EMIRATES MARS MISSION 2020: SCIENCE TARGETS AND OBSERVATIONS

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The Arab world's first mission to explore Mars

Program Objectives

- Program goals announced by UAE's Government on 16 July 2014:
  - Complete Mars orbiter insertion by the **UAE's 50th anniversary** in 2021
  - Contribute to the **development of the Science and Technology Sector** in the UAE
  - Develop UAE **Scientific Capabilities**
  - Increase **UAE's Contribution to the Scientific Community**

- Program Requirements
  - The mission should be **unique**, and should aim for significant discoveries.
  - The mission should have impactful **contributions** to the ongoing work of the global space science community, and should be of a great value to humanity.
  - The mission should help **build** a sustainable outer space exploration program in UAE.
  - The mission should include **valuable** contribution from UAE engineers and scientists.

Academic Partners

Partnerships to share knowledge

EMM mission is an international collaboration

*All EMM technology is the result of **collaborative** effort between the UAE and the International Partners.*

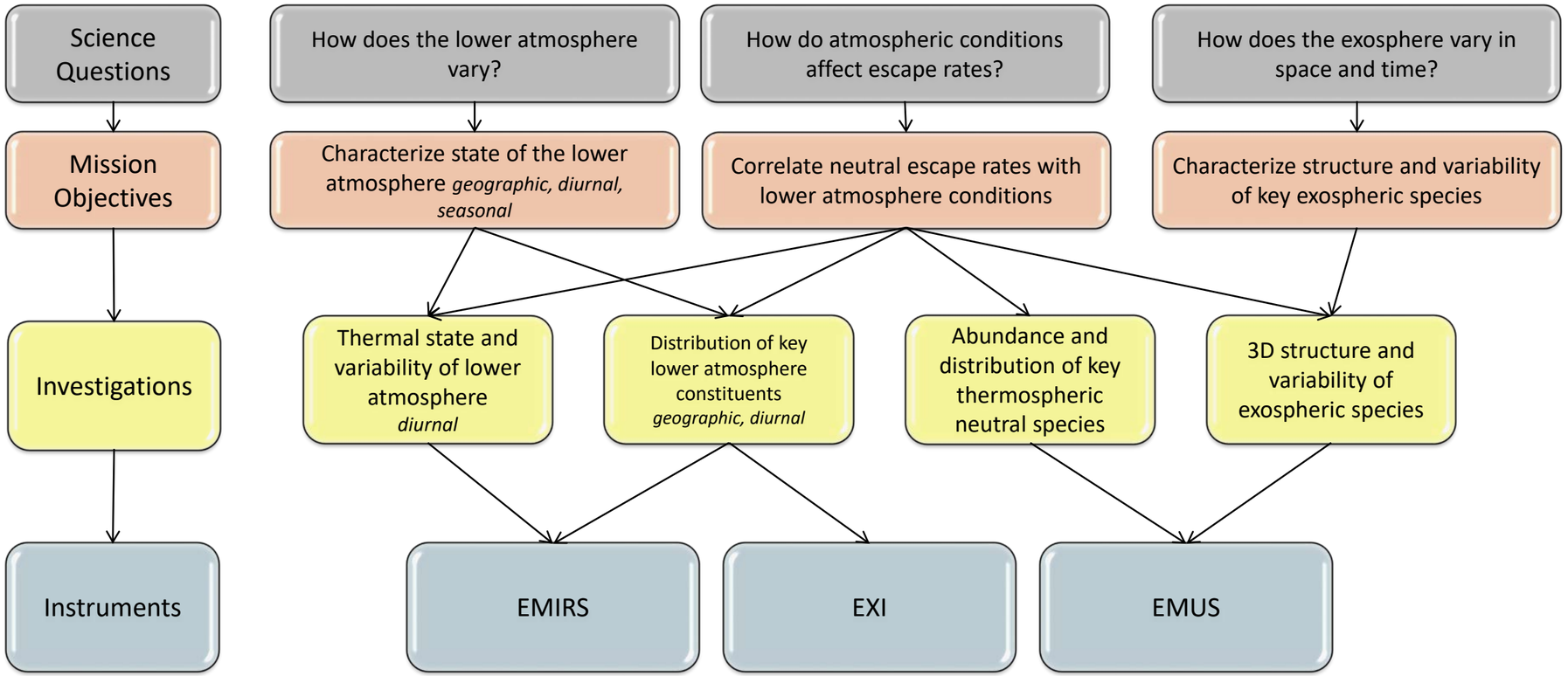
EMM Partnerships

EMM Science Questions

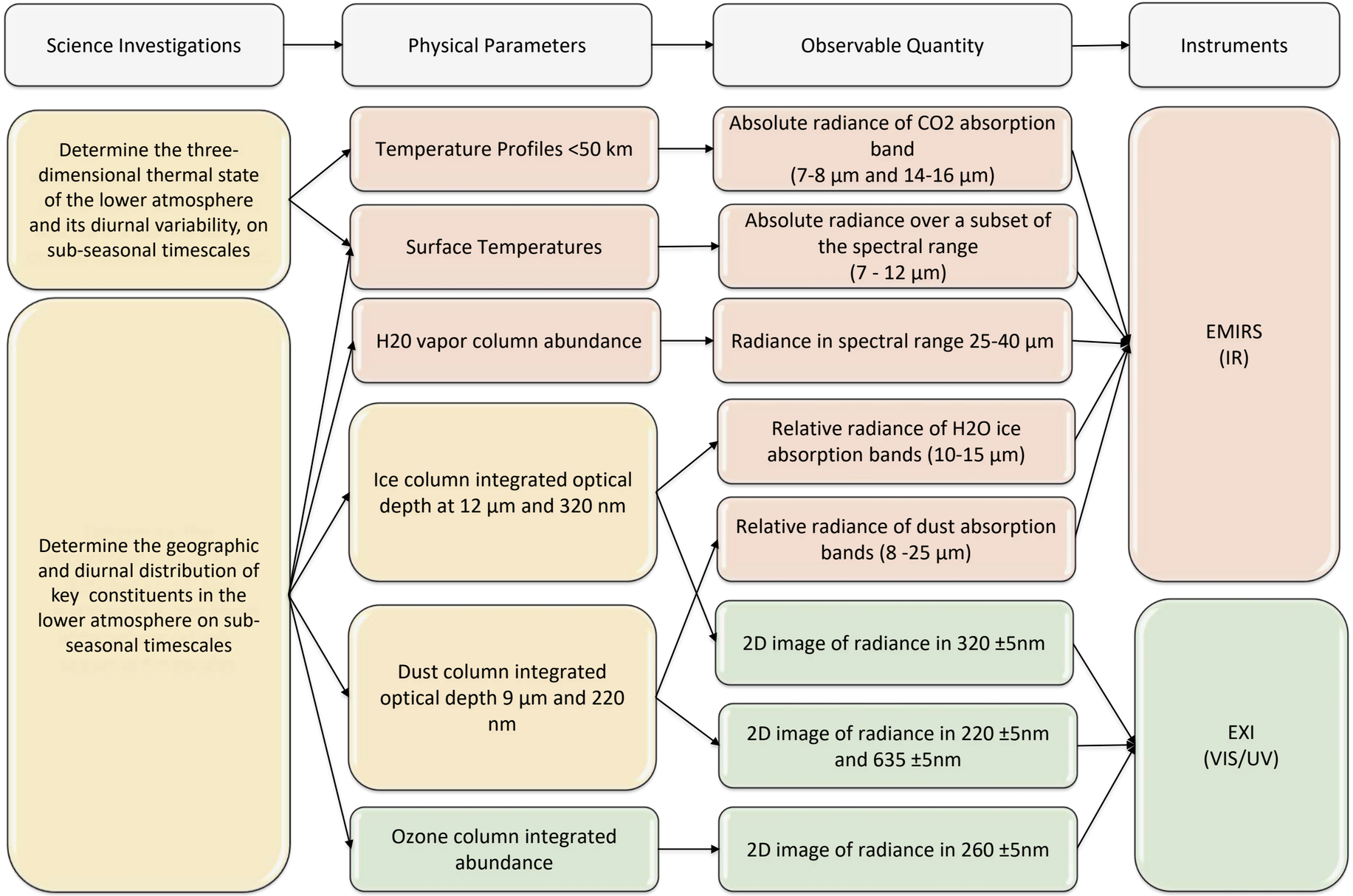
EMM is a mission focused on atmospheric dynamics.
It will explore the atmosphere of Mars **globally**
while sampling both **diurnal** and **seasonal** timescales.

