EMIRATES HOPE MARS MISSION (EMM)

SCIENCE OVERVIEW

Presented by Sarah Amiri on behalf of the EMM Team

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The Emirates Mars Mission is the first planetary exploration mission for the UAE, announced in 2014.

Hope Probe is developed through a partnership between Mohamed bin Rashid Space Centre (MBRSC), LASP at University of Colorado Boulder, and Arizona State University (ASU)

Due to launch July 2020
PROGRAM OBJECTIVES

- Develop science and engineering capabilities
- Data from the mission should be beneficial to the global science community
- Arrive at Mars by the 50th anniversary of the formation of the UAE.
SCIENCE OBJECTIVES

EMM is a mission focused on atmospheric dynamics. It will explore the atmosphere of Mars **globally** while sampling both **diurnal** and **seasonal** timescales.

<table>
<thead>
<tr>
<th>Science Questions</th>
<th>Science Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the Martian lower atmosphere respond globally, diurnally and seasonally to solar forcing?</td>
<td>Characterize the state of the Martian lower atmosphere on global scales and its geographic, diurnal and seasonal variability</td>
</tr>
<tr>
<td>How do conditions throughout the Martian atmosphere affect rates of atmospheric escape?</td>
<td>Correlate rates of thermal and photochemical atmospheric escape with conditions in the collisional Martian atmosphere</td>
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<tr>
<td>How do key constituents in the Martian exosphere behave temporally and spatially?</td>
<td>Characterize the spatial structure and variability of key constituents in the Martian exosphere</td>
</tr>
</tbody>
</table>
EMM PARTNERSHIPS

Project Management & Development

Science

Spacecraft, Mission Operations, Observatory and Spacecraft I&T

Instruments

Navigation

Launch Vehicle
EMM PROJECT DEVELOPMENT TIMELINE

We are here

- 2015: Concept
- 2016: Preliminary Design
- 2017: Detailed Design
- 2018: Assembly & Test
- 2019: Preliminary Engineering Review (PER)
- 2020: Launch
- 2021: Mission Operations Initiation (MOI)
- 2022: Science Operations
- 2023: Extended Science Operations
- 2024:
### MISSION TIMELINE

#### EMM

**Timeline version 2017-01-20**

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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#### Critical Events
- 14 July: Capture Orbit
- 9 Feb: Transition to Science Phase
- 13 March: Decommissioning

#### Mission Phase

- **Cruise**
- **Science**
- **Extended Mission**

#### Maneuvers
- TCM = Trajectory Correction Maneuver
- DOI = Mars Orbit Insertion
- TSM = Transition to Science Maneuver

#### High Cadence Science

#### Occultations

#### Eclipses

#### Solar Conjunction

#### Distance to Earth

#### Distance to Sun

#### Standard Tracks / wk

#### DDORs / wk

#### Data DL Vol (Gb/wk)

#### Angle of Sun out of Orbit

#### LST of Perilune

#### Solar Longitude L₅

#### Mars Seasons

(Northern Hemisphere)

#### Stopping Slit Geometry

#### Winter

#### Spring

#### Summer

#### Autumn

#### Winter

#### Spring

#### Dust Storm Season

<table>
<thead>
<tr>
<th>2020</th>
<th>2021</th>
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</table>
EMM INSTRUMENTS

EMIRS
Fourier Transform IR Spectrometer

EMUS
Ultra Violet Imaging Spectrometer

EXI
Imager with 12 MP camera with 6 bandpass filters (VIS/UV)
EMM Science Flow

Science Investigations

Determine the three-dimensional thermal state of the lower atmosphere and its diurnal variability, on sub-seasonal timescales

Determine the geographic and diurnal distribution of key constituents in the lower atmosphere on sub-seasonal timescales

Physical Parameters

Temperature Profiles <50 km

Surface Temperatures

H2O vapour column abundance

Dust column integrated optical depth 9 μm

Ice column integrated optical depth at 12 μm and 320 nm

Ozone column integrated abundance

Observable Quantity

Absolute radiance of CO2 absorption band (7-8 μm and 14-16 μm)

Absolute radiance over a subset of the spectral range (7 - 12 μm)

Relative radiance of H2O vapor absorption (25-40μm)

Relative radiance of dust absorption bands (8 -25 μm)

Relative radiance of H2O ice absorption bands (10-15 μm)

2D image of radiance in 320

2D image of radiance in 260

Instruments

EMIRS (IR)

EXI (VIS/UV)
EMM Science Flow

Science Investigations

Determine the abundance and spatial variability of key neutral species in the thermosphere on sub-seasonal timescales

Determine the three-dimensional structure and variability of key species in the exosphere and their variability on sub-seasonal timescales

Physical Parameters

Carbon Monoxide Column Density

Oxygen Column Density

Density of Hydrogen Corona

Density of Oxygen Corona

Observable Quantity

CO Emission (CO 4PG: 140–170 nm)

