National Aeronautics and Space Administration

CubeSat Infrared Atmospheric Sounder (CIRAS) for measuring temperature profiles on Mars

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Objectives:
Our objective for this short-term study is twofold: 1) Investigate how well the CubeSat Infrared Atmospheric Sounder (CIRAS), a hyperspectral infrared spectrometer operating from 4.08-5.13 μm with 4 nm spectral resolution, will measure important atmospheric meteorological parameters on Mars. The instrument for Mars applications, would be called the Mars Infrared CubeSat Atmospheric Temperature Sounder (MIRCATS). The objective is to provide quantitative sensitivity analysis, given the instrument parameters, including vertical resolution and temperature sensitivity. The analysis must also determine the horizontal and temporal coverage of the instrument for a typical Mars orbit. 2) Identify the highest-priority areas for technology maturation (e.g., longer wavelength detectors, 11-15 μm vs. 4-5 μm as presently on CIRAS, for better sensitivity and/or lower power cryocoolers) to make MIRCATS capability sufficient for Mars science. This includes investigating the suitability of the size, mass, power and data rate for a Mars mission.

Background:
The CIRAS instrument was developed at JPL to measure temperature and water vapor profiles and carbon monoxide in Earth's atmosphere. Due to the high CO2 concentration, MIRCATS is expected to be able to make accurate temperature profile measurements at Mars, as well as provide total column water vapor and CO concentrations, which can be used to improve weather prediction on Mars and support science investigations. The MIRCATS would include observations in the Martian PBL where current instruments have limited sensitivity, and where numerical models of the Martian atmosphere lack data, thus filling a needed gap in Mars atmospheric study. Additionally, the design of MIRCATS includes a continuous surface scanning mode which significantly increases the spatial coverage of the instrument against the current state of the art, providing nearly contiguous global daily coverage. Scientific results from MIRCATS would address key recommendations from the 2022 Planetary Science Decadal Survey as well as high-priority science goals of the Mars Exploration Program Analysis Group. MIRCATS fits in a 4U volume (Figure 1). The recent Mars Architecture Strategy Working Group report emphasizes the role of small spacecraft in next-decade Mars science. Presently, a CIRAS/MIRCATS breadboard has been developed and tested (Figure 2).

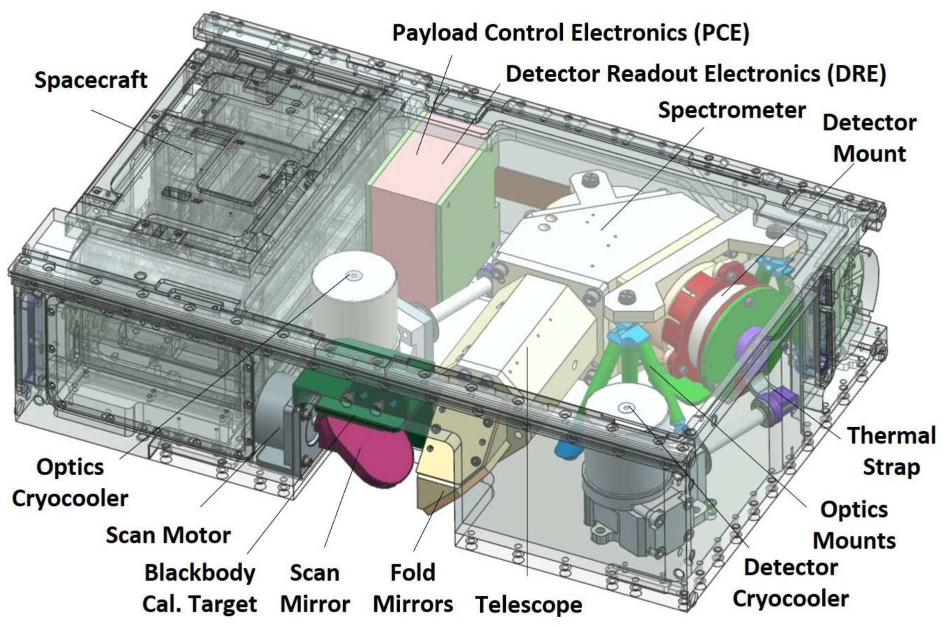

Figure 1. MIRCATS flight instrument concept is compact, occupying only a 4U volume.

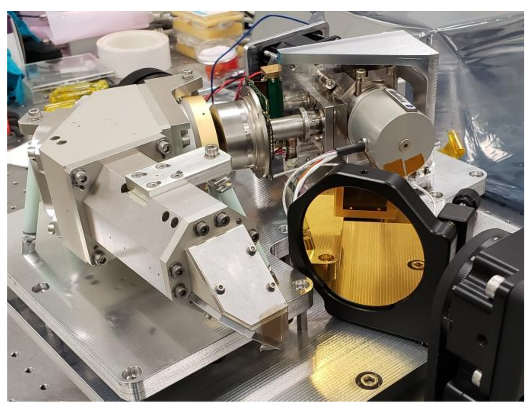

Figure 2. MIRCATS breadboard meets key performance requirements.