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

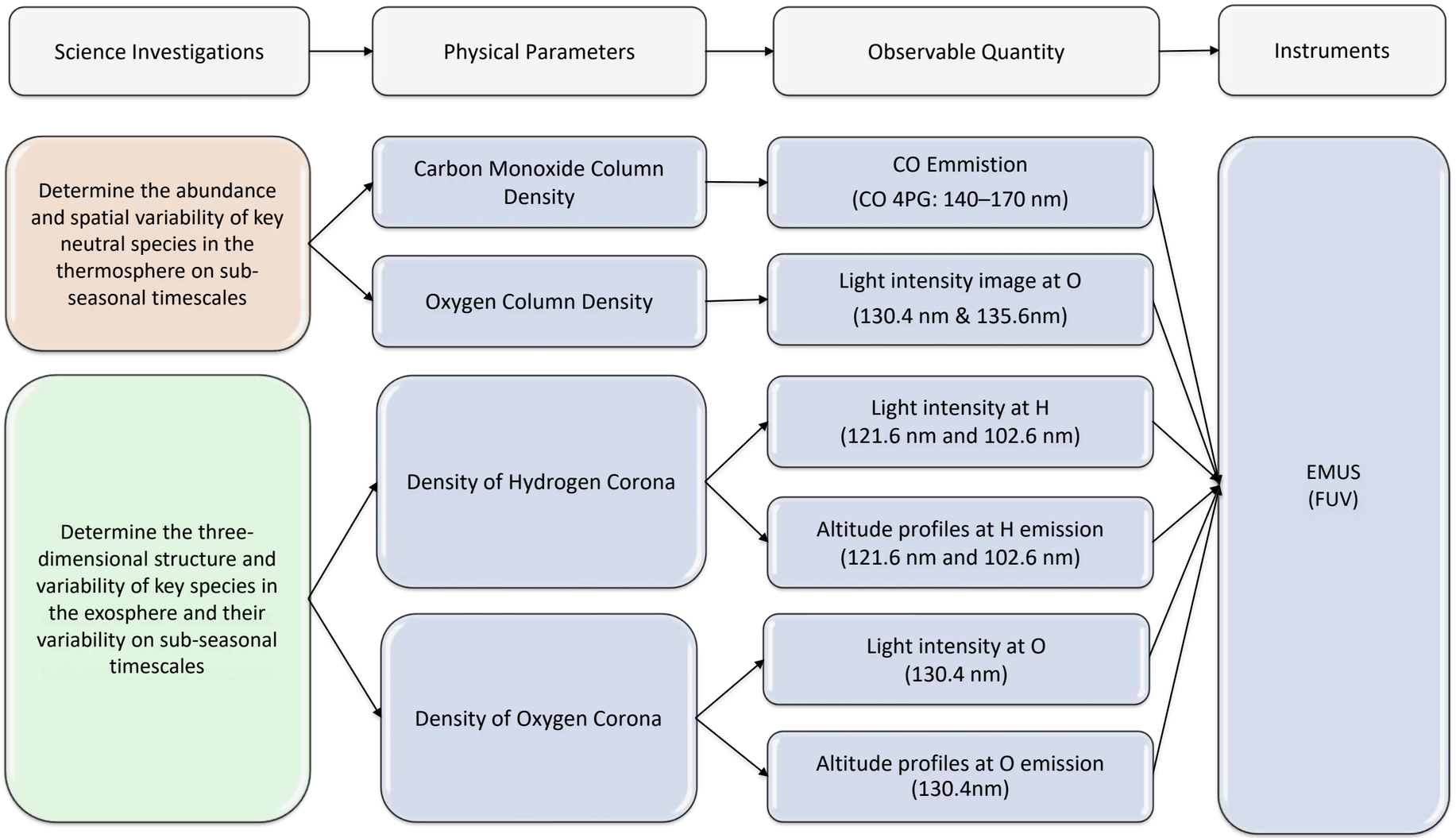
Science Flow



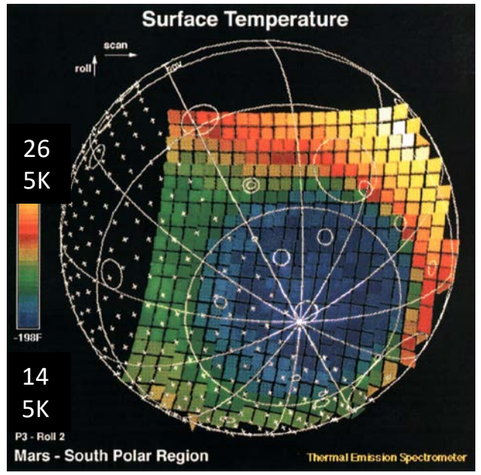
Investigations 1 & 2

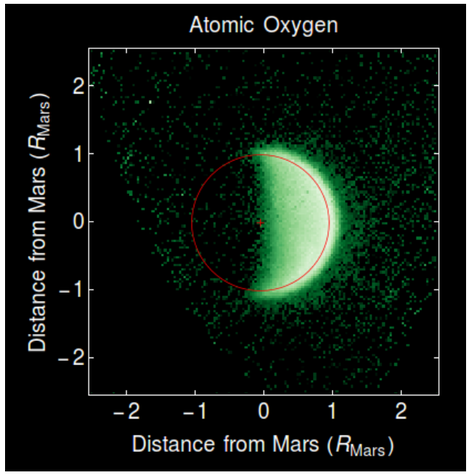


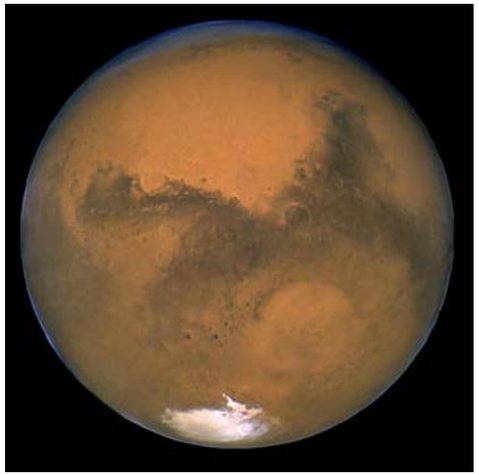
Investigations 3 & 4



EMM Instruments

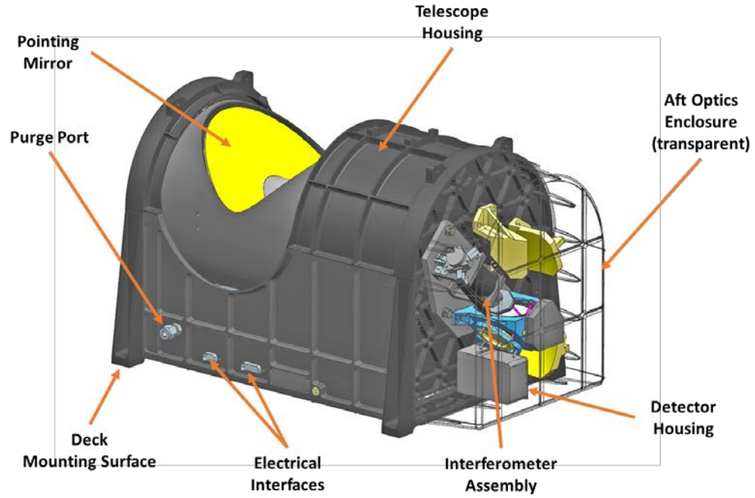






EMIRS (ASU/MBRSC)	EMUS (LASP/MBRSC)	EXI (LASP/MBRSC)
Fourier Transform IR Spectrometer	Ultra Violet Imaging Spectrograph	Imager with 12 MP camera with 6 bandpass filters (VIS/UV)

