THE ATMOSPHERIC CHARACTERIZATION FOR EXPLORATION AND SCIENCE (ACES) INSTRUMENT SUITE FOR MARS.

S. Rafkin[1], D. Banfield[2], J. Andrews[1], A. Soto[1], K. Nowicki[1], T. Case[1], R. Dissly[3], A. Dwyer-Cianciolo[4], L. Fenton[5], M. Genzer[6], O. Karatekin[7], J. Merrison[8], C. F. Lange[9], and K. Neal[1], [1]Southwest Research Institute, [2]Cornell University, [3]Ball Aerospace and Technologies Corp, [4]NASA Langley Research Center, [5]SETI, [6]Finnish Meteorological Institute, [7]Royal Belgian Observatory, [8]University of Aarhus, [9]Univeristy of Alberta.

Introduction: The Atmospheric Characterization for Exploration and Science (ACES) instrument suite is designed to address the highest priority lower atmosphere goals and investigations identified by MEPAG[1] and to address both exploration technology Strategic Knowledge Gaps (SKGs) and science goals identified for the Mars 2020 mission[2][3]. The investigation goals and objectives are outlined in Table 1. The ACES instrument suite measures atmospheric dust properties, fundamental atmospheric parameters, and the energy inputs that drive the atmosphere in ways that far exceed previous landed experiments.

Table 1. ACES Goals and Objectives

GOALS	OBJECTIVES
I. Technology: Address Highest Priority HEOMD Strategic Knowledge Gaps and Reduce Risk for Cache Return (2020Goal C2, D2 & D3)	IA: Obtain dust characteristics and atmospheric properties important to current and future ISRU activities and human health. IB: Validate atmospheric models to improve all elements of atmospheric flight and to reduce risk for humans and cache return.
II. Science: Characterize Processes that Formed and Modified Landing Site Geology (2020 Goal A)	IIA: Quantify aeolian erosion/deposition potential to provide geological context. IIB: Determine particle entrainment surface stress thresholds and dust deposition rates.
III. Conduct Outstanding, High-Priority MEPAG Climate Investigations (2020 Synergistic Goal)	IIIA: Determine the processes controlling the present distributions of H_2O, CO_2 and dust in the atmosphere. IIIB: Quantify heat, momentum and mass exchange in the planetary boundary layer.

Science and Exploration Value: The data to be returned by ACES is the comprehensive and necessary type of information that has been sought after by the atmospheric, aeolian, and Entry, Descent, and Landing (EDL) communities since the Viking Landers provided the first in situ glimpse of Martian meteorology. The intervening experiments since Viking have only marginally increased the knowledge necessary to address Mars Exploration Program and Human Exploration and Operations Mission Directorate (HEOMD) goals; continuing to repeat these meteorological experiments is an exercise in diminishing returns.

In addition to temperature, pressure, and relative humidity, ACES measures for the first time airborne particle concentration and size distribution, 3D wind components, and infrared and visible radiative fluxes. By combining the unique capabilities of ACES to determine turbulent eddy momentum fluxes and dust characteristics, ACES also measures the wind stress that lifts sand and dust. This capability enables operational ISRU activities by predicting CO_2 and water cycles, and characterizing wind and the ambient dust load. Using the derived eddy heat flux and radiative sources and sinks, ACES measures the surface energy exchanges to validate atmospheric models in critical but previously unachievable ways, providing new, unique data to test the underlying physics in the models. Future Mars missions, such as sample return, will demand increasingly more accurate and lower risk EDL operations, and the data returned by ACES meets this demand.

By leveraging the instrumentation needed to address Mars 2020 Technology and Science Goals, ACES synergistically provides additional scientific benefit by obtaining the critical measurements necessary to undertake, in a manner never before possible, the still outstanding and highest priority MEPAG Climate Goal II boundary layer investigations.

