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Emirates Mars Mission – Al Amal Overview

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Al Amal Mars Probe is United Arab Emirates' catalyst project to explore the Red Planet. It is part of the ambitious programme known as "Emirates Mars Mission (EMM)" which was announced by the government of UAE in July 2014. Al Amal Mars Probe will, for the first time, explore the dynamics in the atmosphere of Mars on a global scale. To achieve this, Al Amal Mars Probe will consist of three science instruments: 1) Emirates eXploration Imager (EXI) will measure the properties of water ice and dust aerosols, and abundance of ozone in Mars' atmosphere using a visible imager; 2) Emirates Mars Ultraviolet Spectrometer (EMUS) will measure the global characteristics of hydrogen and oxygen coronae; and 3) Emirates Mars InfraRed Spectrometer (EMIRS) will measure the global thermal structure and abundances of water ice, and water vapor in Mars' atmosphere. Al Amal Mars Probe is expected to be launched in mid-2020 onboard an H-IIA launch vehicle. And it should reach Mars Orbit in Q1 2021 coinciding with the 50th anniversary of the United Arab Emirates.

I. Introduction

July 2014 witnessed the establishment of the United Arab Emirates Space Agency (UAESA) and the announcement of the UAE's ambitious programme known as "Emirates Mars Mission (EMM)" to explore the Red Planet. The UAESA signed an agreement with Mohammed Bin Rashid Space Centre (MBRSC) to implement the space, ground and launch segments as well as programme management. MBRSC has partnered with international partners – University of Colorado at Boulder's Laboratory for Atmospheric and Space Physics (CU/LASP), University of California at Berkeley's Space Sciences Laboratory (UCB/SSL), and Arizona State University (ASU) – to jointly design and develop the different segments of the mission.

The EMM, also known as "Al Amal" Mars Probe, will have significant contribution to the ongoing activities of the global space science community. It will, for the first time, explore the dynamics in the atmosphere of Mars on a global scale. To achieve this, Al Amal Probe will consist of three science instruments: 1) Emirates eXploration Imager (EXI) will measure the properties of water ice and dust aerosols, and abundance of ozone in Mars' atmosphere using a visible imager; 2) Emirates Mars Ultraviolet Spectrometer (EMUS) will measure the global characteristics of hydrogen and oxygen coronae; and 3) Emirates Mars InfraRed Spectrometer (EMIRS) will measure the global thermal structure and abundances of water ice, and water vapor in Mars' atmosphere. Al Amal Mars Probe will launch in mid-2020 for arrival at Mars in early 2021, coinciding with the 50th anniversary of the UAE. The spacecraft will be equipped with a 20-GB onboard data storage capacity to store the science data generated by the science instruments. The three instruments will be hosted on an orbiting spacecraft that will be inserted into an elliptical Mars science orbit of 22,000 – 44,000 km with a 55-hour period. Figure 1 below shows the EMM project timeline through its different phases.

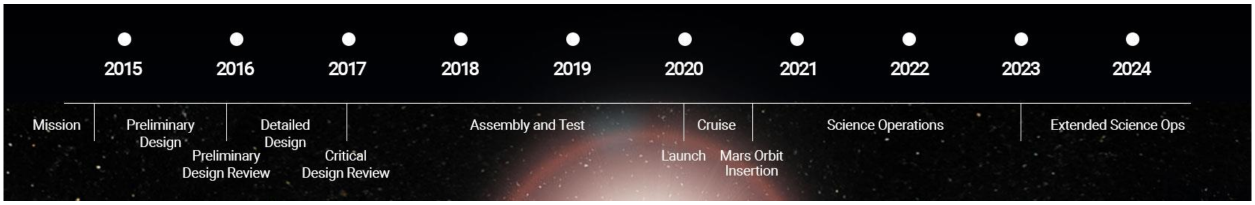

Figure 1 Project Timeline

II. EMM Science Overview

The scientific objectives and investigations of EMM were closely coordinated with the international Mars Exploration Program and Analysis Group (MEPAG). As a result, the science generated by EMM will complement the current international efforts to study the Red Planet and also provide unique insights to fill the gaps in human knowledge.