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 9 interferograms every 4 seconds
  - Space and internal blackbody provide 1.5% absolute calibration
  - Electronics compress and packetize science and housekeeping data

Instrument Specifications

Specification	
Instantaneous Field of view	6 mrad
Spectral Resolution	5 cm-1
Spectral Range	6-40+ µm
Spatial Resolution	<300 km resolution
Observation Capability	Observe ½ of Mars within ½ hour of observing ~60 observations per week (~20/orbit)

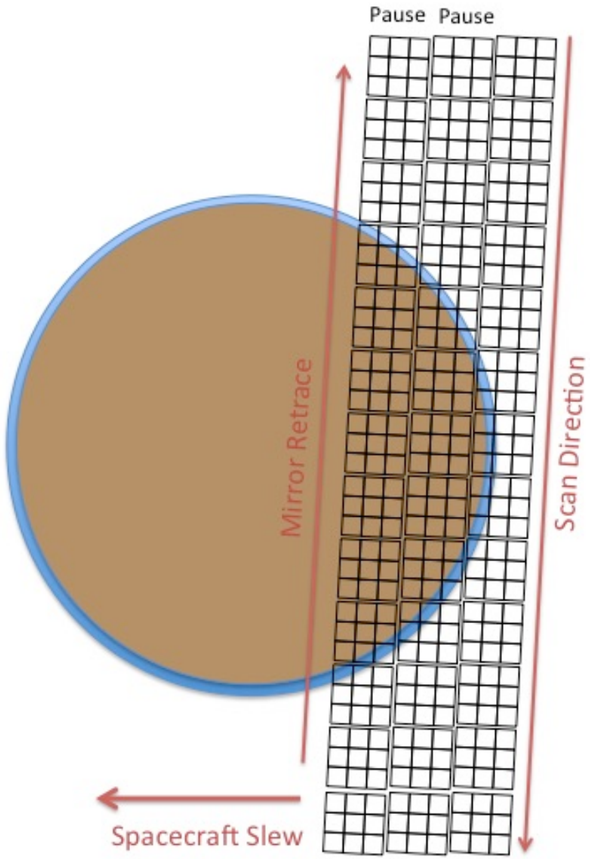
Science Targets

Measurement Required	Science Need
Relative radiance of dust absorption bands	To characterize dust.
Relative radiance of ice absorption bands	To characterize water ice clouds.
Relative radiance of H_2O vapor absorption bands	To track the Martian water cycle.
Absolute radiance of CO_2 absorption band	Track the thermal state of the Martian atmosphere.
Radiance at 1300 cm^{-1}	Boundary condition for the lower atmosphere.

EMIRS Observation Summary and Data

- The EMIRS Instrument has only one observation strategy.
  - It is done 20 times per orbit in the nominal science orbit.
  - The observation will be with EMIRS boresight controlled to within 1 degree.
  - The spacecraft will begin a single axis slew across the disk, maintaining a constant slew rate according to either the smear limit requirement .

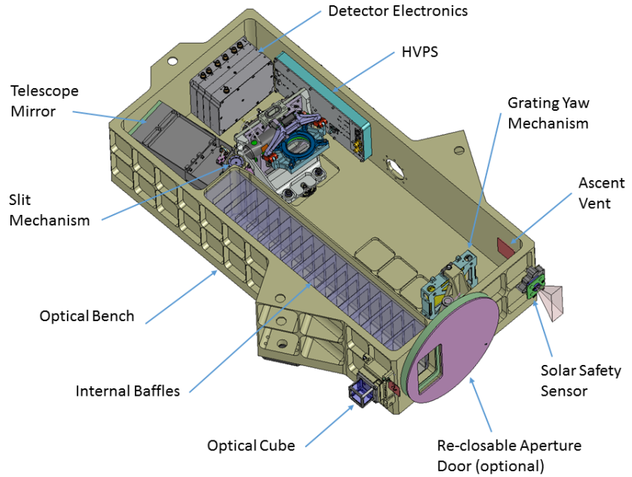
Observing Strategies	Degree
S/C Slew Across Disk:	10.4º – 18.7º based on altitude
Instrument Scan:	15.6º – 23.9º based on altitude
Effective Scan Rate:	1.3º FOV takes 4 sec acquisition
Slew Rate:	≤ 0.94º/min (0.0156º/s) from periapsis to TBD altitude (scan driven) ≤ TBDº/sec above TBD altitude (smear driven)
Observation Duration:	~20 min at Periapsis; ~8 min at Apoapsis



EMIRS Data Completeness

EMIRS Coverage Requirement	
Diurnal Requirement	In any given **span of 10 days**, the 8 three-hour intervals **defining a complete diurnal cycle are sampled with at least 80% coverage of longitudes in**: ≥ 6 of 8 local time intervals for all latitudes equatorward of ±30°, ≥ 4 of 8 local time intervals for all latitudes equatorward of ±50°. In any given span of 10 days, at least one of the 8 three-hour intervals defining a complete diurnal cycle is sampled with at least 50% coverage of longitudes for **all latitudes equatorward of ±80°.**
Geographic Requirement	**≥ 80% of the geographic area of Mars (regardless of local time) sampled more frequently than every 72 hours.** Latitudes equatorward of ±80° sampled more frequently than every 72 hours.
Seasonal Requirement	Observations over **1 full Martian yea**r (Goal: 20 of the 24 15° intervals of LS sampled).

EMUS



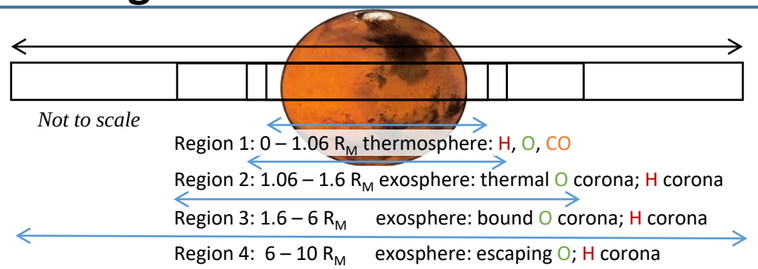
Instrument Description

- 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).

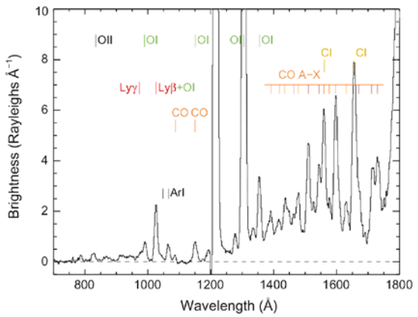
Instrument Specifications

Specification	
Field of view	(0.18° , 0.25° , 0.7°) × 11.0°
Wavelength range	100 – 170 nm
Spectral resolution	1.3, 1.8, 5 nm
Spatial resolution with narrow slit	0.14° × 0.20°
Detector photocathode	CsI

Science Targets



Targets	Wavelength
H	102.6, 121.6 nm
O	130.4, 135.6 nm
CO 4PG	140-170 nm



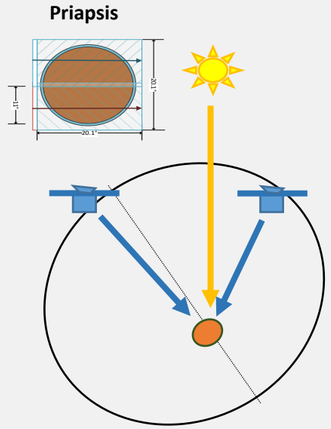
FUV spectrum of Mars
[Feldman. Icarus 214.2 (2011): 394-399]

