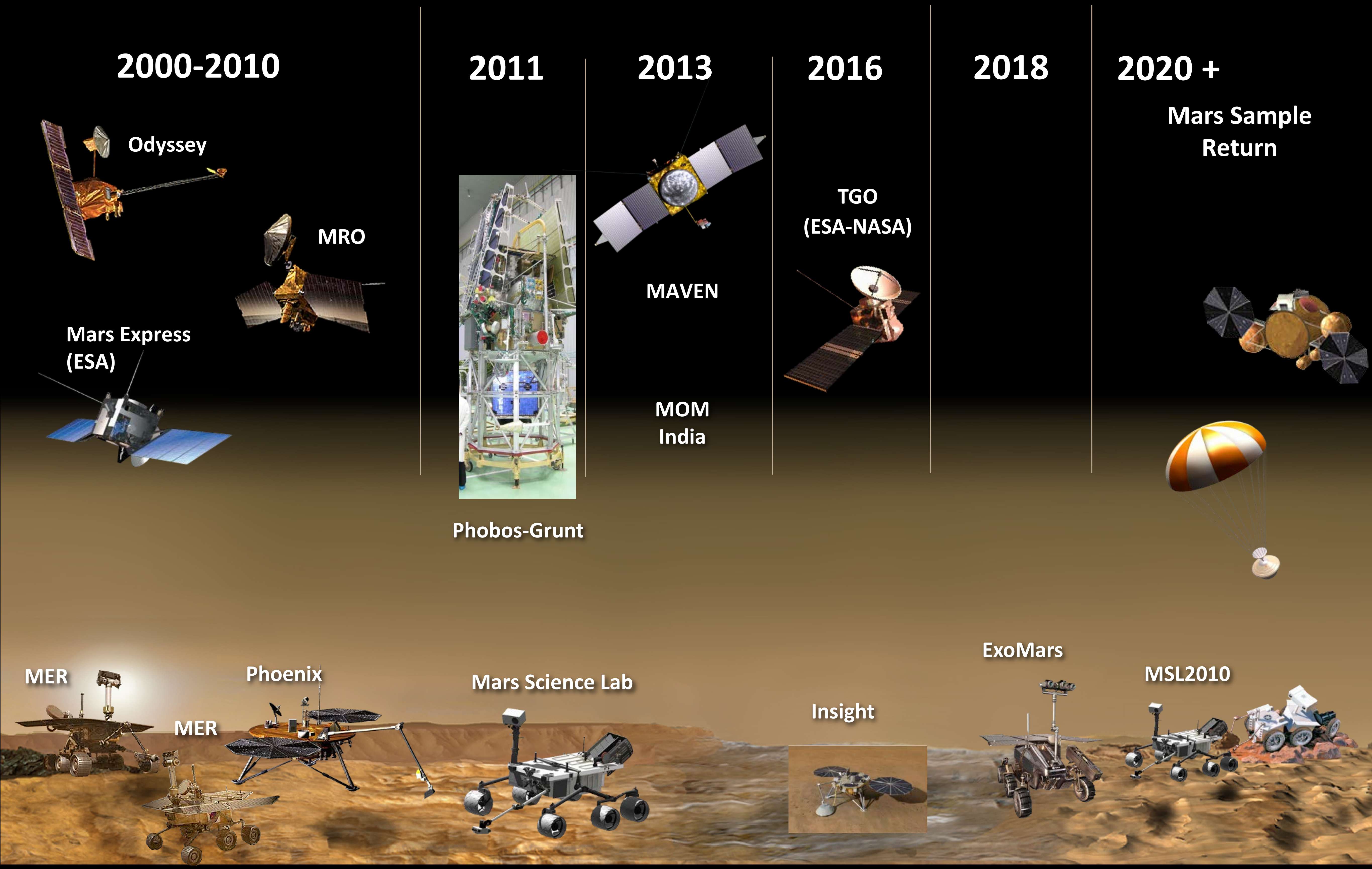
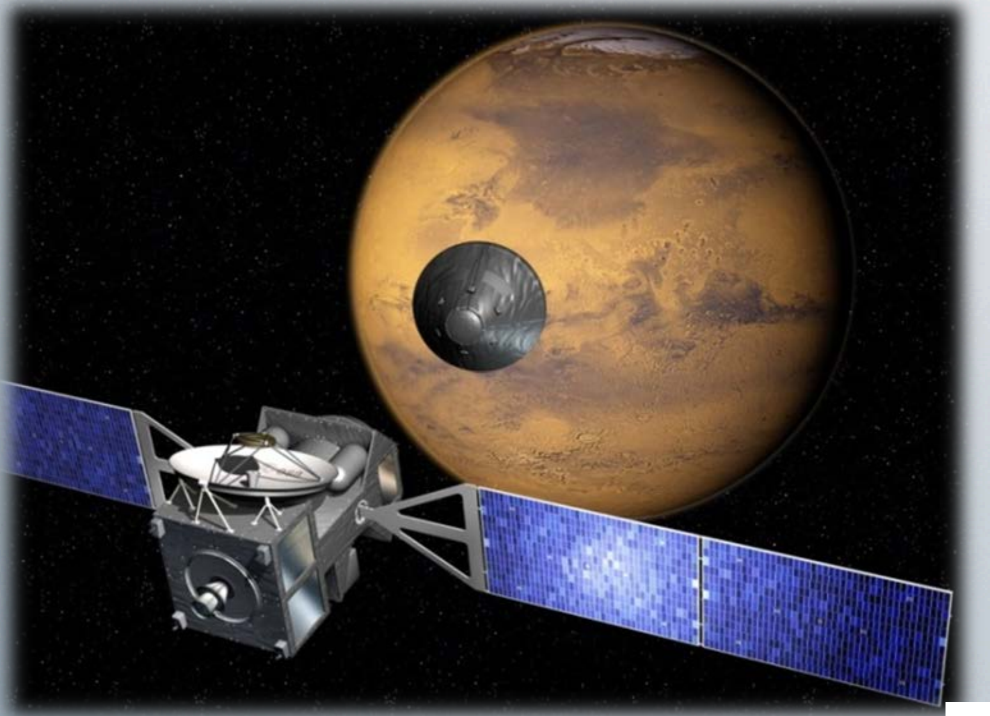
The ExoMars Programme

