Direct measurements of winds from Mars orbit. M. Allen[1], M. Mischna[2], G. Chin[3], R. Stachnik[4], I. Mehdi[5], E. Schlecht[6], and R. Jarnot[7]. [1]Mail stop 321-250, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Mark.Allen@jpl.nasa.gov; [2]Mail stop 183-601, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Michael.A. Mischna@jpl.nasa.gov; [3]Mail Code 693, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, Gordon.Chin-1@nasa.gov; [4]Mail stop 183-401, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Robert.A.Stachnik@jpl.nasa.gov; [5]Mail stop 168-314, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Imran.Mehdi@jpl.nasa.gov; [6]Mail stop 168-314, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Erich.T.Schlecht@jpl.nasa.gov; [7]Mail stop 183-701, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, Robert.F.Jarnot@jpl.nasa.gov.

A central exploration goal for the Mars Exploration Program identified in the 2013-2022 Planetary Decadal Survey is to characterize Mars's atmosphere, present climate, and climate processes. Global atmospheric wind structure is one top level measurement goal. Another key exploration goal is to determine if life ever arose on Mars.

A submillimeter wave spectrometer (SWS) in Mars orbit would provide a precise wind, temperature, and trace gas constituent measurement capability. Measurement of wind and temperature would provide important diagnostics to complete the picture of Mars circulation. SWS could detect and map trace gases in the atmosphere that might be signatures of extant subsurface biological or geological sources. *All* measurements of SWS could be performed pole-to-pole on every orbit and under all environmental conditions, including dust storms (unique to longwave spectrometry).

SWS measurement capabilities could address several human exploration strategic knowledge gaps: atmospheric state (temperatures, winds), biohazard identification, and forward planetary protection, the latter related to identification of extant biology.

The SWS vertical resolution at the limb of 4 km could enable observations that: resolve the limb vertical structure much smaller than the vertical thickness of typical daytime boundary layers; probe winds within dust storms that provide unique insights into the atmospheric impact of dust storms; measure the lower branch of the global Hadley cell circulation within the boundary layer, providing direct measurements of circulation patterns thus quatifying the transport of water as it sublimates off the polar cap.

The NASA Mars Science Orbiter (MSO) Science Definition Team (SDT) report (dated December 15, 2007) placed great emphasis on direct measurement of winds as a major new contribution to understanding the current atmospheric state. A minimum requirement is sensitivity to winds of 10 m/s. Figure 1 shows that SWS could meet or exceed this requirement from the near-surface to ~75 km. Table 1 shows that SWS measurement capabilities meet/exceed multiple spatial and temporal wind measurement requirements identified by this SDT.

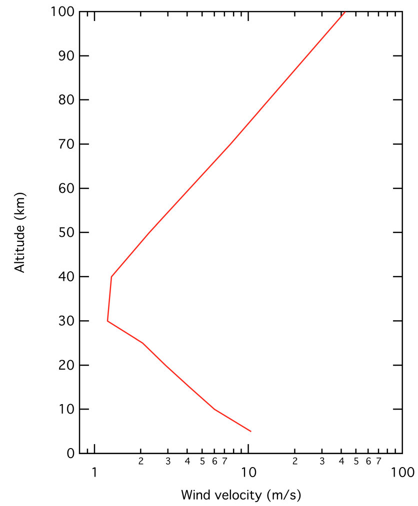

Figure 1. SWS wind measurement capability is ≤10 m/s from the surface to ~75 km.

Table 1. SWS measurement capabilities meet or exceed MSO SDT wind measurement requirements

Measurement Requirement	MSO SDT report: Minimum	MSO SDT report: Desired	SWS capability
Wind direction	Zonal, meridional		Zonal, meridional
Global distribution	Whole globe each sol		Pole-to-pole each orbit
Vertical range	Within lowest scale height to ~80 km		~3 to >75 km
Vertical resolution	10 km	<10 km	4 km
Latitude resolution	10°	5°	2.5° (equator) ~10° (70° latitude)
Temporal distribution	Day & night		Day & night, under all dust conditions
Precision	10 m/s	5 m/s	1-10 m/s

Figures 2 and 3 show general circulation model results for zonally-averaged zonal and meridional winds one scale height above the surface of Mars. The SWS sensitivity of ~5 m/s at 10 km would provide direct detection of winds throughout a full Mars year.