EMUS Observation Summary and Data

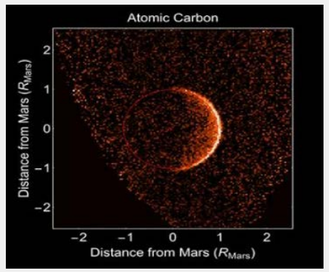
Thermosphere

U-OS1: Raster scanned images of the disk of Mars

Thermospheric Emissions



R1, 1.3nm slit

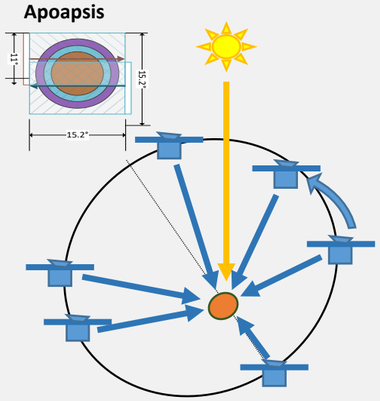


At least 2 times per orbit in one orbit per week

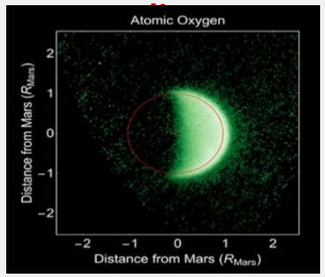
Corona

U-OS2: Raster scanned images of the disk and the inner corona of Mars

H and O corona



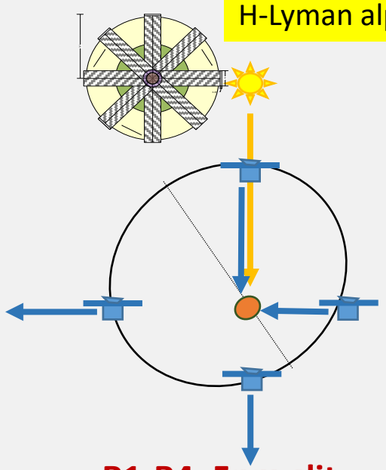
R1-R2, 1.8nm



At least 6 times in one orbit per week

U-OS3: Spacecraft will slew out to ±50 degrees in an asterisk pattern performed in 4 swaths

H-Lyman alpha



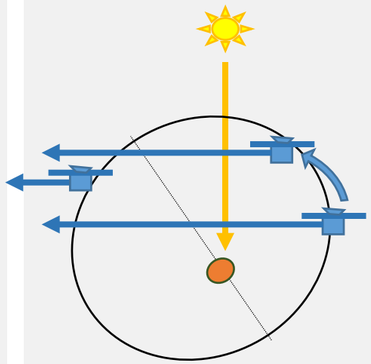
R1-R4, 5nm slit

At least 4 times in one orbit every other week

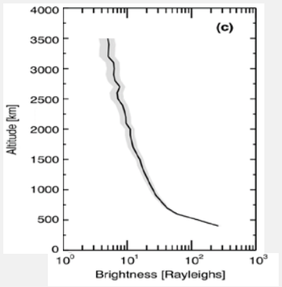
Strafe

U-OS4: Long exposure times for mid and outer corona when instrument is not imagining / during charging

H and O corona



R2-R4, 1.8nm

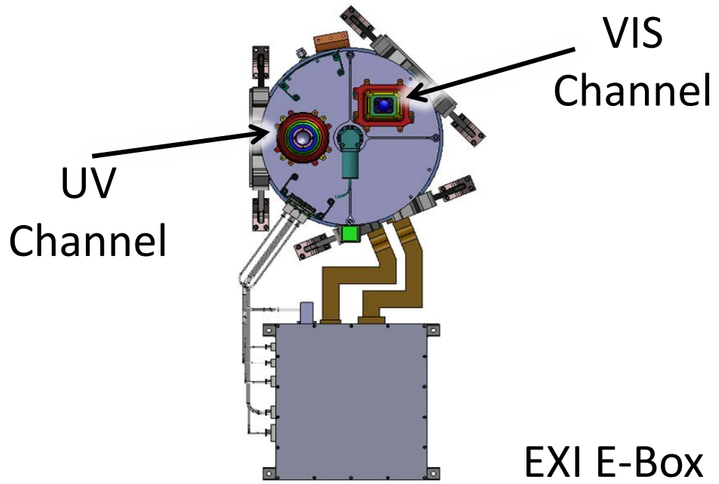


Observe lines of sight in each 500km bin in one orbit per month

EMUS Data Completeness

Data Sets:	Standard Cadence	High Cadence
Thermospheric Measurements:	At least 6 images (OS1) taken on the dayside within 1 orbit (56 hours)	At least 12 images (OS1 or OS2) taken on the dayside within 1 orbit (56 hours)
Coronal Measurements:	At least 5 images (OS2) taken within 1 orbit At least 4 images (2 coronal, 2 background) (OS3) taken within 1 orbit	
Cadence:	At least 1 image set taken per week (3 orbits) (For OS3, at least 1 image set taken every other week)	
Seasonal Coverage:	At least 20 times per Martian year	At least 7 times per Martian year
Coronal Strafe:	Two profiles (1 coronal, 1 background) (OS4) from 1.06 to ≥ 6 Mars radii taken at least once per month	

EXI



Instrument Description

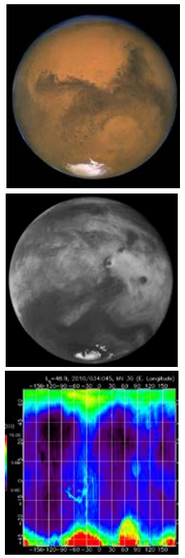
- 12 Mpix CMOS Imager with re-closeable door and filter wheel
- 6 filter band-passes
  - UV1: 220±5 nm CW, ≤30 nm FWHM
  - UV2: 260±5 nm CW, ≤30 nm FWHM
  - UV3: 320±5 nm CW, ≤30 nm FWHM
  - Blue: 437±5 nm CW, ≤20 nm FWHM
  - Green: 546±5 nm CW, ≤20 nm FWHM
  - Red: 635±5 nm CW, ≤20 nm FWHM

Instrument Specifications

Specification	UV	VIS
Focal Plane Format	12.6 MP 4:3 format 4096x3072 @5.5 um	
Technology	CMOS	
Dynamic Range	12-bit, 13,500 e full well	
Lens System	48 mm, f/3.6	51 mm, f/4.25
Field of View	19.0°	25.8° by 19.2°
Pixel Angular View	23 arcsec per pixel	22 arcsec per pixel
Plate Scale	0.85 mm/°	0.9 mm/°
Distortion @9.35°	+6%	-2%
Ground coverage at apoapsis and priapsis	Full Disk	
Ground resolution at apoapsis / priapsis	4.9 /2.3 km per pixel	4.6 / 2.2 km per pixel
Filter Spectral Bands	UV1: 205-235 nm UV2: 245-275 nm UV3: 305-335nm	Blue: 427-447 nm Green: 536-556 nm Red: 625-645 nm