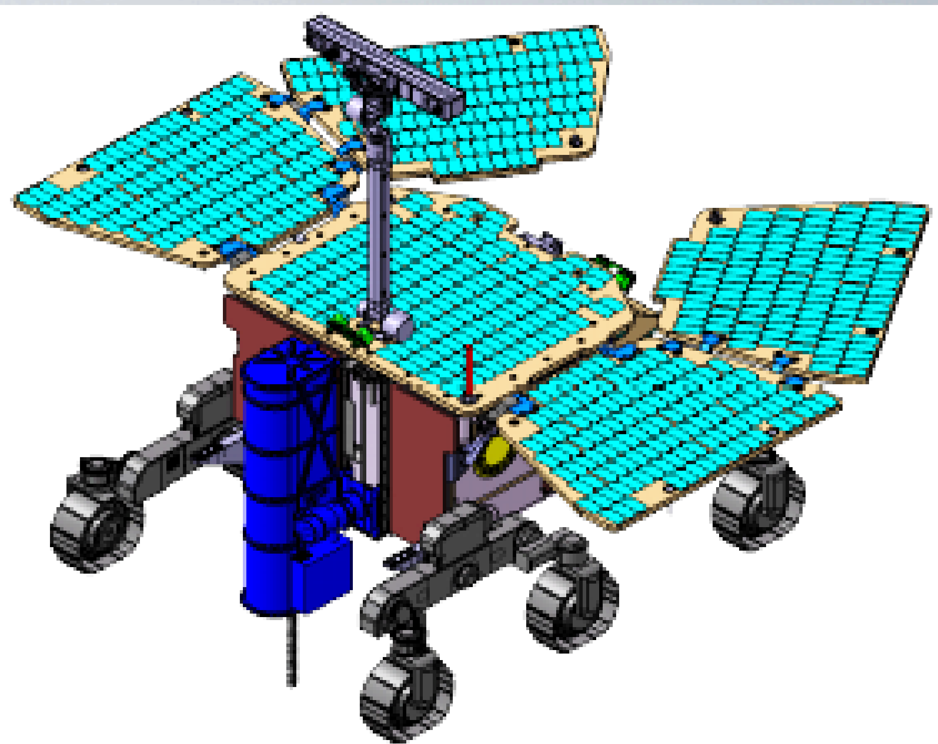
O. Witasse, J. L. Vago, and D. Rodionov

June 2014

ESTEC, NOORDWIJK, THE NETHERLANDS


2000-2010
2011
2013
2016
2018
2020 +
Odyssey
MRO
Mars Express
(ESA)
Phobos-Grunt
MAVEN
MOM
India
TGO
(ESA-NASA)
Mars Sample
Return
MER
MER
Phoenix
Mars Science Lab
Insight
ExoMars
MSL2010





Cooperation

esa

РОСКОСМОС

ExoMars Programme Objectives

1. Technology Demonstration

2. Science

3. Relay orbiter

ExoMars Programme Objectives

- **Technology Demonstration Objectives**
  - Entry, Descent and Landing (EDL) on the Mars' surface
  - Mobility on Mars surface (several kilometres)
  - Access to Mars sub-surface (2 metres)

- **Scientific Objectives**
  - To search for signs of past and present life on Mars
  - To characterise the water/geochemical environment as a function of depth in the shallow subsurface
  - To study the surface environment and identify hazards to future human missions
  - Atmosphere characterisation – Trace Gas detection

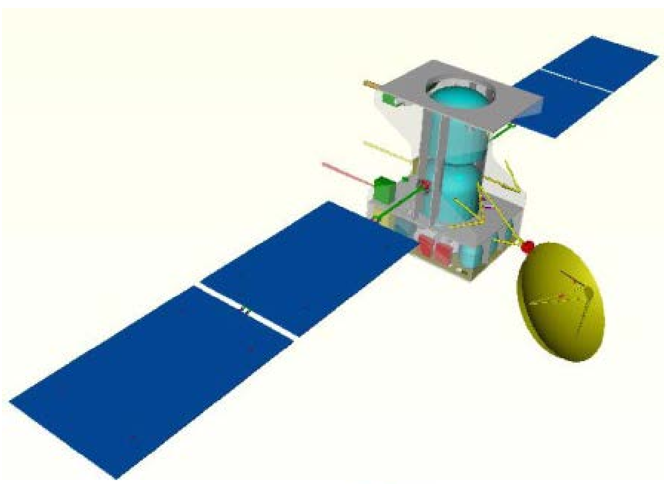
- **Programmatic Objective**
  - Provide link communication to Mars landed surface assets