EMM will provide holistic, global and diurnal understanding of the atmospheric dynamics of Mars. The science instrument suite will provide necessary measurements to understand the atmospheric properties aligned with the following science objectives:

1. Characterize global state of the Mars lower-middle atmosphere and its geographic, seasonal and diurnal variability.
2. Characterize atmospheric tides and other wave modes, which are important for controlling many aspects of the current Martian climate system, including thermal structure, circulations, transport processes, lower-to-upper atmosphere connections, cloud formation and genesis and development of dust storms.
3. Correlate variability in lower atmospheric conditions with densities, temperatures and escape rates in the extended Martian hydrogen and oxygen coronas.

To date, measurements of the Martian atmosphere have been made at very limited timeframes, leaving more than 80% of the Mars diurnal cycle unexplored. EMM will investigate the geographic regions of Mars at all times of day, facilitating understanding of both global circulation and energy transport. The data returned from EMM will reveal the connection between these conditions in the lower atmosphere and the escape of hydrogen and oxygen from the upper atmosphere, a process that may have been responsible for the transition of the Mars atmosphere from a thick, wet one billions of years ago to the cold, thin, arid one observed today.

The two fundamental science questions that 'Al Amal' Mars Probe will address are:

1. How does Mars' atmosphere respond to solar forces on a global scale and what role does that play in the current climate of Mars?
2. How do conditions in the lower-middle atmosphere affect the rates of hydrogen and oxygen escape from the upper atmosphere?

III. EMM Instruments

Al Amal 'Hope' Mars Probe spacecraft carries an instrument suite optimized for the primary mission goal of understanding circulation and weather patterns in the Mars atmosphere on a global scale. It will consist of three primary scientific instruments:

A. Emirates eXploration Imager (EXI)

EXI is a multi-wavelength camera that will be designed and built at CU/LASP with MBRSC support. It will operate at visible wavelengths consisting of a lens system, filter wheel, and detector. It has a field-of view sufficient to capture the entire Mars disk from the Probe prime science orbit.

EXI will measure the properties of water ice and dust aerosols, and abundance of ozone in Mars' atmosphere using a visible imager. It will be used scientifically to image the Martian atmosphere at visible wavelengths. Red and blue filters will allow the identification of dust and clouds, respectively. The high spatial resolution of the camera over the entire disk will complement measurements of dust in the infrared; dust opacities derived from infrared measurements at 100-200 km/pixel can be compared to dust opacities estimated from the visible camera at much higher spatial resolution. Clouds can be identified and tracked with respect to local time and geography.

Together, these features will reveal the global atmospheric circulation on Mars. Images recorded are sufficient for tracking global circulation.

B. Emirates Mars Ultraviolet Spectrometer (EMUS)

EMUS Coronal Imager will be designed and built at CU/LASP, and detectors will be provided by UCB/SSL. It consists of a one-dimensional imaging spectrograph with scan mirror. The primary science goal of the EMUS is to measure the structure – radial extent and scale height – of both the hydrogen and oxygen coronas at Mars. Additionally, it will measure changes in the structure of the corona with season, solar inputs, and lower atmosphere forcing (dust storms). Measurements of both hydrogen and oxygen in the upper atmosphere are essential in determining the loss of water from the upper atmosphere.

In order to observe and discriminate between the hydrogen and oxygen coronals, the EMUS will make one-dimensional spectral measurements. In addition, two-dimensional images of the corona will be constructed with the aid of a scanning mirror in conjunction with spacecraft motion.

C. Emirates Mars InfraRed Spectrometer (EMIRS)

EMIRS will be designed and built at ASU with support from MBRSC. It will measure the global thermal structure and abundances of water ice, and water vapor in Mars' atmosphere. The instrument is optimized to capture the integrated, lower-middle atmosphere dynamics over a Martian hemisphere. The EMIRS scan-mirror capability enables a full-aperture calibration, allowing for highly accurate radiometric calibration (<1% projected performance) to robustly measure atmospheric and surface properties. The suite of atmospheric observations covering a wide range of local times that is captured by the EMIRS instrument on a daily basis constitutes a unique set of measurements not previously accessible to polar orbiting spacecraft, which have been locked to a particular local time of day. As a part of the EMM primary mission, EMIRS will enable numerous lower-middle atmospheric properties to be retrieved in detail, including the 3-D atmospheric thermal structure, and the spatial distribution of water vapor, water ice clouds, and dust aerosols. Temperature profiles will be retrieved for all nadir observations in the global, synoptic views. The spatial distribution of water vapor, water ice clouds, and dust aerosols will be retrieved as column integrated values.