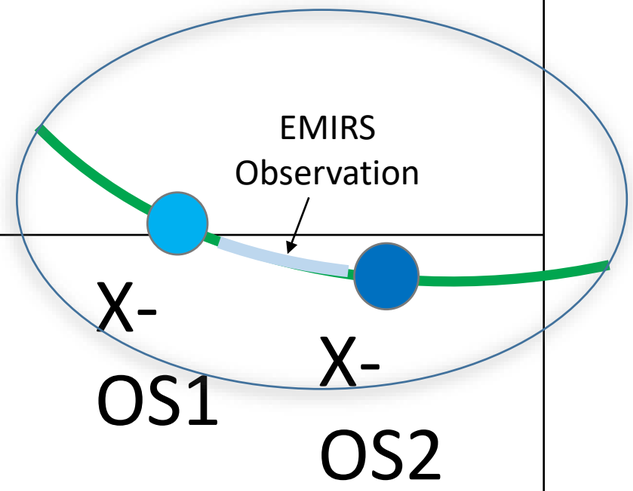
Science Targets

Science Product	Spatial Resolution	Image Wavelengths
Dust Column-integrated optical Depth	≤ 10 km	220 and 635 nm
Water Ice cloud Column- integrated optical depth	≤ 10 km	320 nm
Ozone Column-integrated abundance	≤ 10 km	260 nm
Color images of Mars	≤ 10 km	437, 546, and 635 nm



EXI Observation Summary and Data

Observation Strategy	Observation Strategy Set
X-OS1 (science)	4 Contemporaneous images • 220nm, 260nm, 320nm, 635nm • Incident<80°; emergence<70° • 2x2 pixel binning (≤0.19 mrad spatial resolution) 2 dark images (for each detector)
X-OS2 (science)	4 Contemporaneous images • 220nm, 260nm, 320nm, 635nm • Incident<80°; emergence<70° (≤0.49 mrad spatial resolution) 2 dark images (for each detector)
X-OS3 (PR)	3 Contemporaneous visible images • 437nm, 546nm, 635nm • Full resolution (≤0.11 mrad spatial resolution



EXI Data Completeness

EXI Coverage Requirement	
Diurnal requirement	In any given **span of 10 days**, the 4 three-hour intervals **spanning 6am-6pm local time** are sampled with at **least 80% coverage of longitude** in: ≥ 3 local time intervals for all latitude equatorward of ±30° ≥ 2 local time intervals for all latitude equatorward of ±50° In any given span of 10 days, at least one in the 4 three-hour intervals spanning 6am-6pm local time is sample with at least 50% coverage of the longitudes for all latitude equatorward of ±80°
Geographic requirement	**≥ 80% of the geographic area** of Mars sampled more frequently than **every 72 hours.** Latitude ≤80° sampled more frequently than every 72 hours.
Seasonal requirement	Observations over **1 full Martian year** (Goal: 20 of the 24 15° intervals of L_s sampled)

EMM Data Assimilation

- Plan to apply the LMD-LETKF scheme to the thermal observations to provide a 4D climatology (reanalysis) of the Martian atmosphere:
  - Temperature
  - dust
  - water ice
- Water vapor and ozone could also be assimilated with a realistic model and it could in theory be possible to perform data assimilation of thermospheric data.
- Ultimately EMM datasets will be made available to the community and usable by different teams and with different schemes.

Scientific Value of EMM

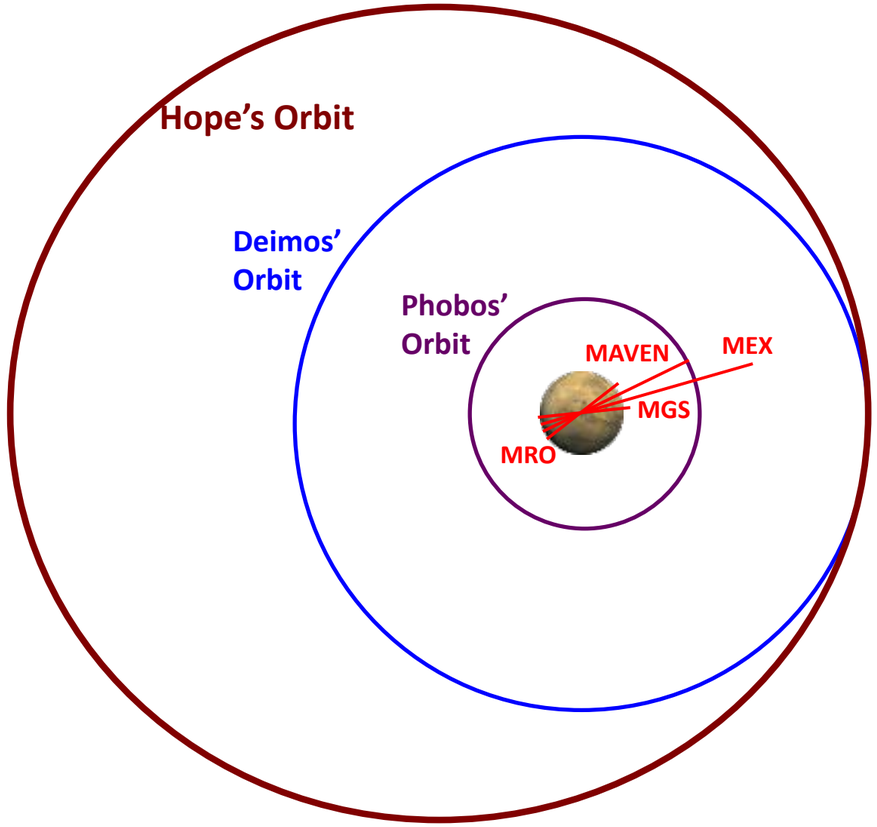
- Uniqueness of EMM Measurements
  - Many Mars missions measure(d) the atmosphere
  - Only EMM will have the combination of global geographic and local time coverage on diurnal and sub-seasonal timescales to allow detailed assessment of atmospheric circulation and transport

Scientific Topic	Geographic Coverage	Seasonal Coverage	Full diurnal coverage on sub-seasonal timescales
Inner Hydrogen exosphere	N/A		
Outer Hydrogen exosphere	N/A		
Bound O exosphere	N/A		
Escaping O exosphere	N/A		
Thermosphere O, C, CO			
Dust abundance			
Ice abundance			
Water vapor			
Atmosphere temperature profiles			
Surface temperature			

Emirates Mars Mission	Mars Global Surveyor (NASA)	Mars Odyssey (NASA)	MAVEN (NASA)	Mars Reconn. Orbiter (NASA)	Mars Express (ESA)