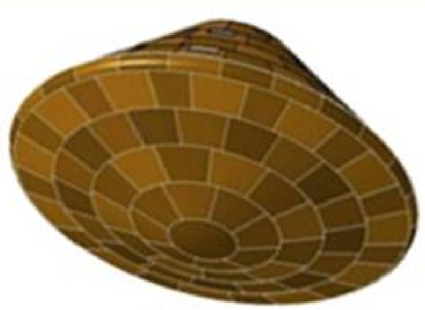
Programme Overview

- ***Two missions launched in 2016 and 2018, respectively***
  - The 2016 flight segment consists of a **Trace Gas Orbiter (TGO)** and an **EDL Demonstrator Module (EDM)**
  - The 2018 flight segment consists of a **Carrier Module (CM)** and a **Descent Module (DM)** with a **Rover** and a stationary **Landing Platform**

2016 Mission

Trace Gas Orbiter (TGO)





EDL Demonstrator Module (EDM)

Proton M/Breeze M

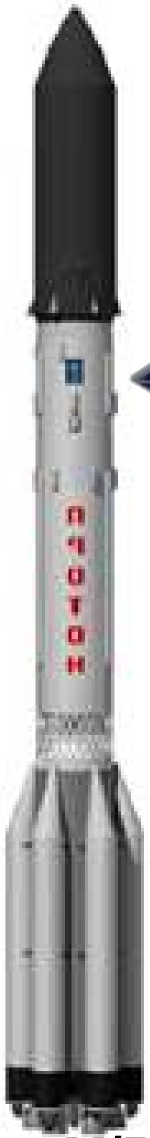
&

ESA ESTRACK

Roscosmos Ground Segment Antennas

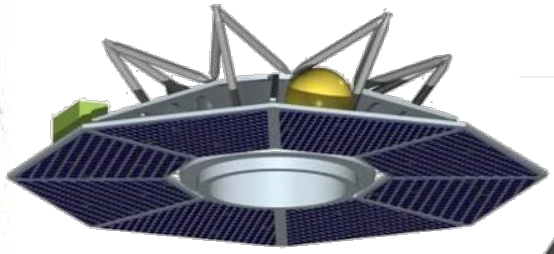
NASA DSN

2018 Mission

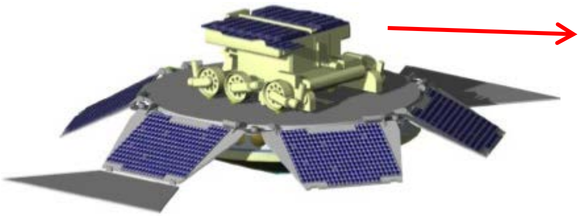


Proton M/Breeze M

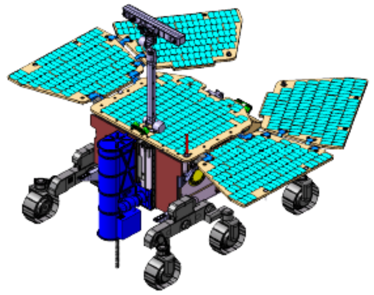
Carrier Module (CM)



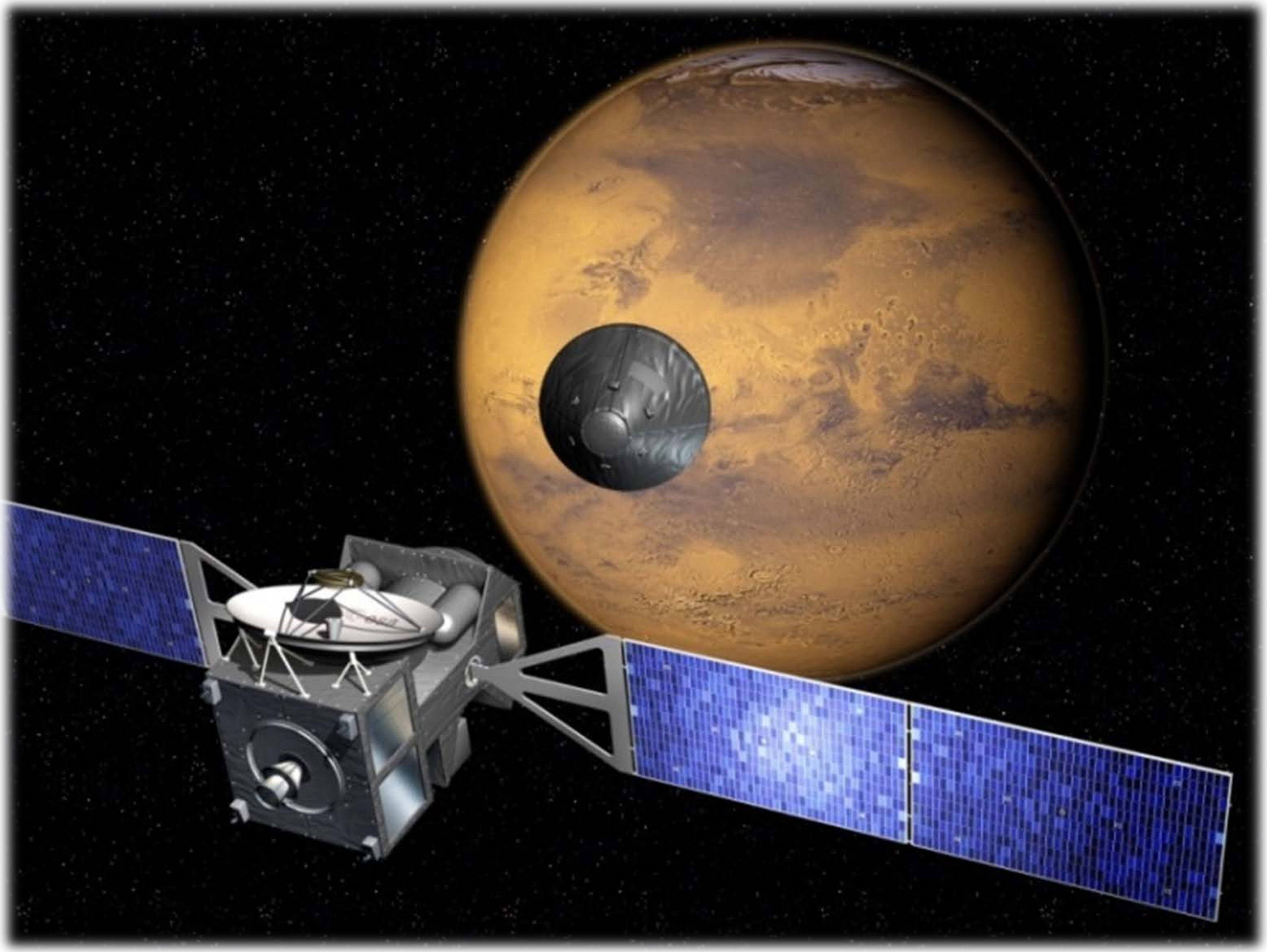
Descent Module (DM)