Light intensity image at O (130.4 nm & 135.6nm)

Light intensity at H (121.6 nm and 102.6 nm)

Altitude profiles at H emission (121.6 nm and 102.6 nm)

Light intensity at O (130.4 nm)

Altitude profiles at O emission (130.4nm)

Instruments

EMUS (FUV)
**EMIRS**

**Instrument Description**

EMIRS is the 5th generation ASU built FTIR spectrometer with OTES, Mini-TES (2x), MGS-TES and MO-TES heritage

- Simple, FTIR spectrometer w/ pointing mirror
- Acquires interferograms every 4 seconds
- Space and internal blackbody provide 1.5% absolute calibration
- Electronics compress and packetize science and housekeeping data

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**SPECIFICATION**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous Field of view</td>
<td>6 mrad</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>5 cm⁻¹ or 10 cm⁻¹</td>
</tr>
<tr>
<td>Spectral Range</td>
<td>6-40+ µm</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>&lt;300 km resolution</td>
</tr>
<tr>
<td>Observation Capability</td>
<td>Observe ½ of Mars within ½ hour of observing</td>
</tr>
<tr>
<td></td>
<td>~60 observations per week (~20/orbit)</td>
</tr>
</tbody>
</table>

**MEASUREMENT REQUIRED**

- Relative radiance of dust absorption bands
- Relative radiance of ice absorption bands
- Relative radiance of $H_2O$ vapor absorption bands
- Absolute radiance of CO$_2$ absorption band
- Radiance at 1300 cm$^{-1}$

**SCIENCE NEED**

- To characterize dust.
- To characterize water ice clouds.
- To track the Martian water cycle.
- Track the thermal state of the Martian atmosphere.
- Boundary condition for the lower atmosphere.
**EMUS**

**Instrument Description**

- Far ultraviolet imaging spectrograph that will characterize the escape of hydrogen and oxygen from Mars and the state of the Mars Thermosphere.
- It consists of a single telescope mirror feeding a Rowland circle imaging spectrograph with a photon-counting and locating detector.
- The EMUS spatial resolution of less than 300km on the disk is sufficient to characterize spatial variability in the Martian thermosphere (100-200 km altitude) and exosphere (>200 km altitude).

**Instrument Specifications**

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of view</td>
<td>(0.18°, 0.25°, 0.7°) × 11.0°</td>
</tr>
<tr>
<td>Wavelength range</td>
<td>100 – 170 nm</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>1.3, 1.8, 5 nm</td>
</tr>
<tr>
<td>Spatial resolution with narrow slit</td>
<td>0.14° × 0.20°</td>
</tr>
<tr>
<td>Detector photocathode</td>
<td>CsI</td>
</tr>
</tbody>
</table>

**Science Targets**

**TARGETS**

- **H**: 102.6, 121.6 nm
- **O**: 130.4, 135.6 nm
- **CO 4PG**: 140-170 nm

FUV spectrum of Mars
(Feldman. Icarus 214.2 (2011): 394-399)
EXI

**INSTRUMENT DESCRIPTION**
- 12 Mpix CMOS imager with re-closeable door and filter wheel
- Filter band-pass targets
  - Blue: 437±5 nm CW, ≤20 nm FWHM
  - Green: 546±5 nm CW, ≤20 nm FWHM
  - Red: 635±5 nm CW, ≤20 nm FWHM
  - UV1: 260±5 nm CW, ≤30 nm FWHM
  - UV2: 320±5 nm CW, ≤30 nm FWHM

**INSTRUMENT SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Specification</th>
<th>UV</th>
<th>VIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focal Plane Format</td>
<td>12.6 MP 4:3 format 4096x3072 @5.5 um</td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>CMOS</td>
<td></td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>12-bit, 13,500 e full well</td>
<td></td>
</tr>
<tr>
<td>Lens System</td>
<td>48 mm, f/3.6</td>
<td>51 mm, f/4.25</td>
</tr>
<tr>
<td>Field of View</td>
<td>19.0°</td>
<td>25.8° by 19.2°</td>
</tr>
<tr>
<td>Pixel Angular View</td>
<td>23 arcsec per pixel</td>
<td>22 arcsec per pixel</td>
</tr>
<tr>
<td>Plate Scale</td>
<td>0.85 mm/°</td>
<td>0.9 mm/°</td>
</tr>
<tr>
<td>Distortion @9.35°</td>
<td>+6%</td>
<td>-2%</td>
</tr>
<tr>
<td>Ground coverage at apoapsis / priapsis</td>
<td>Full Disk</td>
<td></td>
</tr>
<tr>
<td>Ground resolution at apoapsis / priapsis</td>
<td>4.9 / 2.3 km per pixel</td>
<td>4.6 / 2.2 km per pixel</td>
</tr>
<tr>
<td>Filter Spectral Bands</td>
<td>UV1: 245-275 nm</td>
<td>UV2: 305-335 nm</td>
</tr>
<tr>
<td></td>
<td>Blue: 427-447 nm</td>
<td>Green: 536-556 nm</td>
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<tr>
<td></td>
<td>Red: 625-645 nm</td>
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</tbody>
</table>

