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

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Introduction:

The Emirates Mars Mission (EMM, Figure 1) will launch in 2020 to explore the dynamics in the atmosphere of Mars on a global scale. EMM has three scientific instruments selected to provide an improved understanding of circulation and weather in the Martian lower and middle atmosphere as well as the thermosphere and exosphere. Two of the EMM's 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.

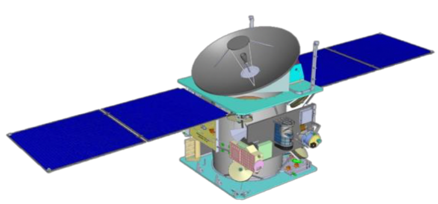

Figure1: Emirates Mars Mission.

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 constitunets 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)

Table 1: Science Questions and EMM Objectives

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

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

Table 2: EMM Investigations.

Objective A is achieved through the completion of Investigations 1 and 2, which are to determine the structure and variability of atmospheric temperatures (Investigation 1) 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 2) is an interferometric thermal infrared spectrometer that is developed by Arizona State University (ASU) in collaboration with the Mohammed Bin Rashid Space Centre (MBRSC). It builds on a long heritage of thermal infrared spectrometers 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).

Comparing EMIRS to its heritage line, it has the smallest instantaneous field of view (6 mrad, enabling small footprints from large distances), higher default spectral resolution (5 cm^{-1}) and a wider spectral range (6-40+ µm), with expected performance well beyond 50 µm. Further, this heritage enabled a relatively small (50x30x30cm), modest mass (~17kg) and relatively low power requirements (21W) without sacrificing measurement performance and reliability.

Figure 2: EMIRS Instrument System.

The EMIRS instrument will give a better understanding of how the Martian atmosphere will respond globally, diurnally, and seasonally to solar forcing as well as how conditions in the lower and middle atmosphere affect the rates of atmospheric escape. EMIRS will look at the geographical distribution of dust, water vapor and water ice, as well as the three-dimensional thermal structure of the Martian atmosphere and its diurnal variability on sub-seasonal timescales. The EMIRS instrument has a rotating mirror that will allow the instrument to do scans of Mars.

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.

Concept of Operation:

The EMIRS Instrument has only one observation strategy, which is shown in Figure 3. 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.

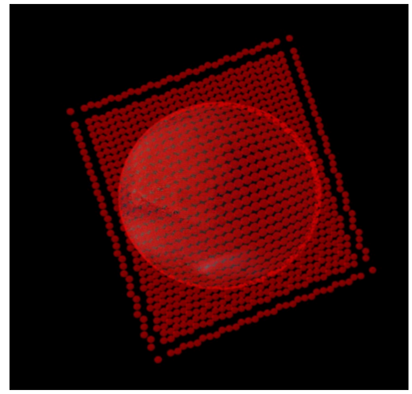

Figure 3: EMIRS Synoptic Observation strategy.

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.

Observing Strategies	
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

Table 3: Summary of EMIRS Observations.

Data Completeness:

EMIRS will measure the global distribution of key atmospheric parameters over the Martian diurnal cycle and year, including dust, water ice (clouds), water vapor and temperature profiles. In doing this, it will also provide the linkages from the lower to the upper atmosphere in conjunction with EMUS and EXI observations. A summary of the level 3 science product and level 2 measurement required is found in Table 4.

EMIRS will study the three-dimensional thermal state and diurnal variability of the lower atmosphere (0-50km) on sub-seasonal timescales and measures the CO_2 absorption band, from which temperature profiles can be retrieved via radiative transfer modeling. The atmospheric temperature profile accuracy will be ± 2.0K for 0-25 km altitude, ± 4.0K from 25-40 km altitude. The vertical resolution of the retrieved profile will be 10 km over all altitudes from 0-50 km. Dust will be retrieved using the broad and distinctive "V" shaped absorption centered at about 10.75 cm^{-1}. Water ice clouds will be retrieved using the broad and distinctive bowl-shaped absorption centered at about 825 cm^{-1}. Water vapor gas has a distinctive set of narrow absorptions between about 200 and 400 cm^{-1} that will be used for the retrieval. The EMM orbit and observation plan enables nearly complete global and diurnal coverage of all retrieved quantities over a time span of ~ 10 day.

Level 3 Science Product	Level 2 Measurement Required	Purpose
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 ice clouds.
Water vapor column abundance	Relative radiance of water vapor absorption bands.	To track the Martian water cycle.
Temperature profiles w.r.t altitude for 0 to 50 km	Absolute radiance of CO_2 absorption band	Track the thermal state of the Martian atmosphere.
Surface Temperature	Radiance at 1300 cm^{-1}.	Boundary condition for the lower atmosphere.

Table 4: Summary of Level 3 Science Product and Level 2 Measurement Required.

Summary:

The data provided from EMIRS will enhance the understanding of the lower atmosphere of Mars and its variability on sub-seasonal time scales. EMIRS will measure three-dimensional global thermal structure to provide temperature changes throughout the Martian surface and atmosphere. In addition, the abundances of dust, water ice and water vapor in the Martian atmosphere will be measured. The data from EMIRS combined with EXI and EMUS, will give us a better understanding of the connection between the lower and upper atmosphere.

References:

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