SCIENTIFIC PAYLOAD OF THE EMIRATES MARS MISSION: EMIRATES MARS INFRARED SPECTROMETER (EMIRS) K. Badri [1], C. Edwards [2], M.D. Smith [3], E. AlTunaiji [1], P.R. Christensen[4] , S. AlMheiri [1], H. Reed [5] and the EMIRS Team [4].
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Introduction: The Emirates Mars Mission (EMM), seen in figure 1, will launch in 2020 to explore the dynamics of the Martian atmosphere, while sampling on both diurnal and seasonal timescales. EMM has three scientific instruments on board in order to enhance the understanding of circulation and weather in the Martian lower-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 investigate the lower atmosphere by studying the core constituents of the lower atmosphere: dust, ice clouds, water vapor, ozone, and the thermal structure of both the lower atmosphere and the surface. The Emirates Mars Ultraviolet Spectrometer (EMUS), will focus on both the thermosphere and exosphere of the planet.

EMIRS Science Targets:

Dust: This constituent plays a major role in driving the atmospheric circulation of the Martian atmosphere. In addition, dust affects the thermal structure of the atmosphere in regards to temperature distribution of the lower and middle layers of the atmosphere. EMIRS will measure the optical depth of dust at 9µm. Combining that measurement with the retrieved optical depth of dust from EXI at 220nm will enable the determination of dust aerosol particle size during the science orbit.

Water Ice: Water ice clouds will be measured at 12µm, and have a major impact on thermodynamic processes of the Martian atmosphere. This constituent provides important information about the transport of water thought the Martian atmosphere and contributes to temperature changes that affect the energy balance of Mars.

Temperature: The atmospheric and surface tem-peratures of the Red planet will be retrieved using the 15-µm carbon dioxide absorption band and the relatively transparent window near 7 µm (1300 cm-1), respectively. This enables measurement of the thermal state of the planet and contributions to the energy balance of the Mars. Moreover, the temperature observations and the thermal contrast between the surface and atmosphere is vital for the retrievals of aerosol optical depth and water vapor column.

Water Vapor: In addition to water ice clouds, water vapor is also an important part of the Martian water cycle, thus retrieving the column abundance of water vapor will help understanding of the mechanisms behind the transportation of water in the Martian atmosphere. Water vapor is also a key driver in understanding the correlation between the lower and upper atmosphere, where the mechanism of photolysis occurs.

Instrument Overview: The Emirates Mars Infrared Spectrometer (EMIRS) instrument shown in 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 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 time-scales. The EMIRS instrument observations are taken through a tilting mirror along with spacecraft motion to provide complete coverage of the Martian disc.

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 DLaTGS 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, this observation strategy is performed 20 times per orbit in the nominal science orbit. 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.

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 3.

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 3: Summary of Level 3 Science Product and Level 2 Measurement Required

Summary: The EMIRS instrument will provide data which will enhance the understanding of the lower atmosphere of Mars and its variability on sub-seasonal time scales. EMIRS will provide temperature changes throughout the Martian surface and atmosphere, by measuring three-dimensional global thermal structures. Moreover, the abundances of constituents such as 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.