IV. Spacecraft Overview

The EMM mission will be designed and built at CU/LASP with MBRSC support. The EMM mission is an orbiter mission with the observatory comprised of the instrument suite, as described above, and spacecraft bus. The spacecraft will be three-axis stabilized, using sensor inputs from star trackers, sun sensors, and inertial measurement units, to provide actuation through reaction wheels and thrusters, the latter being used for both orbital maneuvers and momentum management. The bus will also provide power, thermal control, and communications, as well as command and data handling support for the instruments as shown in Figure 2. The total observatory mass at launch is estimated at 1500 kg.

The telecommunication subsystem on-board Al Amal Mars Probe will consist of a standard transponder unit that was used on a previous LEO mission, and that will be used on the Solar Probe Plus (SPP) and Europa deep-space missions. The main functions of the unit are to:

- Support the uplink and downlink communication from/to the ground station at X-band (7/8 GHz).
- Support the deep space ranging for navigation activities.

The spacecraft will communicate with Mission Control on Earth using a high-gain antenna (HGA) with a diameter of 1.85 m. Additionally, three low-gain antennas will provide near-omnidirectional coverage for low-rate commanding and telemetry.

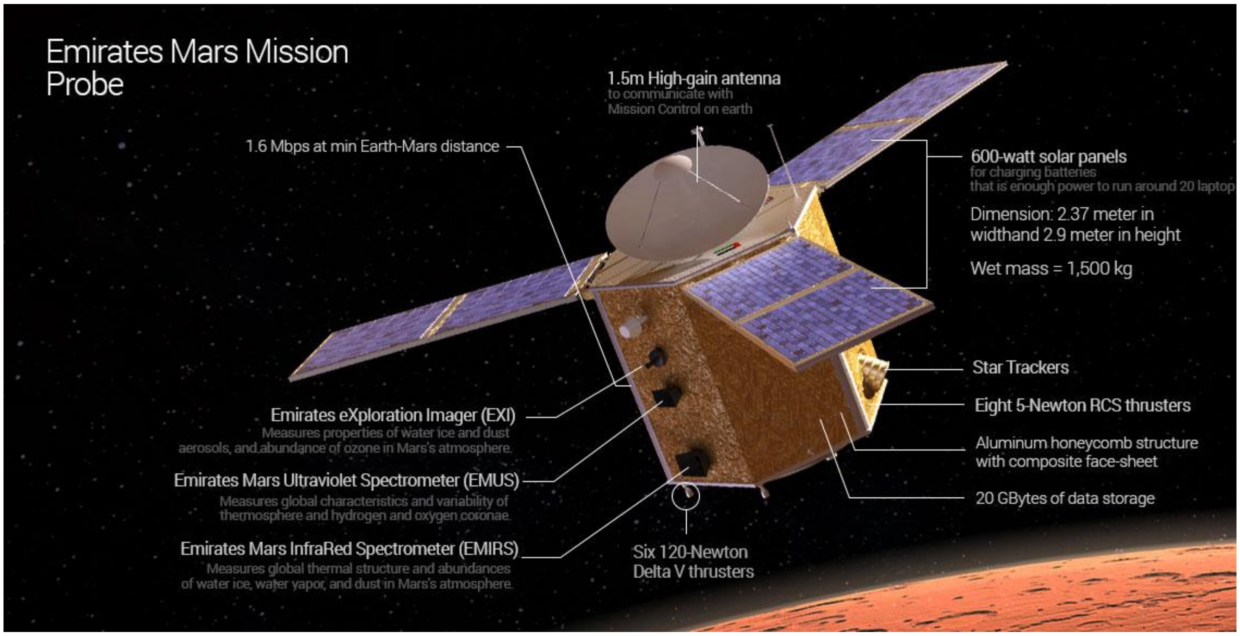

Figure 2 Al Amal Mars Probe Preliminary Design

The EMM mission will have six on-orbit phases as follows:

- **Launch/Early Operations:**
  Launch/Early Operations will consist of the first four weeks on-orbit. The phase will start at separation and will run through the steps to check-out and commission the vehicle. The separation events will execute on the spacecraft via a sequence started from launch vehicle separation. The spacecraft subsystems will have a detailed commissioning plan that will confirm each subsystem is working properly, calibrate subsystems for space, and to properly power on components not powered on at separation. This phase will also perform aliveness tests for the instruments plus any checkout to confirm the instruments are functioning properly. During Launch/Early Operations, Trajectory Correction Maneuvers (TCM) may occur to correct any initial errors from separation.

- **Cruise**
  During the ~6-month cruise, TCMs will be performed to finalize the approach to Mars. Calibration of the HGA, power and thermal subsystems will be performed to account for the growing sun range. Near the end of the Cruise phase, the spacecraft will be checked out and prepared for Mars Orbit Insertion.

- **Mars Orbit Insertion**
  The ~1-week Mars Orbit Insertion (MOI) period will focus on the large thruster burn required to remove the excess observatory velocity for the successful insertion into a Mars orbit. The entire event will be sequenced, as the two-way light time prevents any real-time interaction. Most of the spacecraft subsystems will be powered off except those required for the burn, as well as any backups for failover cases.

- **Mars Transition**
  The ~3-month Mars Transition phase will look similar to the Launch/Early Operations phase, but with the emphasis on the instruments. A quick check-out will be performed on the spacecraft subsystems that were not used during MOI. Then the instruments will be powered on and checked out and commissioned for routine science operations. Any orbit maneuvers to place the vehicle into the final science orbit will be conducted during this phase.

- **Routine Science**

The two-Earth-year, and one-Mars-year, Routine Science phase is the focus for the mission. This phase will see the observatory run through its routine data collection and communications to deliver the science back to Earth. The expectation will be to plan each week's worth of three orbits in a similar manner, which will include the calibrations, spacecraft slews, and data takes for science collection, as well as battery charging and Mars-to-Earth communications. Special science campaigns may be planned to put more emphasis on collecting data unique to a time or place, and special periodic calibrations can also be performed to aid in the processing of the data. Twice each week the spacecraft will interrupt science collection to slew and point its HGA at Earth in order to downlink the recorded science and engineering data, as well as to uplink new sequences for upcoming orbits.

- **Decommissioning**
  The Decommissioning phase will include any steps necessary to passivate the spacecraft. These steps could be orbit maneuvers to place the spacecraft into a safe orbit, depleting pressurized vessels, and condition the power systems to keep subsystems unpowered.

Note that there is also an option for an extended mission that would cover an additional two-Earth-year/one-Martian-year period, and could include additional new science activities.

V. Ground Segment Overview

The Ground Segment will consist of three primary facilities, plus ancillary support facilities. The former include the Mission Operation Center (MOC), Mission Support Facility (MSF), and Science Data Center (SDC); the latter include Navigation, which will be handled by KinetX as prime navigation service provider, and Instrument Team Facilities (ITF), which will be located at the associated instrument development facilities. In addition, the mission will make use of external facilities, such as the ground network to support direct communications with the observatory (the selection progress for this partner is in progress).

The EMM mission will have its MOC at MBRSC with backup and support capabilities at the MSF at LASP. The MOC is the central facility for command transmission and telemetry receipt to/from the spacecraft. The MOC will run independently, with assistance from the MSF, to command and control the spacecraft via the ground network. The MOC and MSF will be responsible for planning all routine events, both for the spacecraft and the instrument suite, as well as for command upload and spacecraft configuration management. The MOC will process and store all spacecraft telemetry for post-event analysis, and will package and transfer all science data to the SDC for further processing and delivery to the science team for analysis.

VI. Launch Segment Overview

MBRSC has recently signed a launch agreement with Japan's Mitsubishi Heavy Industries (MHI) to launch Al Amal Mars Probe in mid-2020, using its HII-A launch vehicle from the launch site on Tanegashima Island. The HII-A rocket is capable of providing the direct injection capability to send the Probe on its cruise to Mars.

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