THE ADVANCED MARS CLIMATE SOUNDER (AMCS) - A PROVEN ATMOSPHERIC PROFILER FOR FUTURE MARS ORBITERS.

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Introduction: Remarkable progress has been made in understanding the structure and dynamics of the Martian atmosphere. A decades-long climatology has been acquired, revealing significant interannual variability, dust storms that disrupt the seasonal mean circulation, and complex surface/atmosphere interactions. Many of the underlying dynamical and radiative processes that govern the Martian atmosphere remain poorly quantified. To a large extent the structure and dynamics of the Martian atmosphere are controlled by the atmospheric aerosols of dust, H_2O, and CO_2. Dust storms lift dust into the atmosphere and while some patterns in their occurrence are well characterized [e.g. 1,2], the processes that cause these storms to expand and become global while others dissipate in a matter of days or weeks are still not understood. Water ice clouds are abundant on Mars. Their radiative effects on the atmosphere are profound [3,4] but not well quantified to date. Our understanding of the water cycle is limited by extremely sparse water vapor profile observations [5]. Column water vapor measurements [e.g. 6] have provided insight, but the 3-D water vapor distribution and the processes controlling it are virtually unexplored. Hence there is a continued need for global, vertically resolved measurements of atmospheric temperature, water vapor, and aerosols (dust, water ice, CO_2 ice), and their evolution on diurnal, seasonal, and interannual time scales. Measured climatologies and near real-time atmospheric density profiles support landing, aerocapture and surface operations of future human and robotic missions to Mars.

Here we describe the Advanced Mars Climate Sounder (AMCS), a mature, low-cost, and low-risk infrared atmospheric sounder for a future Mars orbiter mission that is ideally suited to address these outstanding questions and support landed missions. AMCS builds on the instrument and measurement heritage of the Mars Climate Sounder (MCS, Fig. 1) [7], which has been operating on Mars Reconnaissance Orbiter (MRO) for ~10 years. It also incorporates flight development work completed for the ExoMars Climate Sounder (EMCS) instrument [8], which was selected to fly on ESA's ExoMars Trace Gas Orbiter. AMCS would provide daily, global, pole-to-pole profiles of atmospheric temperature, dust, water ice, CO_2 ice, and water vapor. Atmospheric profiles would be assimilated into Mars General Circulation Models to generate global, interpolated fields of measured and derived parameters such as winds.

AMCS would address the highest priority MEPAG Goal II to "understand the process and history of climate" and the high priority decadal survey goal on climate on Mars [9]. It would provide several of the highest priority precursor measurements for manned missions based on MEPAG Goal IV and the Human Mission Strategic Knowledge Gaps.

Figure 1: The MRO/MCS flight instrument during thermal vacuum testing at JPL.

AMCS Instrument: Like MCS and EMCS, AMCS is a passive infrared limb-sounding filter radiometer. It would use 8 spectral channels in the IR from 12-45 µm as well as a visible/near-IR channel to address its measurement objectives. The instrument would consist of two telescopes, with visible and mid-IR channels in one and far-IR channels in the other. Azimuth and elevation actuators, with a range of 270° each, would allow pointing of the telescopes anywhere in the downward hemisphere from a nadir-oriented spacecraft. Each channel would consist of a linear array of uncooled thermopile detectors, which instantaneously measures a radiance profile when vertically pointed at the limb. This results in better sensitivity and geometrical stability than scanning the limb with a single detector. While an MRO/MCS detector array consists of 21 detectors, the AMCS array size could be increased to achieve improved vertical resolution or preserve a target vertical resolution from a higher orbit altitude. Accurate calibration of the IR channels would be achieved with thermally stabilized blackbody targets and frequent spaceviews. A solar target would enable calibration of the visible/near-IR channel.

An overview of the AMCS channels and their measurement functions is given in Tab. 1. Most channels are heritage from MRO/MCS. The combination of channels B2 and B3 would enable water vapor profiling by discriminating between water vapor and aerosols (Fig.

2). This was not achieved with MCS because B3 was sensitive to water vapor. The B3 design was improved during EMCS development to address this issue.