Landing Platform



Rover



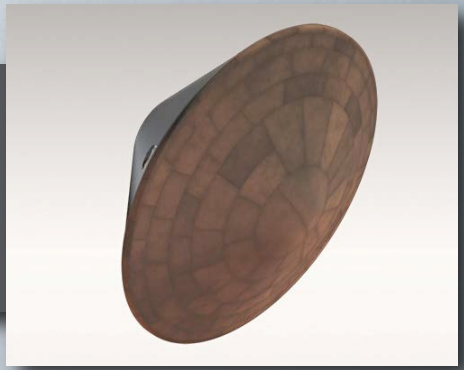
2016 Mission Objectives

EXOMARS

2016

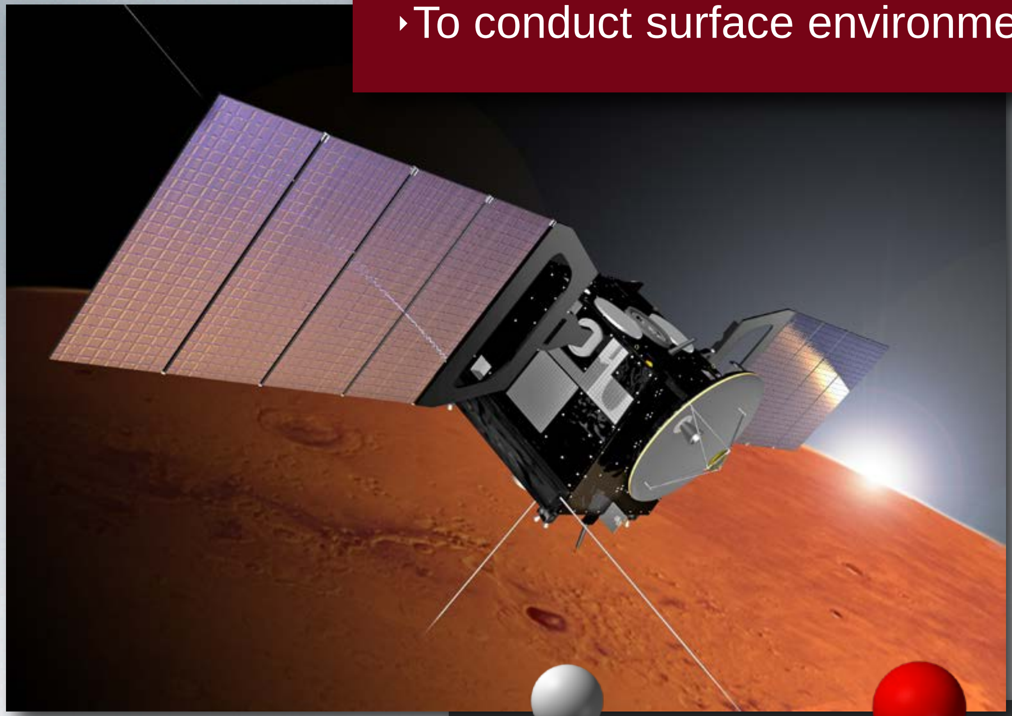
TECHNOLOGY OBJECTIVE

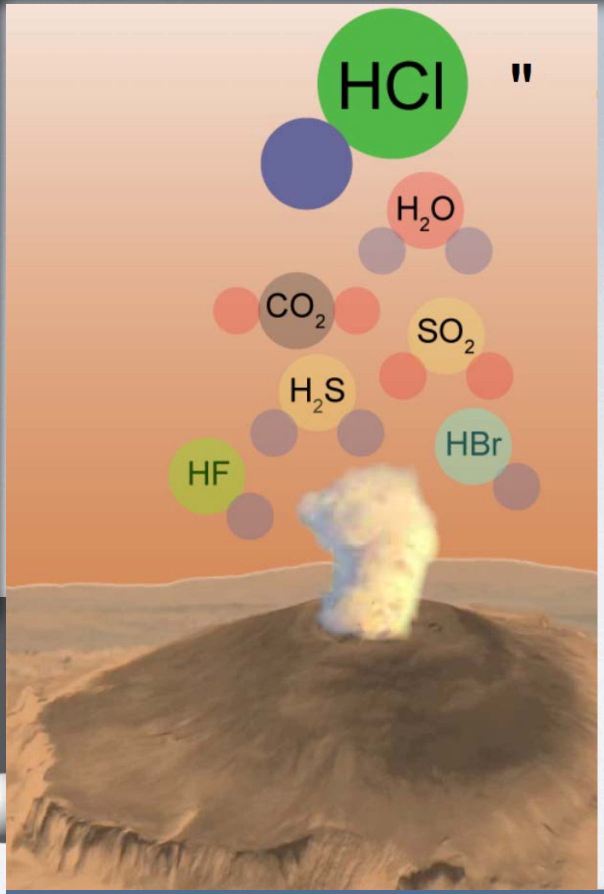
- Entry, Descent, and Landing (EDL) of a payload on the surface of Mars.