**SCIENCE TARGETS**

<table>
<thead>
<tr>
<th>SCIENCE PRODUCT</th>
<th>SPATIAL RESOLUTION</th>
<th>IMAGE WAVELENGTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust Column-integrated optical Depth</td>
<td>≤ 10 km</td>
<td>635 nm</td>
</tr>
<tr>
<td>Water Ice cloud Column-integrated optical depth</td>
<td>≤ 10 km</td>
<td>320 nm</td>
</tr>
<tr>
<td>Ozone Column-integrated abundance</td>
<td>≤ 10 km</td>
<td>260 nm</td>
</tr>
<tr>
<td>Color images of Mars</td>
<td>≤ 10 km</td>
<td>437, 546, and 635 nm</td>
</tr>
</tbody>
</table>
INSTRUMENT PAYLOAD ON THE OBSERVATORY

- EMUS
- Star Tracker
- EMUS Electronics
- Launch Vehicle Adapter (LVA)
- EMIRS
- EXI Electronics
- Star Tracker
- EXI
- Reaction Wheel
EMM’S SCIENCE ORBIT

- **High altitude**: 20,000 km x 43,000 km altitude.
- Each observation covers the majority the Martian disk, providing substantial coverage of several local solar time ranges.

- **At periapse**, the orbit is ~synchronous with Mars’ motion. During this time, the spacecraft observes a large part of Mars at various lighting conditions.
- **At apoapse**, Mars rotates quickly beneath the observatory, giving EMM opportunities to survey the globe.

- **Period**: 2.25 sols.
  - From one periapse to the next, Mars rotates 360+360+90 deg. That last 90 deg is key. At each periapse, the spacecraft observes the next quadrant of Mars.
  - Every 4 orbits fills in a full map. 2.25 sols * 4 = 9 sols

- **Inclination**: 25 deg.
  - The orbit is inclined enough to see each pole

- **Argument of periapse**: ~180 deg. This balances the time we spend over each of Mars’ hemispheres.
Altitude_Mars (km): 33816
Altitude Mars (km): 30307

26 Apr 2021 02:57:45.032
Altitude_Mars (km): 26556

26 Apr 2021 05:40:22.466
Altitude_Mars (km): 23032

26 Apr 2021 08:22:05.261
Altitude Mars (km): 20540

26 Apr 2021 11:04:51.801
Altitude_Mars (km): 20116

26 Apr 2021 13:48:58.070
Altitude_Mars (km): 22027

26 Apr 2021 16:34:24.067
Altitude_Mars (km): 25420

26 Apr 2021 19:20:53.809
Altitude_Mars (km): 42987
Altitude_Mars (km): 42534

27 Apr 2021 19:46:10.461
Altitude_Mars (km): 41518

27 Apr 2021 22:20:36.265
Altitude_Mars (km): 39975

28 Apr 2021 00:52:18.525
Altitude_Mars (km): 37827

28 Apr 2021 03:28:35.466
Altitude_Mars (km): 35234

28 Apr 2021 05:59:45.388
Altitude_Mars (km): 32067

28 Apr 2021 08:36:27.605
Altitude_Mars (km): 28707

28 Apr 2021 11:05:56.798
Altitude_Mars (km): 25114

28 Apr 2021 13:42:00.172
Altitude Mars (km): 22132

28 Apr 2021 16:08:41.918
Altitude_Mars (km): 20180

Phobos

28 Apr 2021 18:48:16.414
Altitude_Mars (km): 20288

28 Apr 2021 21:15:26.222
Altitude_Mars (km): 22483

28 Apr 2021 23:58:27.752
# DATA RELEASE POLICY

<table>
<thead>
<tr>
<th>Release Date</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 2021</td>
<td>Quicklook plots from first month of mission; release earlier if possible. After initial release, will be released on a regular basis with a 2-week delay.</td>
</tr>
<tr>
<td>Sept 2021</td>
<td>Level 2 data products, February - April 2021 (MOI + 3 months)</td>
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<tr>
<td>Dec 2021</td>
<td>Level 2 data products, May - July 2021 Level 3 data products, February - April 2021</td>
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<tr>
<td>Mar 2022</td>
<td>Level 2 data products, August - October 2021 Level 3 data products, May - July 2021</td>
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<tr>
<td>Jun 2022</td>
<td>Level 2 data products, November 2021 - January 2022 Level 3 data products, August - October 2021</td>
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<tr>
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<td>and so on through end of nominal mission, until all data is released.</td>
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<tr>
<td>Apr 2026</td>
<td>Final release of all products from mission, including any needed updates to earlier releases, and the radiometric tracking data from NAV.</td>
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