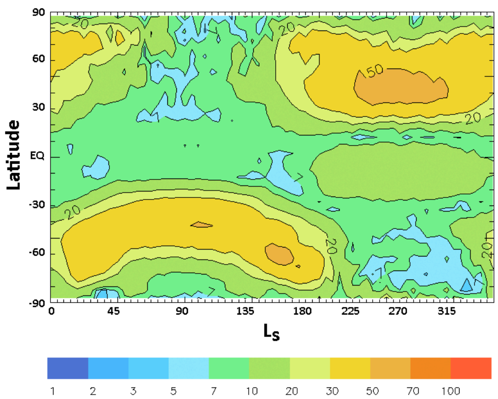

Figure 2. Longitudinally-averaged zonal winds 10 km above surface exceed 5 m/s >80% of the Mars year.

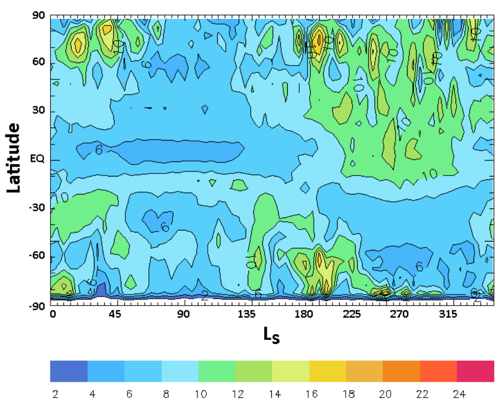

Figure 3. Longitudinally-averaged meridional winds 10 km above surface exceed 5 m/s >80% of the Mars year.

SWS also has the capability to measure temperature, simultaneously with other measurements, from the near-surface to above 80 km. The measurement precision is ~1 K.

SWS trace gas detection capabilities are parts per trillion by volume (pptv) for many chemical species that are potential tracers of extant subsurface biological and geological processes (Table 2). The potential significance of each species is indicated with respect to reflecting an abiogenic source, a biogenic source, importance for the chemistry related to sources or sinks of trace gases, or an exogeneous source of atmospheric trace gases. SWS could map these species, if present, with high surface resolution from pole-to-pole on every orbit under all environmental conditions, including dust storms. This would provide the opportunity to look for compositional differences between clear atmosphere and dust conditions of, for example, water vapor.

Table 2. SWS trace gas detection sensitivities (25 measurements) (pptv) (*Precision units ‰ per measurement) (Import: **A**biogenic, **B**iogenic, **C**hemistry, **E**xogenous material)

Trace gas	**SWS capability**	**Import**
H_2O	1*	C
CO	<1*	C
O_3	1.5*	C
H_2O_2	<1*	C
HO_2	18	C
N_2O	36	B
H_2CO	4	A, B, C
NH_3	6	A, B
HCN	1	E
H_2S	42	A, B
OCS	61	A, B
SO_2	8	A

The conceptual SWS instrument design is an ultrahigh resolution spectrometer ($\lambda/\Delta\lambda=3 \times 10^6$) covering the range (530-590 GHz), tunable during science operations with a 1.5 GHz instantaneous bandwidth. Vertical profiles are obtained using an articulated antenna. The current best estimates for mass and power are 19 kg and 73 W, respectively, without reserves. The SWS design (Figure 4) would include only flight-qualified technology with all components presently at TRL 6 or higher. The design draws upon earlier flight designs of the Microwave Limb Sounder on UARS and EOS, the Microwave Instrument for the Rosetta Orbiter (MIRO), and the Heterodyne Instrument for the Far Infrared (HIFI) on the ESA Herschel mission. A similar submillimeter spectrometer was proposed for Vesper, a Venus orbiter for the Discovery Program, which underwent Phase A development twice. The SWS cost is ~$50M, with the possibility of significant contributions from France.

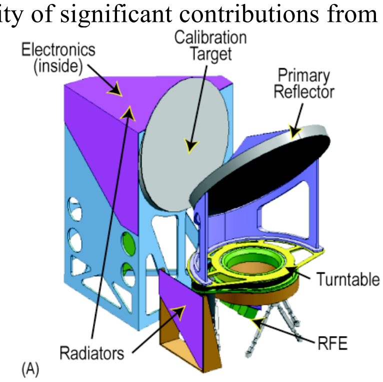

Figure 4: A previous SWS design specifically customized for accommodation on the 2016 ExoMars orbiter. For scale, the diameter of the primary reflector is 30 cm.