EMIRATES MARS MISSION (EMM) SCIENCE OVERVIEW.

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Science Mission Overview: Our understanding of Mars' atmosphere has been significantly limited by the fixed local time of recent measurements made by several spacecraft, leaving most of the Mars diurnal cycle unexplored over much of the planet. Thus important information about how atmospheric processes drive diurnal variations is missing. This limited coverage has hindered our understanding of the transfer of energy from the lower-middle atmosphere to the upper atmosphere. The Emirates Mars Mission (EMM), to be launched by 2020, is designed to address these limitations. The mission focuses on developing national capabilities in both science and engineering within the UAE, and on contributing with novel science to the human knowledge and civilizations. It will be able to observe and investigate the Mars lower and upper atmosphere simultaneously, enabled by a high altitude orbit and synoptic perspective. EMM target science orbit is of 20,000km x 43,000 with 25° inclination, resulting in 55 hour orbital period which enables comprehensive observations of the exosphere, and full sampling of latitude, longitude, and local time. The Science Phase is planned for 2 Earth years (just over 1 Mars year long) to cover all the seasonal variations in the atmosphere.

Science Objectives and Investigations: The Martian atmospheric science issues discussed can be distilled to three motivating science questions leading to three associated objectives summarized in Table 1.

Table 1: EMM Motivating Science Questions and Objectives

Motivating Questions	EMM Science Objectives
How does the Martian lower atmosphere respond globally, diurnally and seasonally to solar forcing?	A. Characterize the state of the Martian lower atmosphere on global scales and its geographic, diurnal and seasonal variability
How do conditions throughout the Martian atmosphere affect rates of atmospheric escape?	B. Correlate rates of thermal and photochemical atmospheric escape with conditions in the collisional Martian atmosphere.
How do key constituents in the Martian exosphere behave temporally and spatially?	C. Characterize the spatial structure and variability of key constituents in the Martian exosphere.

EMM will achieve these three objectives through four science investigations which require atmospheric variability to be determined on sub-seasonal timescales, to enable understanding of the effects of heliocentric distance variation and planetary obliquity on dynamical processes in all regions of the atmosphere. The correspondence between the mission objectives and investigations are shown in Table 2.

Table 2: EMM Science Objectives and Investigations

EMM Science Objectives	EMM Science Investigations
A. Characterize the state of the Martian lower atmosphere on global scales and its geographic, diurnal and seasonal variability	1. Determine the three-dimensional thermal state of the lower atmosphere and its diurnal variability on sub-seasonal timescales.
B. Correlate rates of thermal and photochemical atmospheric escape with conditions in the collisional Martian atmosphere.	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.
C. Characterize the spatial structure and variability of key constituents in the Martian exosphere.	4. Determine the three-dimensional structure and variability of key species in the exosphere and their variability on sub-seasonal timescales.

Investigation 1. Investigation 1 will determine the three-dimensional thermal state of the lower atmosphere and its diurnal variability on sub-seasonal timescales. In this investigation, EMM will measure vertical temperature profiles from the surface to an altitude up to 50 km. Along with Investigation 2, EMM will sample the Martian lower atmosphere on sufficient spatial and temporal scales to elucidate the processes driving global circulation in the current Martian climate. The physical parameters needed are the atmospheric temperature profiles, measured through the absolute radiance of the CO2 absorption band, and the surface temperature of Mars, measured through the absolute radiance over a subset of the spectral range.

Investigation 2. Investigation 2 will determine the geographic and diurnal distribution of key constituents in the lower atmosphere on sub-seasonal timescales. To better understand the processes that are driving the global circulation in the current Martian climate, EMM will sample the key constituents (ozone, water vapor, water ice and dust) that are present in the lower atmosphere on sufficient spatial and temporal scales to usefully constrain current state-of-the-art models of the atmospheric circulation (along with investigation 1). For this investigation, the physical parameters needed are the ice optical depth (at 12 μm and 320 nm), dust optical depth (at 9 μm and 220 nm), ozone column abundance (at 245 – 275 nm), water vapor abundance (at 25 – 40 μm), and the surface temperature of Mars.

Investigation 3. Investigation 3 will determine the abundance and spatial variability of key neutral species in the thermosphere on sub-seasonal timescales. In this investigation, EMM will provide a measure of the dynamics and energetics of the thermosphere, through which all escaping particles must travel, as it forms the lower boundary of the exosphere. This will be done through determining the column abundance and spatial variability of the key neutral species: oxygen, carbon, and carbon monoxide in the thermosphere. The physical parameters needed are the column densities of oxygen (130.4nm & 135.6nm), carbon (156.1nm & 165.7nm), and carbon monoxide (CO 4PG: 140–170nm) in the thermosphere with a relative accuracy (between species) of 30% and a spatial resolution of less or equal to 300 km at nadir (i.e. the resolution of global 3-D atmospheric models).

Investigation 4. Investigation 4 will determine the three-dimensional structure and variability of key species in the exosphere and their variability on sub-seasonal timescales. This investigation is focused on the exosphere, the channel through which Mars' atmosphere escapes to space. In this investigation, EMM will determine the density of hydrogen and oxygen through far ultraviolet measurements made from multiple viewing angles on a weekly cadence or better. Rates of hydrogen escape can be derived by EMM ability to measure optically-thin Lyman beta (102.6 nm) hydrogen emission up to 1.6 Mars radii, allowing intensities to be converted directly to column densities and thereby better constraining three dimensional representations of the exosphere. Further, EMM will periodically measure Lyman Alpha emission up to 10 Mars radii, where it becomes optically thin and where the hot, escaping component of the velocity distribution can be better separated from the colder, bound component. On the other hand, Mars' atomic oxygen corona results almost entirely from dissociative recombination of molecular oxygen ions (the most abundant in the thermosphere/ionosphere). This exothermic photochemical reaction results in fast neutral oxygen atoms with a range of energies up to ~3.6 eV. Those that escape the collisional atmosphere and reach the near-collisionless exosphere can be divided into 2 different categories: those with greater than and less than escape velocity (2 eV). Observations of the OI 130.4 nm FUV emission from 200 km altitude out to several Mars radii will allow these two populations to be separated and hence enable the determination of the rate of photochemical escape of atomic oxygen.

Instruments Overview: EMM will collect information about the Mars atmospheric circulation and connections through a combination of three distinct instruments that image Mars in the visible, thermal infrared and ultraviolet wavelengths and they are the Emirates eXploration Imager (EXI), the Emirates Mars InfraRed Spectrometer (EMIRS), and the EMM Mars Ultraviolet Spectrometer (EMUS). A summary of the three instruments is in Table 3.

Table 3: EMM Payload

Payload	EXI	EMIRS	EMUS
Capability	Ultraviolet-Visible camera	Fourier transform infrared spectrometer	Ultraviolet imaging spectrograph
Supplier	LASP & MBRSC	ASU & MBRSC	LASP & MBRSC
Spectral Range	205-235nm 245-275nm 305-335nm 405-469nm 506-586nm 620-650nm	6 – 40 microns	100 – 170 nm

The primary science goal of EXI is to measure the optical depths of dust and water ice in the Martian atmosphere at 220 nm and 320 nm, respectively, as well as the column abundance of ozone. In contrast, 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. As for EMUS, it is designed to measure relative changes in the thermosphere and the structure – radial extent and scale height – of both the hydrogen and oxygen exospheres. Additionally, it will measure changes in the structure of the corona with season, solar inputs, and lower atmosphere forcing (e.g. dust storms). Measurements of both hydrogen and oxygen in the upper atmosphere are essential for determining the loss of water from the upper atmosphere.