SCIENTIFIC OBJECTIVES

- To study Martian atmospheric trace gases and their sources;
- To conduct surface environment measurements.



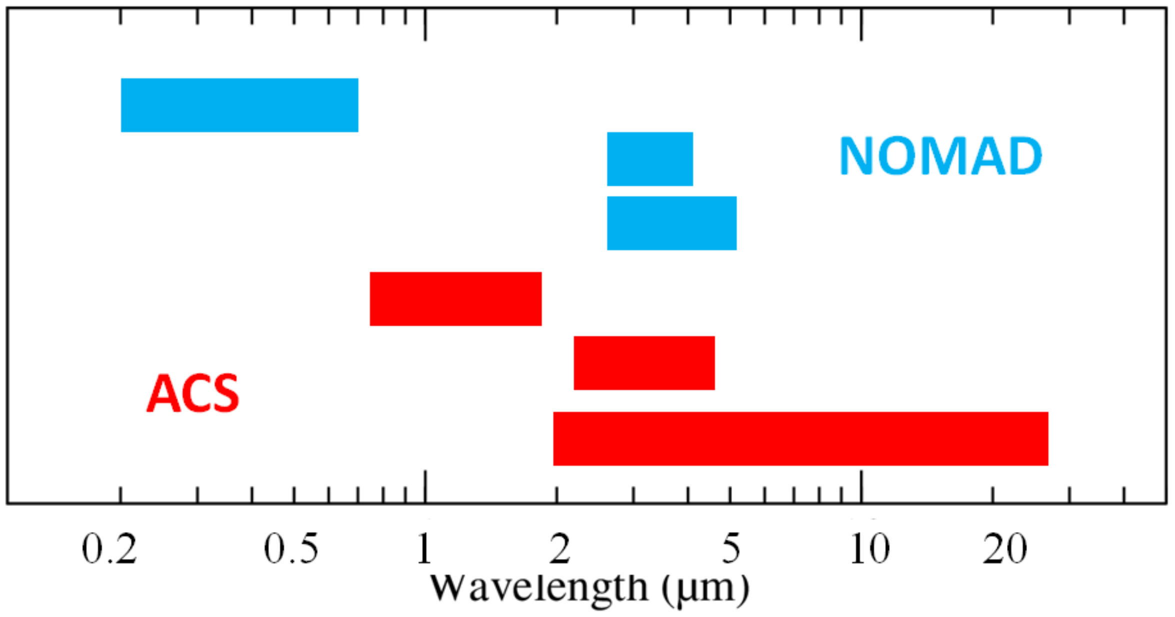


Credit: MEX/HRSC

- Data relay services for landed missions until 2022.