Telescope/ Channel #	Bandpass cm-1	Band Center - µm	Measurement Function
A1	595 - 615	16.5	Temperature 0 - 30 km
A2	615 - 645	15.9	Temperature 30 - 50 km; Pressure
A3	635 - 665	15.4	Temperature 50 - 90 km, Pressure
A4	820 - 870	11.8	Water ice extinction 0 - 90 km
A5	400 - 500	22.2	Dust extinction 0 - 90 km
A6	3300– 33000	1.65	High altitude hazes and particle size discrimination
B1	290 - 340	31.7	Dust and CO_2 ice extinction 0 - 90 km
B2	220 - 260	41.7	Water vapor 0 - 40 km
B3	231 - 243	42.2	Dust and Water ice extinction 0 - 30 km

Table 1: AMCS spectral channels and their measurement functions.

AMCS has heritage in MRO/MCS and the Diviner instrument on the Lunar Reconnaissance Orbiter. It would make use of the EMCS design heritage and utilize mechanical and optical flight hardware already fabricated by the time of EMCS closeout. Based on the maturity of its design, AMCS would be very compact with a mass of only 9 kg, a power consumption of 18 W and a very low data rate of 2000 bps. The instrument would be built at JPL by the hardware and science teams that developed EMCS. The mature design would allow AMCS to be built for the next available opportunity, e.g. a potential Mars orbiter in 2022.

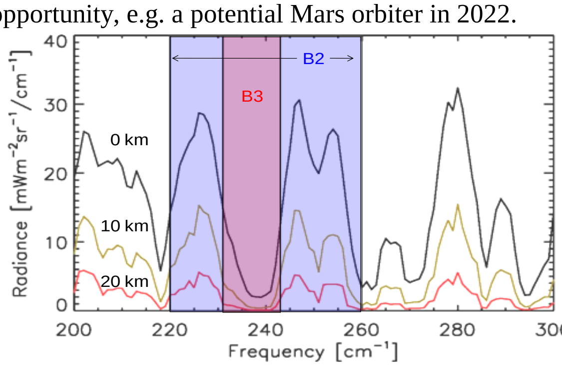

Figure 2: Limb radiance spectrum showing water vapor bands in the far-IR. The positions of channels B2 and B3 are indicated. B2 would be used to measure water vapor while B3 would be designed to be insensitive to water vapor, allowing the discrimination between water vapor and aerosols.

AMCS Observations and Data Products: AMCS can accommodate a large range of orbital geometries. A nadir-oriented spacecraft in near-polar orbit would allow limb observations in all directions and provide daily, global, pole-to-pole coverage, similar to MRO/MCS (Fig. 3). Coverage at multiple local times could be achieved from a precessing orbit and by slewing the instrument in azimuth in order to view perpendicular to the orbit track [3]. From typical orbit altitudes AMCS would achieve 0-90 km vertical coverage with a vertical resolution of 5 km or better. Data products would consist of profiles of temperature, water vapor, and dust, water ice and CO_2 ice extinction. Retrieval algorithms have heritage from MRO/MCS [10,11]. Column quantities of dust, water ice and water vapor would be provided along with atmospherically corrected surface temperature [12] and albedo. Assimilation of the measured atmospheric fields into Mars General Circulation Models would be an integral part of the AMCS investigation and would provide globally interpolated and derived fields, such as winds.

MRO/MCS has demonstrated the ability to rapidly process data into geophysical quantities in order to support the successful landings of Phoenix and MSL as well as MAVEN operations. AMCS would retain this key capability well into the next decade.

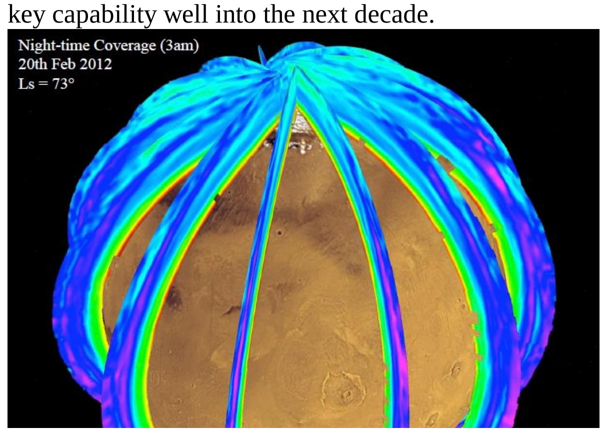

Figure 3: Coverage for one day of nighttime temperature profiles from MRO/MCS. From a near-polar orbit, this kind of coverage would be achieved daily, day and night, for temperature, dust, water ice, water vapor, and CO_2 ice.

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