Science Orbit

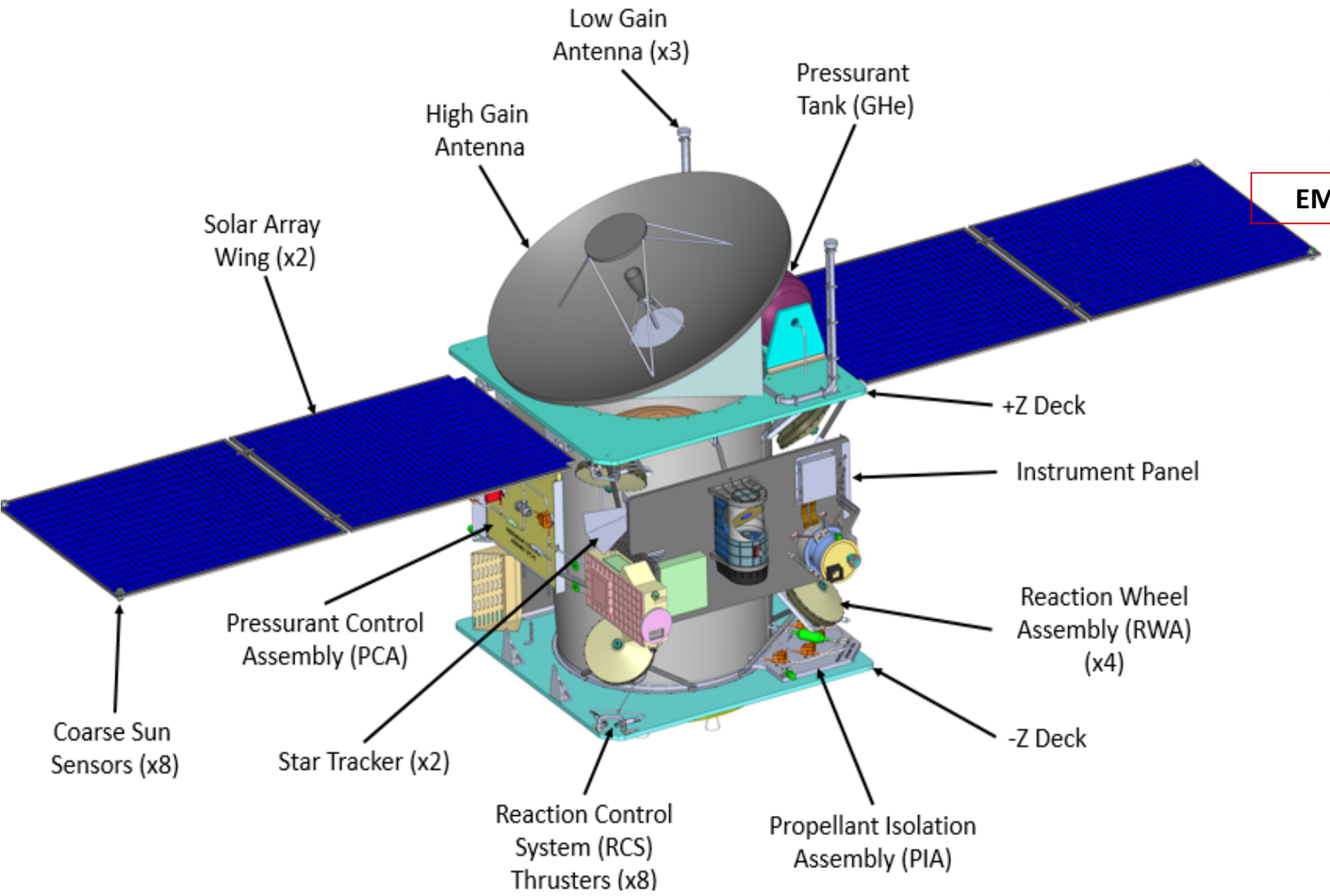
- No spacecraft has flown an orbit like it. Further, it is low-risk, simple to fly, and produces excellent opportunities to collect EMM's science.

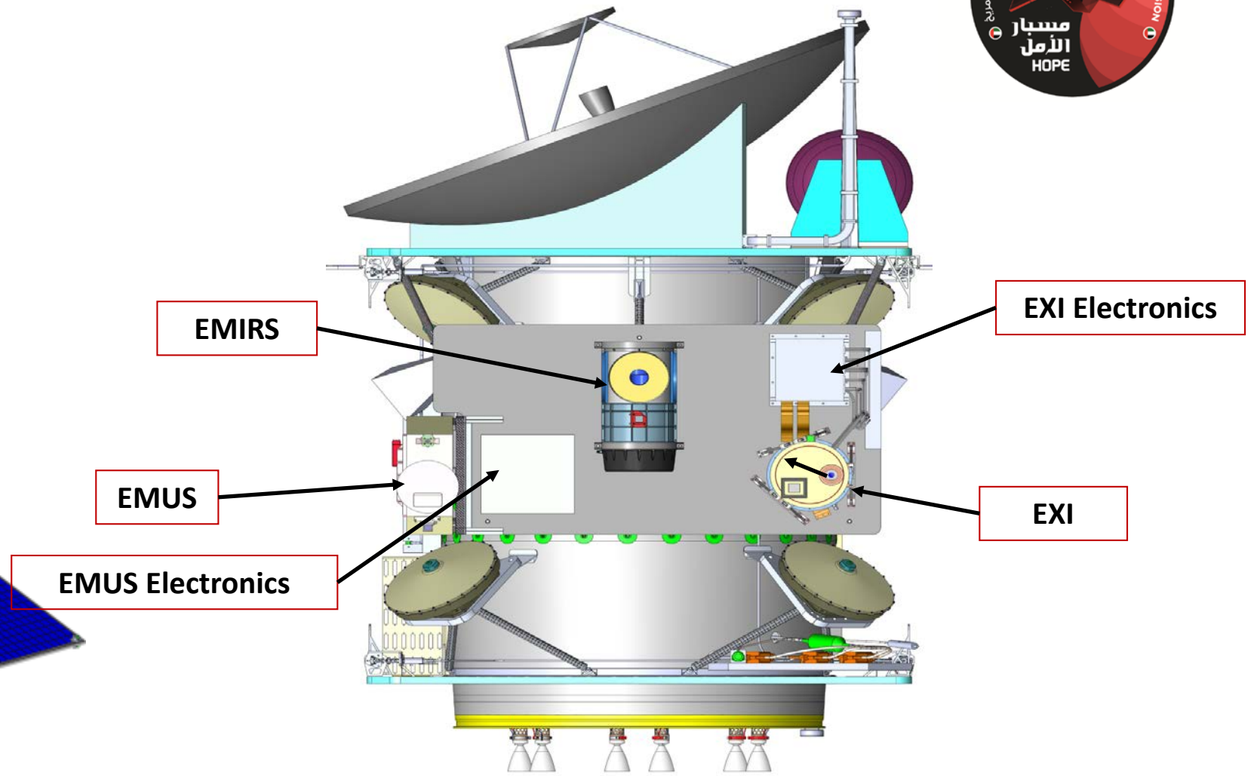


Key Features:

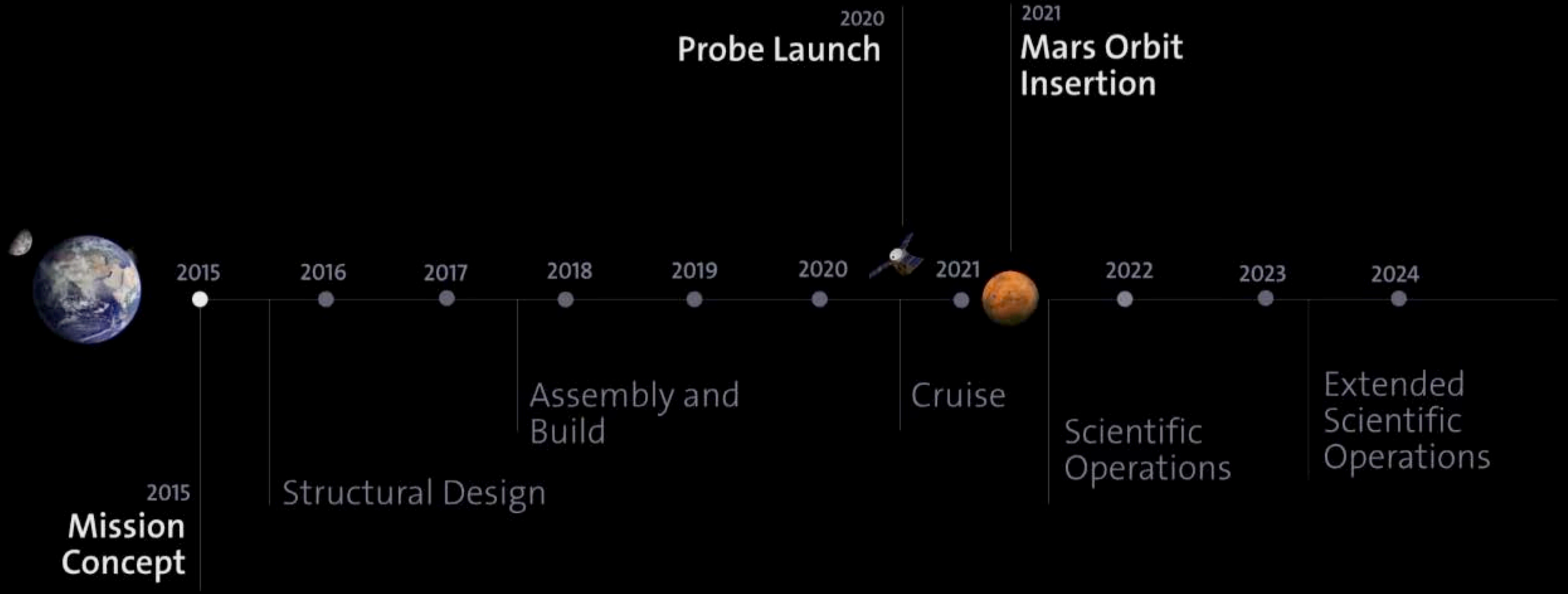
- Periapse altitude: 20,000 km
- Apoapse altitude: 43,000 km
- Orbital period: 55 hours
  3 orbits per week
  ~2.24 sols
- Inclination: 25 deg
- Periapse placed near equator:
  AOP: 177 deg
- Primary science collection
  starts ~May 2021