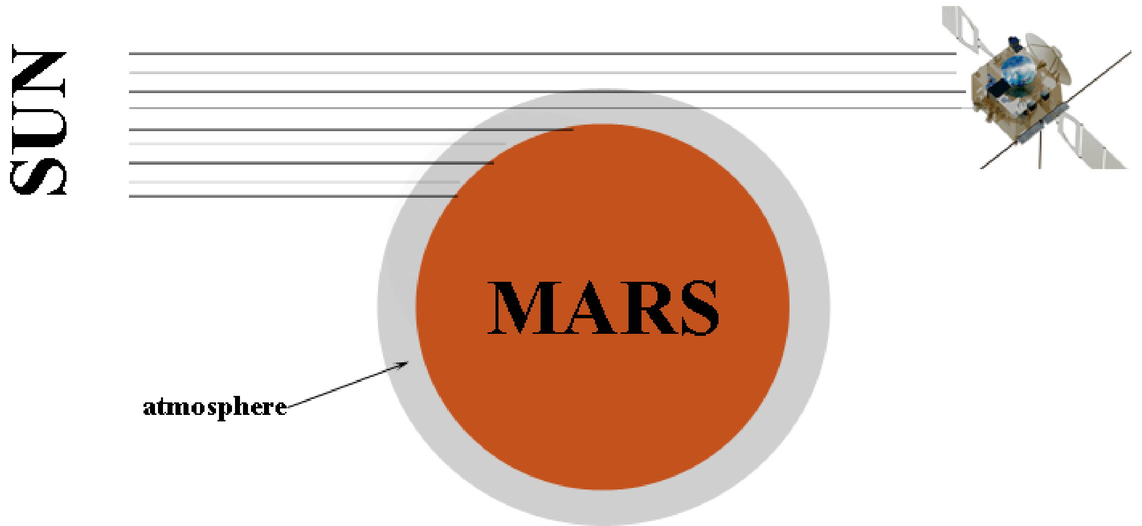
TGO science goal # 1

Monitoring the Martian atmosphere with unprecedented sensitivity using NOMAD and ACS : 6 spectrometers



Several type of observations

- **Solar occultations**
  - Extreme sensitivity; vertical profiles
  - 24 profiles/day , Vertical resolution: 0.5 - 3 km
- **Limb :** vertical profiles
- **Nadir :** systematic mapping



Scientific objectives

o <u>**Trace gas detection and mapping**</u> : reveal activity.

o **First mapping of D/H ratio** : new information on water reservoirs, cloud microphysics, photochemistry

o **Mapping of meteorological fields :** *temperature, dust + ice aerosols, water vapor, ozone*

⇨"data assimilation" methods to reconstruct the circulation and perform ***backtracking of trace gas sources,***

⇨ Long term climatologies.

TGO science goal # 2

Characterize the physical appearance and structure of potential sources of trace gases.

- To characterize sites which have been identified as potential sources of trace gases;
- To investigate dynamic surface processes (e.g. sublimation, erosional processes, volcanism) which may contribute to the atmospheric gas inventory;
- To certify potential future landing sites by characterizing local slopes, rocks, and other potential hazards.