Instruments and Accommodation: ACES consists of four sensor packages: 1) DUST measures the number concentration, size, and velocity of airborne particles by measuring the pulse height and timing of the backscattered light produced from multiple laser diodes, each transmitted through a holographic pattern generator. It is provided by SwRI and is based on development and wind tunnel testing at Aarhus university; 2) PRH measures the ambient pressure and relative humidity, based on capacitive devices that have flown as part of MSL REMS. PRH is a contributed sensor and built by the Finnish Meteorological Institute; 3) WIND measures 3D winds, turbulent eddies, and temperature using a 3-axis sonic anemometer that measures the differential time of flight of an an acoustic chirp between the sensor heads. It has been developed on PIDDP funds and will be built by Ball Aerospace; 4) VISIR measures downwelling visible and up and downwelling infrared radiation, using a differential measurement between sets of bolometers. VISIR is a contributed sensor and will be built by the Royal Belgian Observatory. Estimated resource requirements and expected performance for the suite is given in Table 2.

Table 2. ACES Resource and Preformance Summary

Attribute	Value
Mass	4.4kg
Power	12.7W
Data	15.7Mbit/sol
Pressure	1-100hPa±2Pa @1Hz
RH	1-100%, accuracy <8%
Dust	Number 1-1000/cm^3 Radius 0.2-250µm Velocity 0.1-20m/s
VISIR	VIS(down): 0.3-4um, 0-1000W/m^2 IR(up/down): 4-60um, 0-1000W/m^2
WIND	0-80±0.05m/s @20Hz (u,v,w) T: 150-343±0.1K

Accommodation: The ACES sensors are notionally located in the body of the 2020 rover (Pressure), on the rover deck (DUST and Relative Humidity), and on a deployable boom (WIND and VISIR) canted to the side of the rover, as shown in Fig. 1. Boom placement is chosen to maximize the range of azimuths from which wind can blow and yield largely unperturbed measurements of the ambient flow and turbulent properties. Other locations for the boom are possible, but would need to be assessed to ensure the measurements are not unduly compromised.

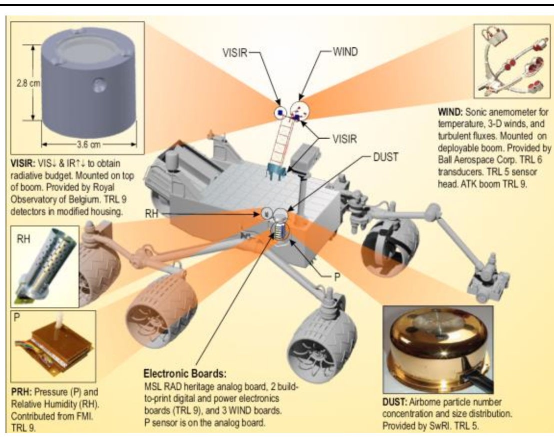

Figure 1. ACES Instrument sensors, electronics and notional accommodation on the 2020 Rover.

Surface Operations: Ideally, ACES would record phenomena from diurnal to annual time scales, making repeatable observations once per hour, sol after sol, for at least one Mars year. Achieving the ACES science goals depends on creating a long time series of regular synoptic measurements. Additionally, boundary layer turbulence must be characterized over occasional longer periods (roughly 1 hour) of higher frequency measurements, interspersed with the synoptic measurements. By changing when this hour-long observation is taken each sol, a record of representative turbulent and short time scale phenomena can be built.

Summary: The knowledge gap between what is needed and what is known is growing as a result of the only incremental gains in knowledge since the Viking Landers over 30 years ago. Doing more of the same, or in many cases, doing nothing at all, will not solve the problem, and failure to act now will impact all landed missions downstream, just as the 2020 EDL activities will feel the impact of previous or nonexistent surface meteorological investigations. A reinvigorated program of in situ meteorological investigations is needed to change the present knowledge trajectory. ACES is an ideal investigation to start addressing the growing knowledge demanded.

References: [1] MEPAG (2008), Mars Scientific Goals, Objectives, Investigations, and Priorities: 2008, J.R. Johnson, ed. [2] Mars 2020 AO (2013), NASA NNH13ZDA018O. [3] Precursor Strategy Analysis Group (P-SAG) (2012) Report.