SURVEYING THE MARS ATMOSPHERE FROM THE SURFACE TO SPACE WITH THE EMIRATES MARS MISSION


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Introduction: The Emirates Mars Mission (EMM) designed, developed, and launched an unmanned observatory called “Hope” with three scientific instruments to study the Martian atmosphere in visible, ultraviolet, and infrared wavelengths, from the surface of the upper atmosphere. The mission aims to provide the first comprehensive picture of Mars’ atmosphere with global coverage examining the diurnal and seasonal variations. EMM is a strategic initiative to disrupt and accelerate the development of the UAE’s science and technologies sectors.

Hope Probe Timeline:
- 2020-07-20: launch
- 2021-02-09: Mars orbit insertion
- 2021-05-21: start of science phase
- 2023-04-08: start of extended mission
- 2024-01-04: start of perpetual operations

Science Objectives: Hope’s scientific mission is focused on studying the atmospheric circulation and dynamics from a high altitude orbit (20,000 x 43,000 km) that provides a unique synoptic perspective and unprecedented local time and seasonal coverage over most of the planet. The three scientific objectives are to (A) characterize the state of the Martian lower atmosphere on global scales and its geographic, diurnal and seasonal variability, (B) correlate rates of thermal and photochemical atmospheric escape with conditions in the collisional Martian atmosphere, and (C) characterize the spatial structure and variability of key constituents in the Martian exosphere [1, 2].

Science Instruments & Results:

EXI Results: Emirates eXploration Imager (EXI) [3] is a dual-telescope imaging system that provides full disk views of Mars using six band-passes (260, 320, 437, 546, 635 nm) with single pixel footprints of 2-4 km on the Martian surface. EXI allows the characterization of cloud and dust storm morphologies, as well as the retrieval of H2O ice optical depth and ozone abundance. EXI’s observational cadence uniquely allows the tracking of clouds and dust storms (see figure 1) over 1-10 hours [4], unlike low altitude orbiters whose image cadence is ~24 hours. EXI has also collected the first close-up collection of images of Deimos (see figure 2).

Figure 1: Five hours of dust storm development from EXI

Figure 2: cloud tracking, color imaging, and Deimos observations from EXI.

EMIRS Results: The Emirates Mars InfraRed Spectrometer (EMIRS) is a Fourier transform infrared spectrometer [5]. EMIRS measures the infrared spectrum from 1666 to 100 cm⁻¹ (6-100 μm) in 10 and 5 cm⁻¹ spectral sampling. EMIRS determines the column integrated abundance of water vapor, total dust and water ice opacities, and 3-D temperature profiles from the surface of 50 km. EMIRS connects the surface interaction with the lower atmospheric dynamics. Over EMM’s several year mission, EMIRS has observed the formation and characteristics of diurnally and seasonally available surface ice [6], has placed constraints on the amount of dust lifting caused by local and regional dust storms [7], and has evaluated the lower-atmospheric diurnal and seasonal dynamics. Specifically related to the atmosphere, EMIRS has monitored the local time coverage of water ice clouds in the aphelion cloud belt, as well as the variation in effective ice [8], unraveled unique and unexpected atmospheric temperature dynamics and thus global tides [9], as well as evaluated
the potential diurnal variability of dust opacity and water vapor.

Figure 3: change in dust coverage from EMIRS before, during, and after regional dust storm

EMUS Results: The Emirates Ultraviolet Spectrometer (EMUS) is a far-ultraviolet (FUV) imaging spectrograph that obtains views of the disk of Mars and the tenuous extended atmosphere surrounding it in the wavelength range of 100–170 nm [10]. EMUS contributes in three major ways. First, EMUS is designed to track O and CO abundance in the thermosphere, with O decreasing during dust storms due to turbulent mixing drawing O to lower altitudes for recombination [11] (100–200 km altitude), see figure 5. Second, EMUS measures the three-dimensional abundance, and escape rates, of both H [12] and O [13] in the Martian exosphere, showing clear trends with both solar activity and season [12]. A set of hydrogen Lyman alpha/beta observations are shown in figure 6. Third, EMUS’s high-sensitivity enables unprecedented synoptic observations of Martian aurora, including the discovery of a new type known as sinuous aurora [14], thought to be related to electron acceleration within Mars’ magnetotail current sheet, as shown in figure 7.

Looking forward: the Hope spacecraft and the instruments are healthy and expected to continue operating. A large and growing data set from all three EMM instruments can be accessed at the EMM Science Data Center (http://sdc.emiratesmarsmission.ae), along with all necessary documentation.


Figure 4: example of synoptic image above the dusk Terminator of lower atmospheric temperature from EMIRS

Figure 5: season-latitude trends between lower atmospheric dust (EMIRS) and upper atmospheric oxygen (EMUS) are anti-correlated, as turbulent mixing draws O lower altitudes for recombination.

Figure 6: a typical single-orbit EMUS observation set in H Ly-α and beta, used to constrain the three-dimensional structure of the hydrogen exosphere.

Figure 7: Examples of different types of Martian sinuous Aurora measured by EMUS.