SCIENTIFIC PAYLOAD OF THE EMIRATES MARS MISSION:EMIRATES MARS INFRARED SPECTROMETER (EMIRS)

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Introduction: The Emirates Mars Mission (EMM) is the first United Arab Emirates (UAE) mission to Mars. EMM will be launched in 2020 and the goal is to explore the dynamics of the Martian atmosphere through global spatial sampling which includes both diurnal and seasonal timescale. The focus of this mission is to provide an improved understanding of circulation and weather in the Martian lower and middle atmosphere as well as the thermosphere and exosphere using three scientific instruments. The Emirates eXploration Imager (EXI) and Emirates Mars Infrared Spectrometer (EMIRS), will focus on the lower atmosphere observing dust, ice clouds, water vapor, ozone, and the thermal structure. In addition, the third instrument, Emirates Mars Ultraviolet Spectrometer (EMUS), will focus on both the thermosphere and exosphere of the planet.EMM will explore several aspects of Martian atmospheric science that are divided to three motivating science questions leading to the three associated objectives shown in Table 1.

Table 1: Science Questions and EMM Objectives.

Motivating Questions	I. How does the Martian lower atmosphere respond globally, diurnally and seasonally to solar forcing?	II. How do conditions throughout the Martian atmosphere affect rates of atmospheric escape?	III. How do key constituents in the Martian exosphere behave temporally and spatially?
EMM Objective	A. Charactarize the state of the Martian lower atmosphere on global scales and its geographic, diurnal and seasonal variability. (EMM Inves. 1&2)	B. Correlate rates of thermal and photochemical atmospheric escape with conditions in the collisional Martian atmosphere. (EMM Inves. 1-4)	C. Characterize the spatial structure and variability of key constituents in the Martian exosphere (EMM Ines. 4)

EMM will achieve these objectives through four investigations shown in Table 2.

Table 2: EMM Investigations.

EMM Investigation	1. Determine the three-dimensional Thermal State of the lower atmosphere and its diurnal variability on sub-seasonal timescales	2. Determine the geographic and diurnal distribution of key constituents in the lower atmosphere on sub-seasonal timescales	3. Determine the abundance and spatial variability of key neutral species in the thermosphere on sub-seasonal timescales.	4. Determine the three-dimensional structure and variability of key species in the exosphere and their variability on sub-seasonal timescale.
Instruments	EMIRS	EMIRS, EXI	EMUS	EMUS

Objective A is achieved through the completion of Investigations 1 and 2, which are to determine the structure and variability of atmospheric temperatures (Investigation1)and the geographic and diurnal distribution of key constituents (Investigation 2), respectively. Objective B is achieved through completion of Investigations 1 and 2, in addition to Investigations 3 and 4, which are to determine structure and variability in the Martian thermosphere and exosphere, respectively. Objective C is achieved solely through Investigation 4, which is to determine the three-dimensional structure and variability of key species in the exosphere and their variability on sub-seasonal timescales.

Instrument Overview:

The EMIRS instrument (Figure 1) is an interferometric thermal infrared spectrometer being developed by Arizona State University (ASU) in collaboration with the Mohammed Bin Rashid Space Centre (MBRSC). The instrument builds on along heritage, designed, built and managed by ASU’s Mars Space Flight Facility, including the Thermal Emission Spectrometer (TES), Miniature Thermal Emission Spectrometer (Mini-TES), and the OSIRIS-REx Thermal Emission Spectrometer (OTES). EMIRS is optimized to capture key constituents in the lower- middle atmosphere using a scan mirror and it takes ~ 60 global images per week in the nominal science orbit at a resolution of ~100-300 km/pixel. Comparing EMIRS to its heritage line, it has higher default spectral resolution (5 cm-1) and the widest spectral range (6-40+ µm) of similar instruments sent to Mars. Moreover, it has a small (5.5 mrad) instantaneous field of view that enables a relatively small footprint from the large EMM orbit (20,000 km x 44, 00).

Figure 1: EMIRS Instrument System.

EMIRS measures light in the 6-40+ µm range with 5 cm^{-1} spectral sampling, enabled by a Chemical Vapor-Deposited (CVD) diamond beam splitter and state of the art electronics. This instrument utilizes a 3×3 array detector and a scan mirror to make high-precision infrared radiance measurements over most of a Martian hemisphere. The EMIRS instrument is optimized to capture the integrated, lower-middle atmosphere dynamics over a Martian hemisphere, using a scan mirror to make ~60 global images per week (~20 images per orbit) at a resolution of ~100-300 km/pixel. The scan-mirror enables a full-aperture calibration, allowing for highly accurate radiometric calibration (<1.5% projected performance) to robustly measure infrared radiance.

