic precursor program needed to support a human mission to the martian surface would consist of at least: • One orbiter • A surface sample return (the first mission element of which would need to be a sample-caching rover) • A lander/rover-based *in situ* set of measurements (which could be made from the sample-caching rover) • Certain technology demonstrations
Finding #4	P-SAG has not evaluated whether it is required to send a lander or rover to the actual human landing site before humans arrive.

Summary of Findings (2 of 2)

Finding #5	For several of the SKGs, simultaneous observations from orbit and the martian surface need to be made. This requires multi-mission planning.
Finding #6	There are five particularly important areas of overlap between HEO and science objectives (in these areas, mission concepts with dual purpose would be possible). 1. Mars: Seeking the signs of past life. 2. Mars: Seeking the signs of present life. 3. Mars: Atmospheric dynamics, weather, dust climatology. 4. Mars: Surface geology/chemistry. 5. P/D: General exploration of P/D.