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Emirates Mars Mission (EMM) 2020 Overview

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Abstract

The United Arab Emirates (UAE) has entered the space exploration race with the announcement of the Emirates Mars Mission (EMM), the first Emirati mission to another planet, in 2014. Through this mission, the UAE is to send an unmanned observatory, called Hope, to be launched in summer of 2020 and reach Mars by 2021 to coincide with the UAE's 50th anniversary. The mission will be unique, and has a strong potential to create novel and significant discoveries that contribute to the ongoing work of the global space science community. EMM has passed its development phase milestone reviews including Mission Concept Review (MCR), System Requirements Review and System Design Review (SRR/SDR), Preliminary Design Review (PDR), and Critical Design Review (CDR) phases. The mission is led by the Mohammed Bin Rashid Space Centre (MBRSC), in partnership with the Laboratory for Atmospheric and Space Physics (LASP) at University of Colorado, Boulder, Space Sciences Laboratory (SSL) at University of California, Berkeley, and School of Earth and Space Exploration at Arizona State University (ASU). The mission is designed to answer the following three science questions:

- How does the Martian lower atmosphere respond globally, diurnally, and seasonally to solar forcing?
- How do conditions throughout the Martian atmosphere affect rates of atmospheric escape?
- How does the Martian exosphere behave temporally and spatially?

Each question is aligned with three mission objectives and four investigations that study the Martian atmospheric circulation and connections through measurements taken using three instruments that image Mars in the visible, thermal infrared and ultraviolet wavelengths. Data will be collected at Mars for a period of an entire Martian year to provide scientists with valuable understanding of the changes to the Martian atmosphere today. This paper provides an overview of the mission and science objectives, instruments and spacecraft, as well as the ground and launch segments.

1. Introduction

The Emirates Mars Mission (EMM) is the United Arab Emirates (UAE) first mission to Mars and is the first Arab mission to another planet. The mission was announced by the UAE's Government in July 2014 with the objectives to complete Mars orbit insertion by the UAE's 50th anniversary in 2021, to contribute to the development of the Science and Technology Sector in the UAE, to develop the UAE's scientific capabilities, and to increase the UAE's contribution to the international scientific community. The mission also should have significant contribution to the ongoing work of the global space science community, and should be of a great value to ".

EMM will launch an unmanned observatory called "Hope" into an elliptical orbit around Mars in the summer of 2020 carrying three scientific instruments to study the Martian atmosphere in the visible, ultraviolet, and infrared bands.

The mission is led by Emiratis from Mohammed Bin Rashid Space Centre and will expand the nation's human capital through knowledge transfer programs set with international partners from the University of Colorado Laboratory for Atmospheric and Space Physics (LASP), University of California Berkeley Space Sciences Laboratory (SSL), and Arizona State University (ASU) School of Earth and Space Exploration.

2. Science Objectives and Investigations

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 (i.e. day-to-night) 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. These Martian atmospheric science issues 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. All four investigations require atmospheric variability to be determined on sub-seasonal timescales. 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.

3. 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. The instrument suite includes the Emirates eXploration Imager (EXI), the Emirates Mars InfraRed Spectrometer (EMIRS), and the Emirates Mars Ultraviolet Spectrometer (EMUS). A summary of the three instruments is in Table 3.

Table 3: EMM Payload

	EXI	EMIRS	EMUS
Payload Type	Ultraviolet & Visible imager	Fourier transform infrared spectrometer	Ultraviolet imaging spectrograph
Developer	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

4. Spacecraft Overview

The spacecraft, named "Hope" and shown in Figure 1, provides the capabilities required to achieve and maintain the Mars orbit post-launch, supply the above-described payloads with needed structural support, power, thermal control, data handling, pointing, and fault management responses, send science, ancillary, and housekeeping data to the ground, and receive command data from mission operations centers. The spacecraft system includes the harnessing required to connect the payloads to the spacecraft for full space segment capability.

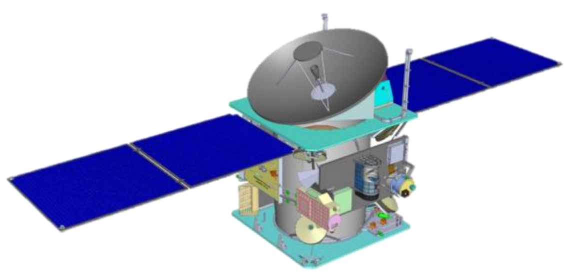

Figure 1: "Hope" Spacecraft Design

The observatory launch mass is 1500kg with a primary structure consisting of composite honeycomb panels and a propulsion subsystem capable of changing orbit trajectory, orbit braking to Mars target orbit plane and orbit maintenance.