Spacecraft – Hope Probe



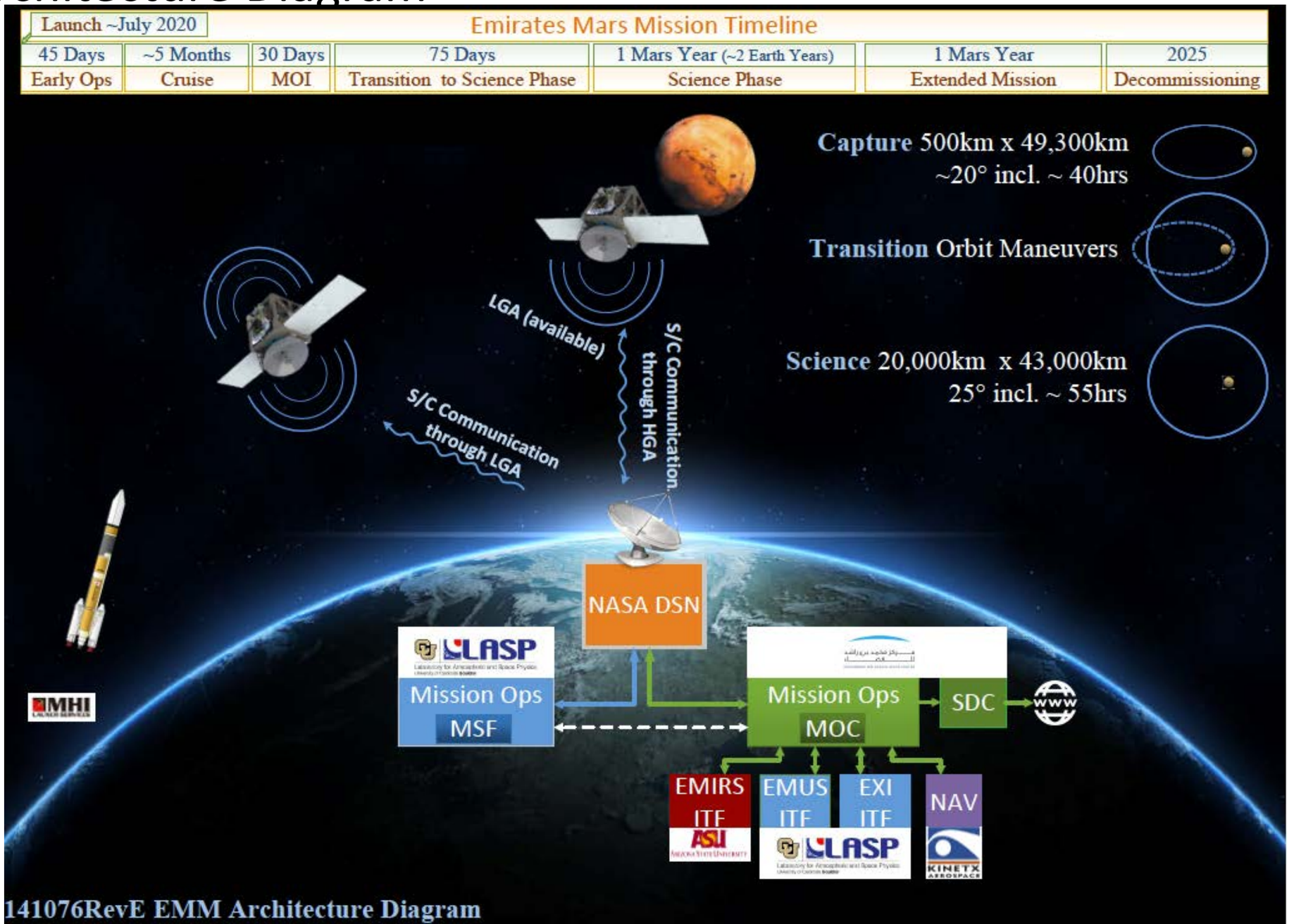


Technical Specifications	
S/C Dimension	3m x 7.9m
Wet Mass	1500kg
RF Band	X Band
Power Requirement	477 W
Propulsion Type	Monopropellant Hydrazine System



Days Until Launch (July 14, 2020): 686

Mission Architecture Diagram



Thank you!

Scientific Value of EMM

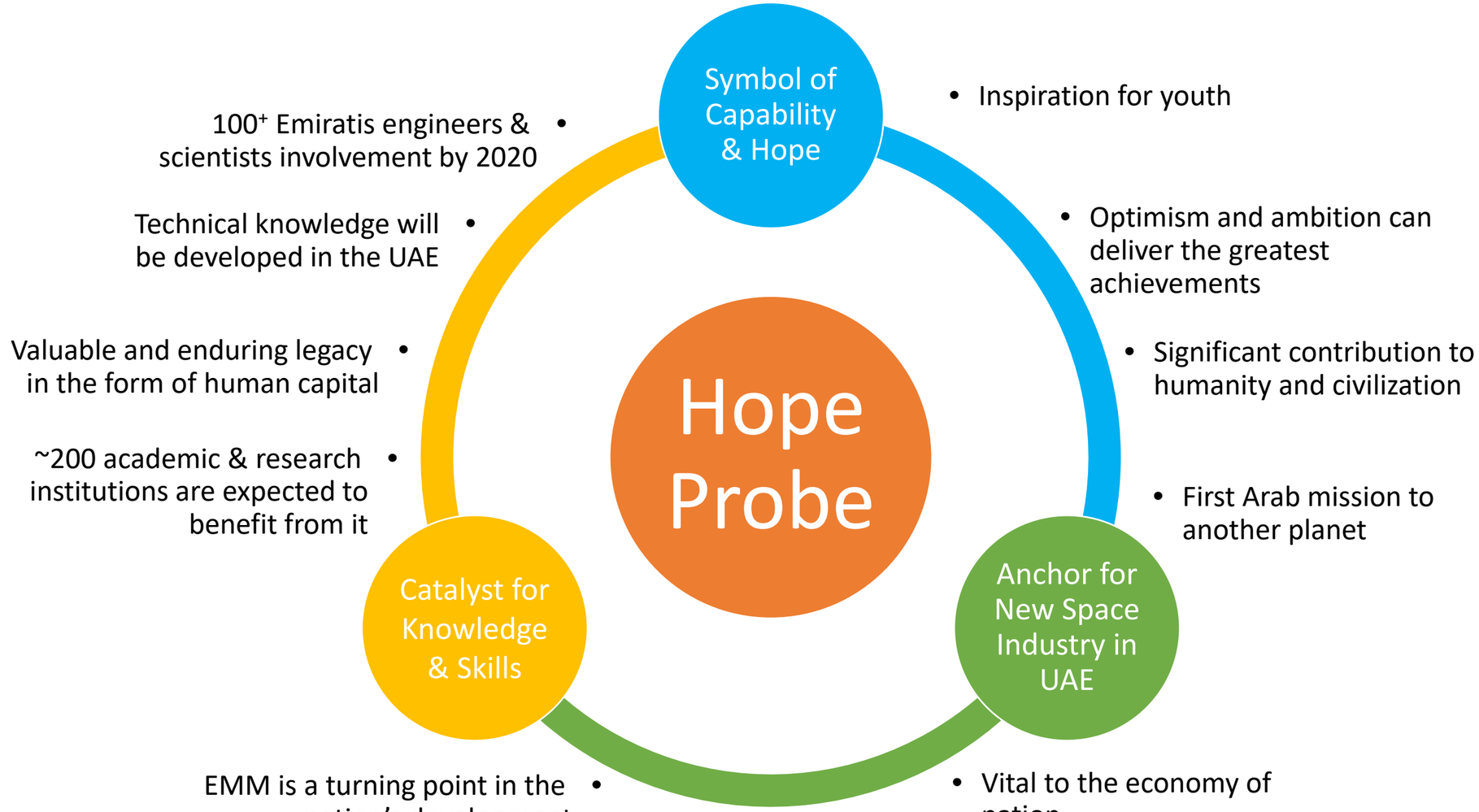
- Goals of the Scientific Community
  - The Mars Exploration Program Advisory Group releases a goals document periodically representing the priorities of the Mars science community.
  - EMM objectives and investigations map directly to MEPAG objectives and investigations.

