Searching for evidence of extant subsurface biological and geological processes from Mars orbit. M. Allen[1], P.O. Wennberg[2], J.T. Schofield[3], and V. Hipkin[4]. [1]Mail stop 321-250, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Mark.Allen@jpl.nasa.gov; [2]Mail code 131-24, California Institute of Technology, Pasadena, CA 91125, wennberg@gps.caltech; [3]Mail stop 169-237, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, John.T.Schofield@jpl.nasa.gov; [4]Canadian Space Agency, 6767 Route de l'Aéroport Saint-Hubert, QC J3Y 8Y9, Canada, Victoria.Hipkin@asc-csa.gc.ca.

A central goal for the Mars Exploration Program identified in the 2013-2022 Planetary Decadal Survey is to determine if life ever arose on Mars. To address this goal, we propose an approach to detect, or set stringent upper limits on, the existence of extant Martian subsurface biological and geological processes on a global scale. The Decadal Survey also placed emphasis on the need for continued study of the Mars climate system. The current concept addresses this goal too. Both goals are central for optimizing the value and reducing the risk of future human exploration of the planet.

In pursuit of these goals, we propose a complete characterization of the chemical composition of the Martian atmosphere, with parts per trillion by volume (pptv) detection sensitivity. The measurements would be made in the context of the most detailed characterization of Martian weather to date under all atmospheric conditions. Continuation, and expansion, of the Mars climate record is a critical input to planning for future landed missions. In addition, characterization of atmospheric physical state would support the first objective in two ways: (1) sets the context for understanding atmospheric sources and sinks of detected trace gases and (2) provides the needed input to model simulations of back trajectories leading to surface sources of trace gases.

Pursuing this science from orbit would allow both acquisition of high spatial resolution vertical profiles (not possible from nadir measurements from orbit or from Earth) and a factor of 100 increase in detection sensitivity that limb measurements provide relative to nadir measurements.

The sensitivity of these measurements enables an investigation that could refocus the whole NASA search for life beyond the Earth. Firm evidence for subsurface active processes, either biological or geological, would be the first evidence for extant habitability or habitancy beyond the Earth. Even if only extant subsurface hydrothermal systems were present, such a locale could be the most important exploration target as it might be the abode for extraterrestrial life. If life were not detected in a later mission, the implications would be significant—life elsewhere might not be as common as previously thought. These implications suggest doing this exploration as soon as possible.

The proposed instrument complement to accomplish these objectives are:

- Solar occultation Fourier transform infrared spectrometer (SO-FTIR)
- Submillimeter wave spectrometer (SWS)
- Thermal infrared radiometer (TIR)

As illustrated from the data products listed in Table 1, these three instruments are highly complementary. The simultaneous measurements from SO-FTIR provide a complete survey and coarse global sam-

Table 1: Instrument complement that provides complete Martian atmosphere state and composition investigation

Instrument	Measurements	Value	Spectral range & resolution	Vertical profile attributes	Global distribution
Solar occultation Fourier transform infrared spectrometer	Simultaneous observations: temperature, dust abundance & composition, trace gases (including CH_4 and C_2H_6)	Game changing potential!	850-4300 cm-1, $\lambda/\Delta\lambda=10^5$	Vertical profiles 0→50+ km, 3 km vertical resolution @ limb, most sunrises and sunsets	Pole-to-pole every month
Submillimeter wave spectrometer	Simultaneous observations: temperature, winds, trace gases (≥1 gas at a time) (excluding CH_4 and C_2H_6)	Game changing potential! New climate science!	530-590 GHz, $\lambda/\Delta\lambda=3 \times 10^6$	Vertical profiles 0→100 km, 4 km @ limb, under ALL atmospheric conditions	Pole-to-pole every orbit
Thermal infrared radiometer	Simultaneous observations: temperature, aerosol, H_2O vapor	Continuation of climate record	12-45 µm, 9 spectral channels, $\lambda/\Delta\lambda=20$	Vertical profiles 0→60+ km, 6 km @ limb	Pole-to-pole every orbit