While in space, Hope generates and stores power using two deployable solar arrays and batteries and communicates with Earth-based ground antennas using a 1.85m diameter high gain antenna and coupled low gain antennas. It utilizes the Applied Physics Laboratory (APL) Frontier Radio deep space transponder that performs uplink and downlink of data and supports deep space tracking for navigation purposes. For attitude determination, it will have a redundant pair of 3-axis inertial reference units and a redundant pair of star trackers. For attitude control, it has a set of four Reaction Wheel Assemblies (RWA), as well as eight Reaction Control System thrusters for momentum dumping.

5. Mission Timeline, Operation and Lifetime

EMM design, development and testing phase commenced in mid-2014 with the launch scheduled in mid-2020 for a total of 6 years. Figure 2 summarizes the timeline and major milestones of the mission.

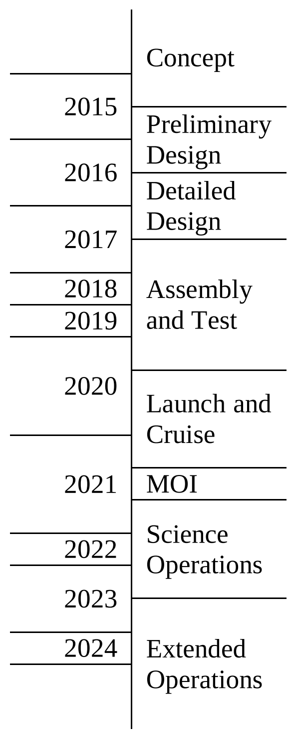

Figure 2: EMM Timeline

The Hope Probe is designed for a three Earth-year lifetime. Its operational life consists of the Cruise Phase, for around seven months, that follows launch and it will be limited to instrument checkout and calibration activities. Following Mars Orbit Insertion (MOI) that will last for a week, the Capture Orbit phase is characterized by a highly elliptical 35-hour orbit (500 km periapsis, 44,500 km apoapsis) from which all three instruments will be checked out and their science sequences tested, resulting in early observations of the Mars disk and upper-atmosphere. Following this, a Transition Orbit phase will be achieved by the gradual enlargement of the orbit over the course of approximately one month until it is optimized. The required science orbit for data collection is 20,000 km x 43,000 km. The Primary Science phase will begin and is expected to last 1 Martian year to meet the science requirements. The 20,000 km periapsis altitude during the Primary Science phase is sufficient to ensure global-scale, near-hemispheric views throughout the orbit and to allow daily coverage of all longitudes and local times. The orbital period will be approximately 55 hours which will enable a comprehensive characterization of Mars' lower atmosphere variability as a function of location, time of day, and season, as well as an understanding of how physical processes in the lower atmosphere affect the rates of escape from the exosphere.

6. Ground Segment Overview

The EMM project is responsible for developing complete ground segment capabilities in support of mission development and operations. The EMM ground segment is composed of the ground network and its ground stations, navigation system, operations centers, mission design, Science Data Center (SDC), and Instrument Team Facilities (ITFs).

The Mission Operations Center (MOC) and SDC are located at the MBRSC and the Mission Support Facility (MSF) is located at LASP. Telemetry is routed to both the MOC and MSF every contact, so that full flight data sets reside at each location. The MSF serves as a redundant operations capability. The ground network supports contacts as scheduled for each phase of the mission.

The navigation team provides determined ephemeris, predicted ephemeris, and burn solutions to maintain the orbit or trajectory. The ITF for each instrument is responsible for instrument builds and tests, as well as building a repository of engineering information supporting each instrument.

7. Conclusions

EMM will explore the dynamics in the atmosphere of Mars on a global scale while sampling contemporaneously both diurnal and seasonal timescales. Using three science instruments on an orbiting spacecraft, EMM will provide a set of measurements fundamental to an improved understanding of circulation and weather in the Martian lower and middle atmosphere. Combining such data with the monitoring of the upper layers of the atmosphere, EMM measurements will reveal the mechanisms behind the upward transport of energy and particles and the subsequent escape of atmospheric constituents from the atmosphere of Mars. The unique combination of instruments and temporal and spatial coverage of Mars' different atmospheric layers will open a new and much-needed window into the workings of the atmosphere of our planetary neighbor.