Approach and Results:
In terms of spatial coverage, the MIRCATS, if flown in a 275 km polar orbit, would provide over 678,000 retrievals per day, providing over 80% contiguous coverage (Figure 3). This coverage provides over 50 samples in every 2°x2° horizontal and 1 hr time bin every 30 days, enabling characterization of the diurnal cycle and addressing current issues of longitudinal and temporal representativeness. The high sampling density provides context to meteorological events including dust storms (Figure 4). The sensitivity results showed that under nominal dust and ice daytime conditions that the MIRCATS vertical temperature resolution on Mars would be better than 5km in the PBL with sensitivity better than 3K (Figure 5). Under high dust conditions, the vertical resolution would not be significantly degraded, and the temperature sensitivity would be 4K. Sensitivity to water vapor is 20%-30% under these conditions. Sensitivity degrades under nighttime and polar conditions.

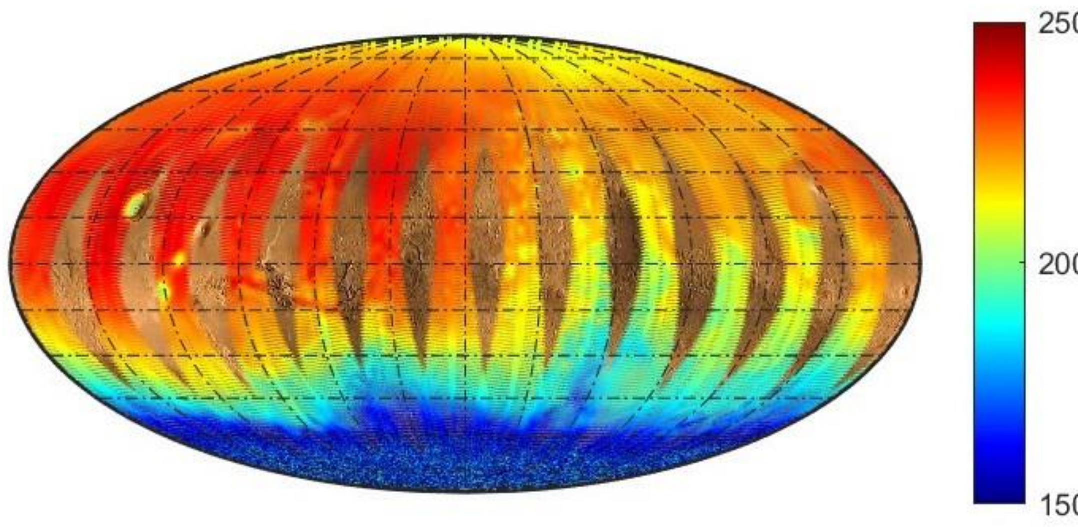

Figure 3. MIRCATS wide swath enables contiguous coverage of over 80% of Mars per day. Colors represent temperature in the PBL with MIRCATS noise added.

A Team-X Study assessed the spacecraft hosting options for MIRCATS. The results showed that the dominant factor in the size of the spacecraft is the delta-V. The payload is sufficiently small and lightweight that it is not the primary driver. The anticipated approach would be to launch the spacecraft from an ESPA ring of a satellite with a Mars bound trajectory, and take approximately 1 years to reach Mars and an additional 10 mo to achieve orbit. The MIRCATS downlink rate of 340 kbps is easily achieved with a number of telecommunications options, and the power requirement of 23 W is not an issue, however minimizing both data rate and power will help a future mission architecture.

Figure 4. A sample, northern hemisphere, early spring, local dust storm, overlaid with approximate MIRCATS scan coverage along a 275 km polar orbit. MIRCATS broad coverage provides improved context of the storm and has better lower tropospheric sensitivity. Diffuse white areas are water ice clouds.

					Uncertainty				
Scenario	Dust OD	Ice OD	Altitude	T-Vertical Resolution	T profile	CO	H_2O	Dust	Ice
Nominal dust and ice Daytime	0.45	0	< 10 km 10-40 km	5 km 8 km	<3 K <7 K	5%	20%	5%	N/A
High dust and ice Daytime	4.3	0.15	< 10 km 10-40 km	5 km 8 km	<4 K <7 K	10%	30%	5%	20%
Nominal dust and ice Nighttime	0.55	0.12	< 10 km 10-40 km	7 km 12 km	< 5K < 9K	10%	N/A	30%	N/A
Polar, high ice Daytime	0.12	2.9	< 10 km 10-40 km	10 km 10 km	< 6K < 10K	10%	N/A	15%	N/A

Figure 5. Summary of the estimated MIRCATS sensitivity to temperature, water vapor, dust, ice and CO in Mars atmosphere for different sample cases. N/A indicates insufficient sensitivity

Significance/Benefits to JPL and NASA:
The RTD effort demonstrated the viability of a high TRL instrument approach developed at JPL for Earth applications to weather prediction and atmospheric science on Mars. MIRCATS will improve forecast for Entry, Decent and Landing, dust storms and weather conditions for ground operations.

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None

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