Table 2: Instrument complement responsive to human exploration precursor measurements

Instrument	**Measurements**	**Human exploration strategic knowledge gaps**
Solar occultation Fourier transform infrared spectrometer	Simultaneous observations: temperature, dust, trace gases (including CH_4 and C_2H_6)	Biohazard identification Toxic dust Forward planetary protection
Submillimeter wave spectrometer	Simultaneous observations: temperature, winds, trace gases (≥1 gas at a time) (excluding CH_4 and C_2H_6)	Atmospheric state Biohazard identification Forward planetary protection
Thermal infrared radiometer	Simultaneous observations: temperature, aerosol, H_2O vapor	Atmospheric state

sampling. The SWS has the unique capability to measure winds directly and characterize atmospheric state and composition in dust storms. The TIR provides simultaneous temperature and dust measurements that could be correlated with the SWS measurements. Both SWS and TIR would provide high spatial resolution measurements on a global scale.

This payload would fulfill multiple measurements listed as needed prior to human exploration (Table 2) and multiple investigations identified for Goals 1-3 in the 2010 MEPAG Goals document.

Table 3 illustrates the high accuracy measurements of temperature, wind, and aerosol available from these 3 instruments.

Detection sensitivities of both SO-FTIR and SWS are in the pptv range (Table 4). Shown for each species is its value for detection of subsurface active processes or as a tracer of atmospheric chemistry. HCN could serve as one possible indicator of a cometary contribution to atmospheric composition.

Table 3: Atmospheric state measurement accuracies

Variable	SO-FTIR	SWS	TIR
Temperature (K)	3	1	2
Wind (m/s)	x	10	x
Aerosol (optical depth) (%)	1	x	10

Table 4: Trace gas detection sensitivities (25 measurements coadded) (pptv)

Trace gas	**SO-FTIR**	**SWS**	**Import**
H_2O	1*	1*	A, C
CO	1.5*	<1*	C
O_3	5*	1.5*	C
H_2O_2	3*	<1*	C
HO_2	24	18	C
N_2O	2	36	B
CH_4	6	x	A, B
C_2H_6	10	x	A
H_2CO	12	4	A, B, C
NH_3	4	6	A, B
CH_3OH	12	?	A, B, C
HCN	6	1	E
H_2S	1000	42	A, B
OCS	2	61	A, B
SO_2	4	102	A

Notes for Table 4: * Precision in units of ‰ per measurement per measurement; x Not measurable. Import: A(abiogenic signature), B(biogenic signature), C (key to atmospheric trace gas loss chemistry), E (exogeneous material).

Taken together, the three instruments would occupy a small fraction of a typical payload deck as illustrated in Figure 1 (payload deck also would have a star tracker). Note that the instrument placement is for illustration purposes only. The current best estimates for mass and power without reserves are listed in Table 5. The technologies for all 3 instruments are at TRL 6 or higher. With significant possible foreign contributions (Canada and France, most likely), the NASA cost would be ~$130 million for the instrument suite.

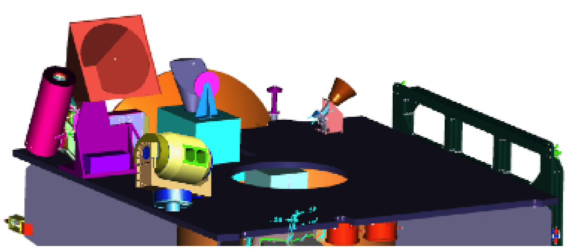

Figure 1: The three instruments, plus a star tracker, occupy only a small portion of a typical payload deck in this rough accommodation illustration.

Table 5: Instrument resource requirements (CBE)*

Instrument	**Mass (kg)**	**Power (W)**
SO-FTIR	45	60
SWS	19	73
TIR	9	18

*Without reserves