Science Targets:

EMIRS will measure the global distribution of key atmospheric parameters over the Martian diurnal cycle and year, these parameters include dust, water vapor, water ice (clouds) and temperature profiles. Measuring these parameters will provide the linkages between the lower and upper atmosphere in conjunction with EMUS and EXI observations.

Table 3: EMIRS data products and rationale

Level 2 Science Observations	**Level 2 Required Measurements**	**Notes**
Dust optical depth at 9 µm	Relative radiance of dust absorption bands.	To characterize dust.
Ice optical depth at 12 µm	Relative radiance of ice absorption bands.	To characterize water ice clouds.
Water vapor column abundance	Relative radiance of H2O vapor absorption bands.	To track the Martian water cycle
Temperature profiles with respect to altitude for 0 to 50 km.	Absolute radiance of CO2 absorption band	Track the thermal state of the Martian atmosphere
Surface temperature	Radiance at 1300 cm-1	Boundary condition for the lower atmosphere

EMIRS measures the CO2 absorption band, using radiative transfer modeling and the CO2 band the temperature profiles from the surface to 50 km above the surface can be measured. The atmospheric temperature profile accuracy must meet the requirements of ± 2.0 K for 0-25 km altitude, ± 4.0 K for 25-40 km altitude and ± 10.0 K for 40-50 km altitude. The spatial resolution shall be less than 300 km at nadir, while the vertical resolution is 10 km spacing over altitudes from 0-50 km. The absolute radiance over a subset of the spectral range will be observed, order to determine the surface temperature. At wavelength of 1300 cm-1 the Martian atmosphere is nearly transparent, thus meaning at that wavelength the surface radiance emitted isn't absorbed by atmospheric gases and aerosols. So in order to measure the surface temperature the radiance at 1300 cm-1 wavelength should be measured.

Moreover, EMIRS will determine the column-integrated ice optical depth at 12 µm wavelength, column-integrated dust optical depth at 9 µm wavelength, and column-integrated water vapor abundance. The observables for these physical parameters are the relative radiance of H2O ice absorption bands, relative radiance of dust absorption bands, and relative radiance of H2O vapor absorption bands each with respect to the continuum.

Concept of Operation:

The EMIRS Instrument has only one observation strategy, which is shown in Figure 2. This observation strategy is performed 20 times per orbit in the nominal science orbit. The spacecraft will do an EMIRS observation with the EMIRS boresight controlled to within 1 degree. The spacecraft will begin a single axis slew across the disk, maintaining a constant slew rate according to either the smear limit requirement or the time it takes EMIRS to complete the acquisition of the full disk of Mars, which is ultimately a function of altitude.

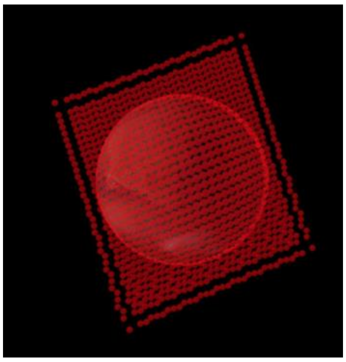

Figure 2: EMIRS Synoptic Observation strategy.

As the spacecraft slews, the EMIRS instrument will move its pointing mirror to scan across the planet with a single directional scan and retrace. This procedure enables EMIRS to collect data over the entire Martian disk with minimal gaps. In order to support a variety of slew rates, EMIRS will also be able to

pause its acquisition sequence at the end of each row to allow for a range of spacecraft slew rates.
A summary of the observation strategy for EMIRS is found in Table 3.

Table 4: Summary of EMIRS Observations.

S/C Slew Across Disk:	10.4º – 18.7º based on altitude
Instrument Scan:	15.6º – 23.9º based on altitude
Effective Scan Rate:	1.3º FOV takes 4 sec acquisition
Slew Rate:	≤ 0.71º/min at periapsis (20,000km) ≤ 1.09˚/min at Apoapsis (44,000km) variable by orbit height
Observation Duration:	~32 min at periapsis; ~15 min at Apoapsis

References:

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