EMM Investigation	**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.**
MEPAG Investigation	**A1.1: Measure the state and variability of the lower atmosphere from turbulent scales to global scales.**	**A1.2: Characterize dust, water vapor and clouds in the lower atmosphere.**	**A2.1: Measure the spatial distribution of aerosols, neutral species, and ionized species in the upper atmosphere.**	**C3.1: Measure spatial and temporal variations in the escape rates of key species.**
MEPAG Sub Objective	A1: Constrain the processes that control the present distributions of dust, water and carbon dioxide in the lower atmosphere, at daily, seasonal and multiannual timescales.		A2: Constrain the processes that control the dynamics and thermal structure of the upper atmosphere and surrounding plasma environment.	C3: Determine present escape rates of key species and constrain the processes that control them.
MEPAG Objective	A. Characterize the state of the present climate of Mars' atmosphere and surrounding plasma environment, and the underlying processes, under the current orbital configuration.			C. Characterize Mars' ancient climate and underlying processes.
MEPAG Goal	II. Understand the process and history of climate on Mars.			

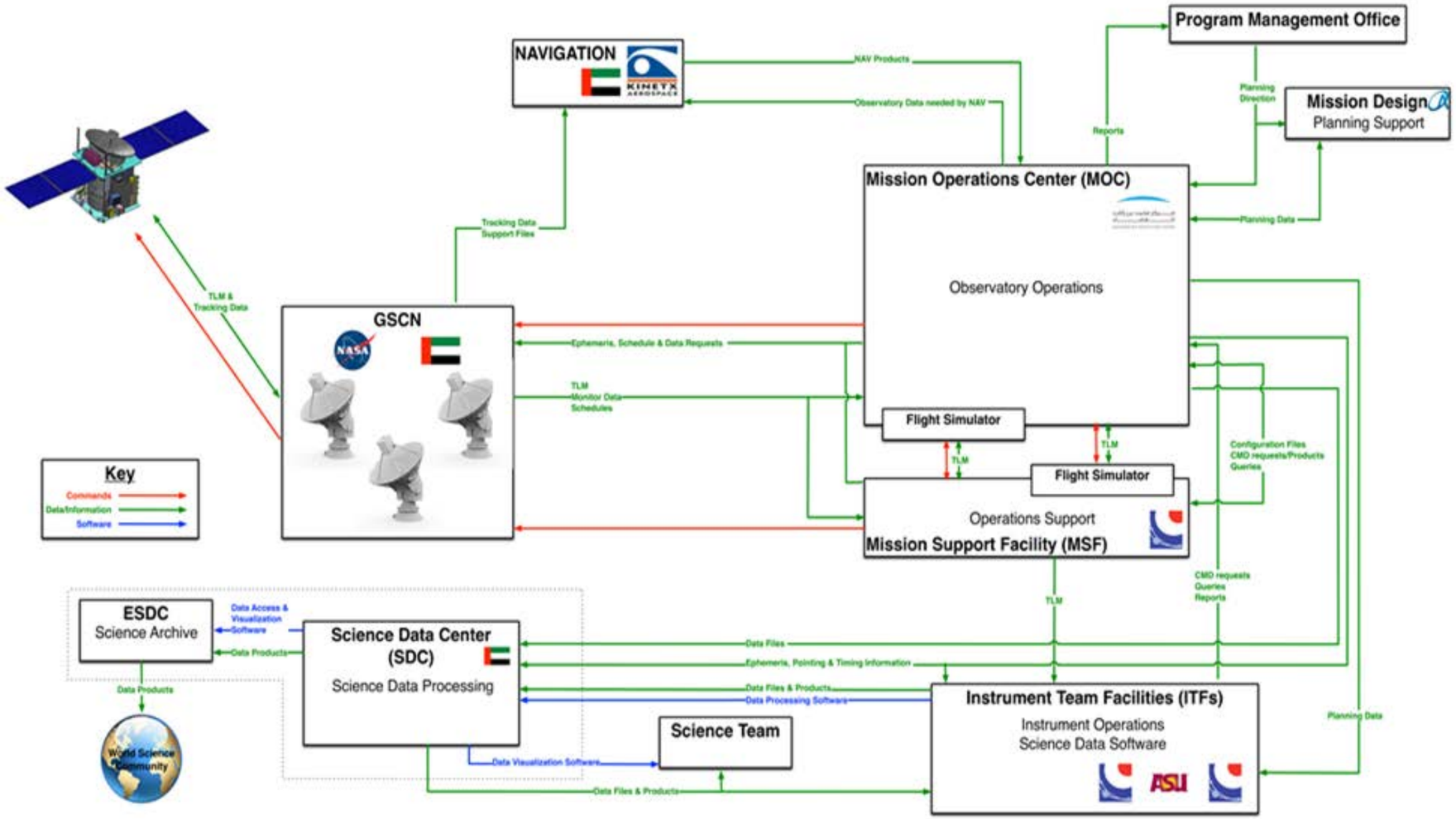
Instrument Data Completeness

Coverage Requirement	
Diurnal Requirement	In any given **span of 10 days**, defining a **complete diurnal cycle** (EXI: spanning 6am-6pm local time) are sampled with at least **80% coverage of longitudes** and all **latitudes equatorward of ±80°.**
Geographic Requirement	**≥ 80% of the geographic area of Mars (regardless of local time) sampled more frequently than every 72 hours.** Latitudes equatorward of ±80° sampled more frequently than every 72 hours.
Seasonal Requirement	Observations over **1 full Martian year** (Goal: 20 of the 24 15° intervals of LS sampled).

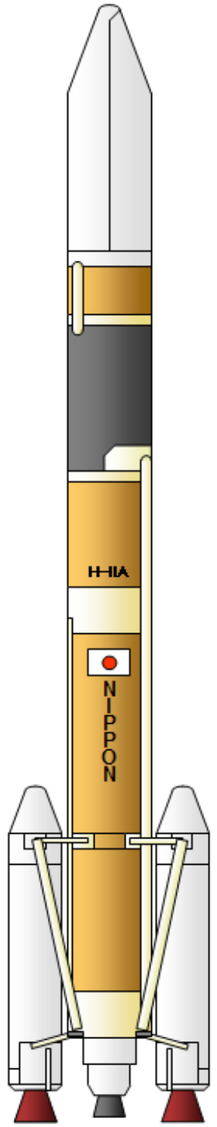
Emirates Mars Mission - Hope



EMM Ground Segment



EMM Launch Segment



- Mitsubishi Heavy Industries, LTD (MHI) H-IIA launch vehicle
- Tanegashima Space Center, Yoshinobu Launch Complex

Launch scheduled for summer 2020