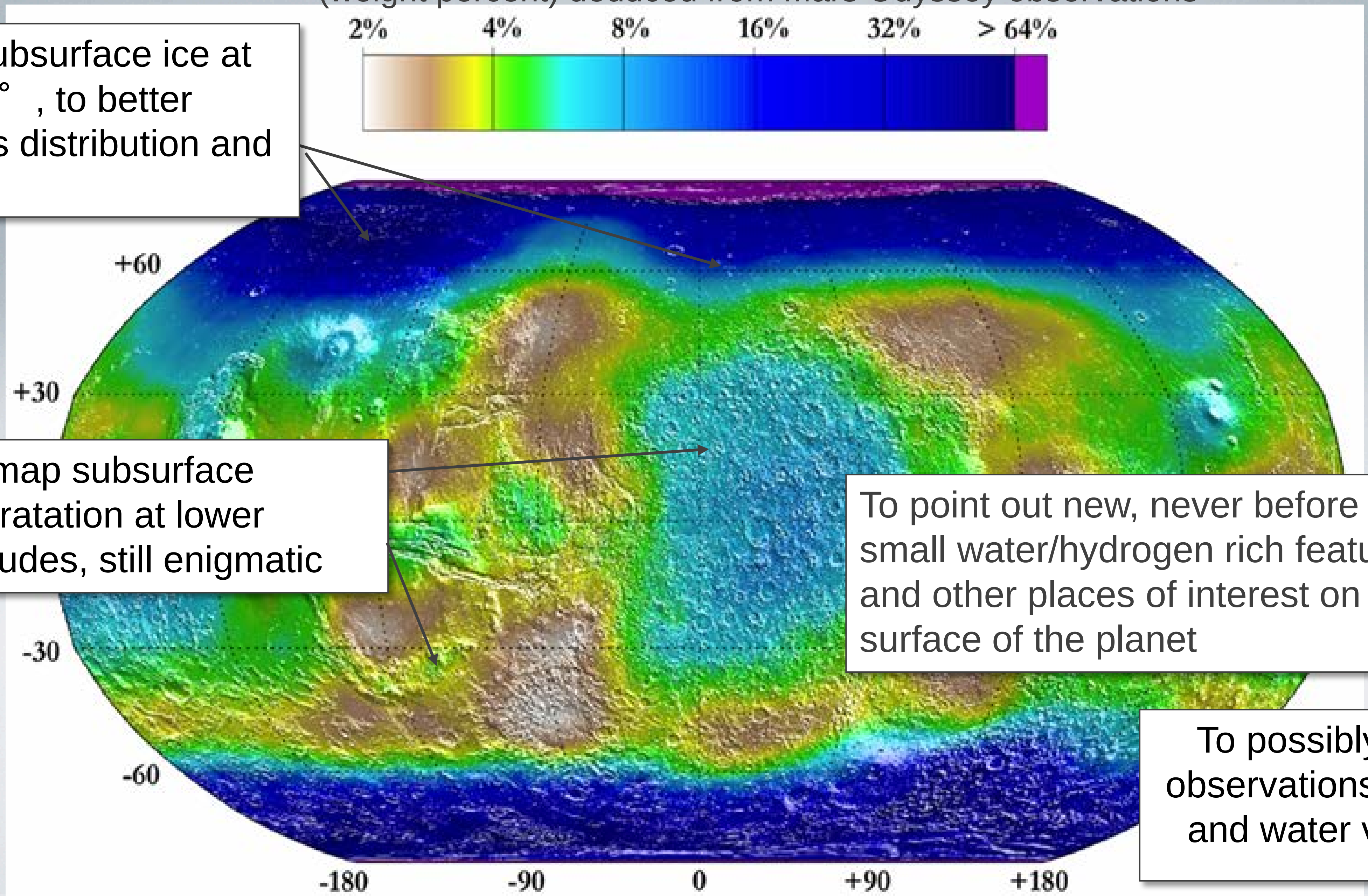
RSL, McEwen et al., Science, 2011

TGO science goal # 3

High resolution mapping of the subsurface (0 - 1m depth) hydrogen (and by inference H_2O) content with a neutron detector.

⇨ *Will resolve the features detected by Mars Odyssey, with a <u>ten times better spatial resolution</u> (40 km)*

Minimum water equivalent hydrogen abundance (weight percent) deduced from Mars Odyssey observations



To map the subsurface ice at latitudes > 55° , to better understand its distribution and origin

To map subsurface hydration at lower latitudes, still enigmatic

To point out new, never before seen small water/hydrogen rich features and other places of interest on the surface of the planet

To possibly relate these observations with trace gas and water vapor sources

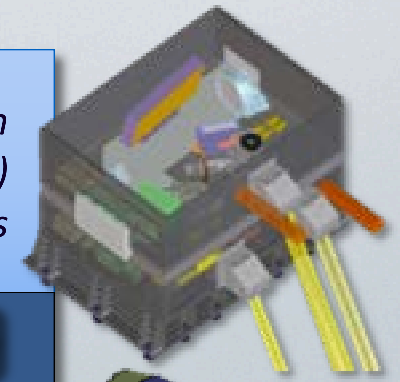
Trace Gas Orbiter

NOMAD

High-resolution occultation and nadir spectrometers

Atmospheric composition (CH_4, O_3, trace species, isotopes) dust, clouds, P&T profiles

UVIS (0.20 – 0.65 µm) λ/Δλ ~250	SO	Limb	Nadir
IR (2.3 – 3.8 µm) λ/Δλ ~10,000	SO	Limb	Nadir
IR (2.3 – 4.3 µm) λ/Δλ ~20,000	SO		



CaSSIS

High-resolution, stereo camera

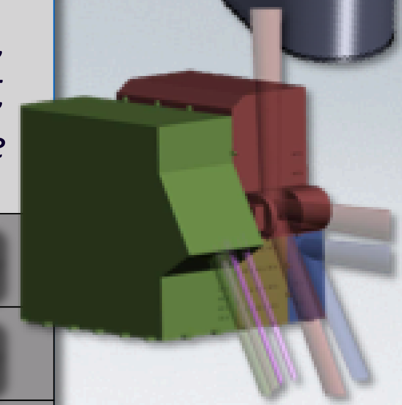
Mapping of sources
Landing site selection

ACS

Suite of 3 high-resolution spectrometers

Atmospheric chemistry, aerosols, surface T, structure

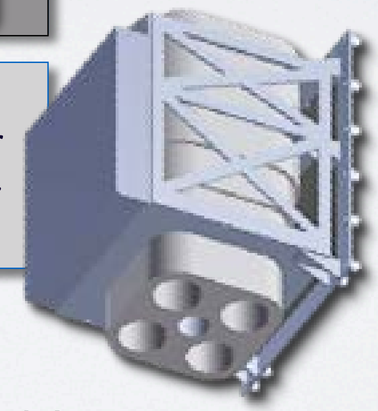
Near IR (0.7 – 1.7 µm) λ/Δλ ~20,000	SO	Limb	Nadir
IR (Fourier, 2.5 – 25 µm) λ/Δλ ~4,000 (SO)/500 (N)	SO		Nadir
IR (2.3 – 4.3 µm) λ/Δλ ~20,000	SO		



