EMIRATES MARS MISSION (EMM) 2020 OVERVIEW and STATUS. O. Sharaf [1], S. Amiri [1], S. AlDhafri [1], A. AlRais [1], M. Wali [1], Z. AlShamsi [1], I. AlQasim [1], K. AlHarmoodi [1], N. AlTeneiji [1], H. Almatroushi [1], M. AlShamsi [1], E. AlTeneiji [1], F. Lootah [1], K. Badri [1], H. AlMazmi [2], M. Yousuf [1], N. AlMehairi [1], M. McGrath [3], P. Withnell [3], N. Ferrington [3], H. Reed [3], B. Landin [3], S. Ryan [3], B. Pramann [3], D. Brain [3], G. Holsclaw [3], J. Deighan [3], M. Chaffin [3], C. Edwards [4], F. Forget [5], R. Lillis [6], M. Smith [7], and M. Wolff [8], [1] Mohammed Bin Rashid Space Centre (MBRSC), Dubai, UAE, [2] United Arab Emirates Space Agency, Abu Dhabi, UAE, [3] Laboratory for Atmospheric and Space Physics (LASP) at University of Colorado, Boulder, USA, [4] Northern Arizona University, Department of Physics and Astronomy, Flagstaff, USA, [5] Laboratoire de Météorologie Dynamique (LMD), IPSL, Paris, France, [6] Space Sciences Laboratory (SSL), University of California, Berkeley, USA, [7] NASA Goddard Space Flight Center, Green-belt, USA, [8] Space Science Institute (SSI) in Boulder, USA.

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. It launched an unmanned observatory called "Hope" into an elliptical orbit around Mars on July 20, 2020 carrying three scientific instruments to study the Martian atmosphere in visible, ultraviolet, and infrared wavelengths. EMM will be the first mission to provide the first truly global picture of the Martian atmosphere, revealing important information about how atmospheric processes drive diurnal variations for a period of one Martian year.

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), Arizona State University (ASU) School of Earth and Space Exploration, and the University of California Berkeley Space Sciences Laboratory (SSL).

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 throughout the lower-middle atmosphere and from it to the upper atmosphere. These Martian atmospheric science issues can be distilled to three motivating science questions leading to three associated objectives:

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

EMM will achieve these three objectives through four science investigations, listed below, that require atmospheric variability to be determined on sub-seasonal timescales:

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 timescales.

Instruments Overview: EMM will collect information about the Mars atmospheric circulation and connections through observations from three distinct instruments that image Mars in 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 1.

Table 1: EMM Payload

	EXI	EMIRS	EMUS
Payload Type	Ultraviolet & Visible imager	Fourier transform infrared spectrometer	Ultraviolet imaging spectrograph
Spectral Range	245-275nm 305-335nm 405-469nm 506-586nm 625-645nm	6 – 40 µm	100 – 170 nm

Spacecraft Overview: The “Hope” spacecraft, provides the capabilities required to a) achieve and maintain Mars orbit post-launch, b) supply the above-described payloads with needed structural support, power, thermal control, data handling, pointing, and fault management responses, c) send science, ancillary, and housekeeping data to the ground, and d) receive command data from mission operations centers.

The observatory launch mass is 1350kg with a primary structure consisting of composite honey-comb panels and a propulsion subsystem capable of correcting Hope’s interplanetary trajectory, performing Mars orbit insertion to the target orbital 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 also utilizes the Applied Physics Laboratory Frontier Radio deep space transponder that performs uplink and downlink of data and supports deep space tracking for navigation purposes. For attitude determination, it has 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, as well as eight Reaction Control System thrusters for momentum dumping.

Mission Timeline, Operation and Lifetime: EMM design, development and testing phase commenced in mid-2014 with the launch taking place in mid-2020.

The Hope Probe is designed for at least a Mission Life of 3 Earth years. Its operational life consists of four main phases. Cruise Phase, has a duration of around seven months following launch and is limited to instrument checkout and calibration activities. Following Mars Orbit Insertion, the Capture Orbit phase is characterized by a highly elliptical 40-hour orbit (1000 km periapsis, 49,380 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 reaches the required science orbit for data collection of 20,000 km x 43,000 km. The Primary Science phase will then 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, enabling 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.

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 MBRSC and the Mission Support Facility (MSF) is located at LASP to serve as a redundant operations capability. 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.

Summary: EMM will explore the dynamics in the atmosphere of Mars on a global scale while sampling contemporaneously both diurnal and seasonal time-scales. 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 the 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.