FREND

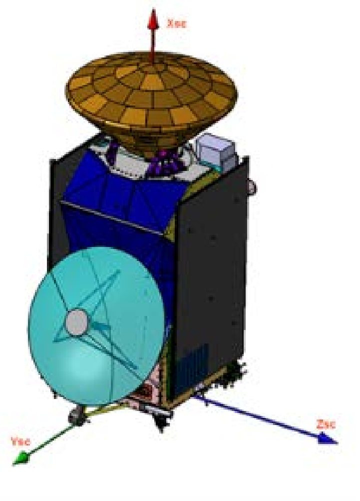
Collimated neutron detector

Mapping of subsurface water and hydrated minerals



2016 Mission Overview – TGO

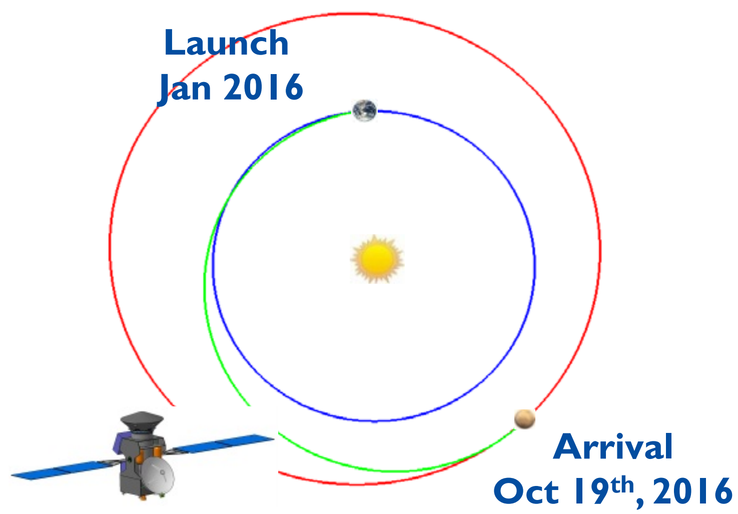
LAUNCH



ExoMars SCC in launch configuration

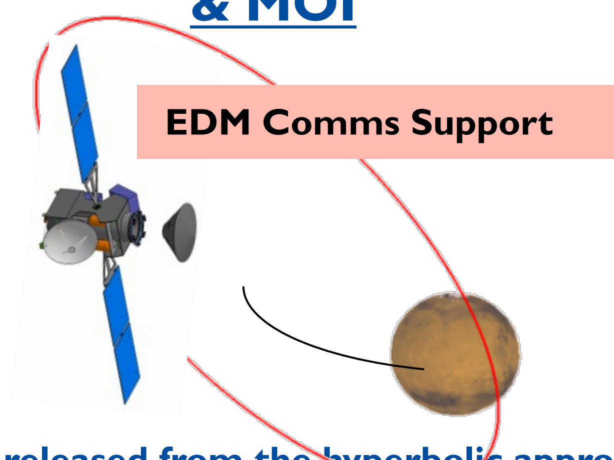
Proton M/Breeze M

INTERPLANETARY CRUISE



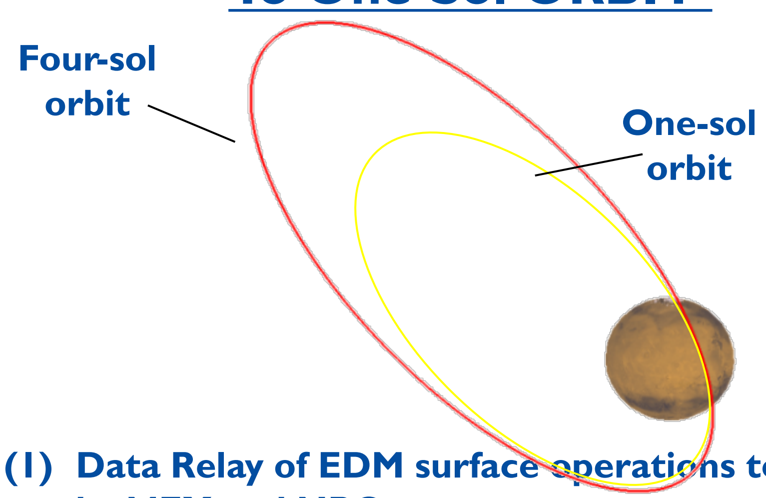
Type II, C3 = 7.44 km²/s²

MARS APPROACH, EDM RELEASE & MOI



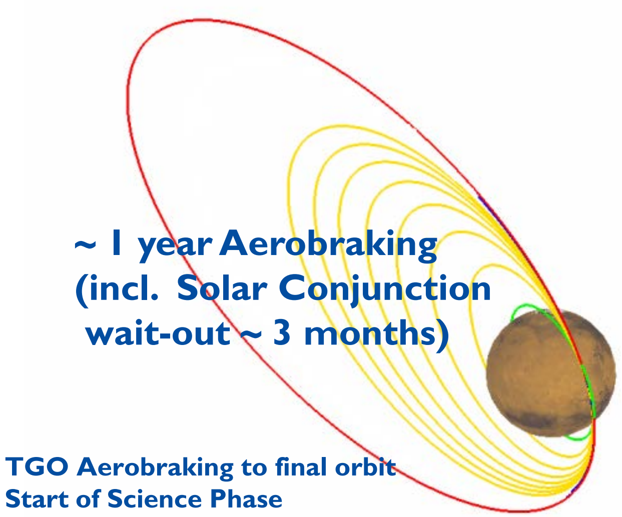
(1) EDM released from the hyperbolic approach 3 days before MOI
(2) TGO performs retargeting and MOI into 4 sol orbit (inclination compatible with target landing site) while guaranteeing data relay coverage for EDM during EDL (TBC)

TRANSITION To One-Sol ORBIT



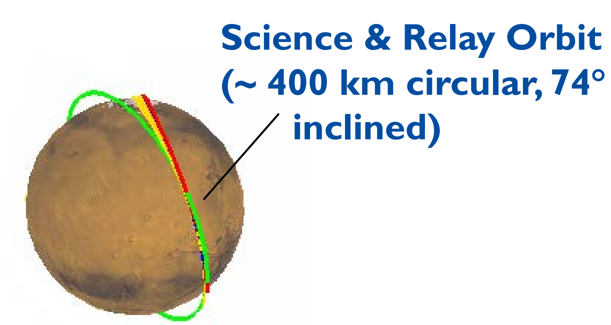
(1) Data Relay of EDM surface operations to be provided by MEX and NRO
(2) TGO orbit inclination change to baseline science and data relay orbit (74° inclined)
(3) Reduction of orbit Apoares to one-sol

AEROBRAKING PHASE



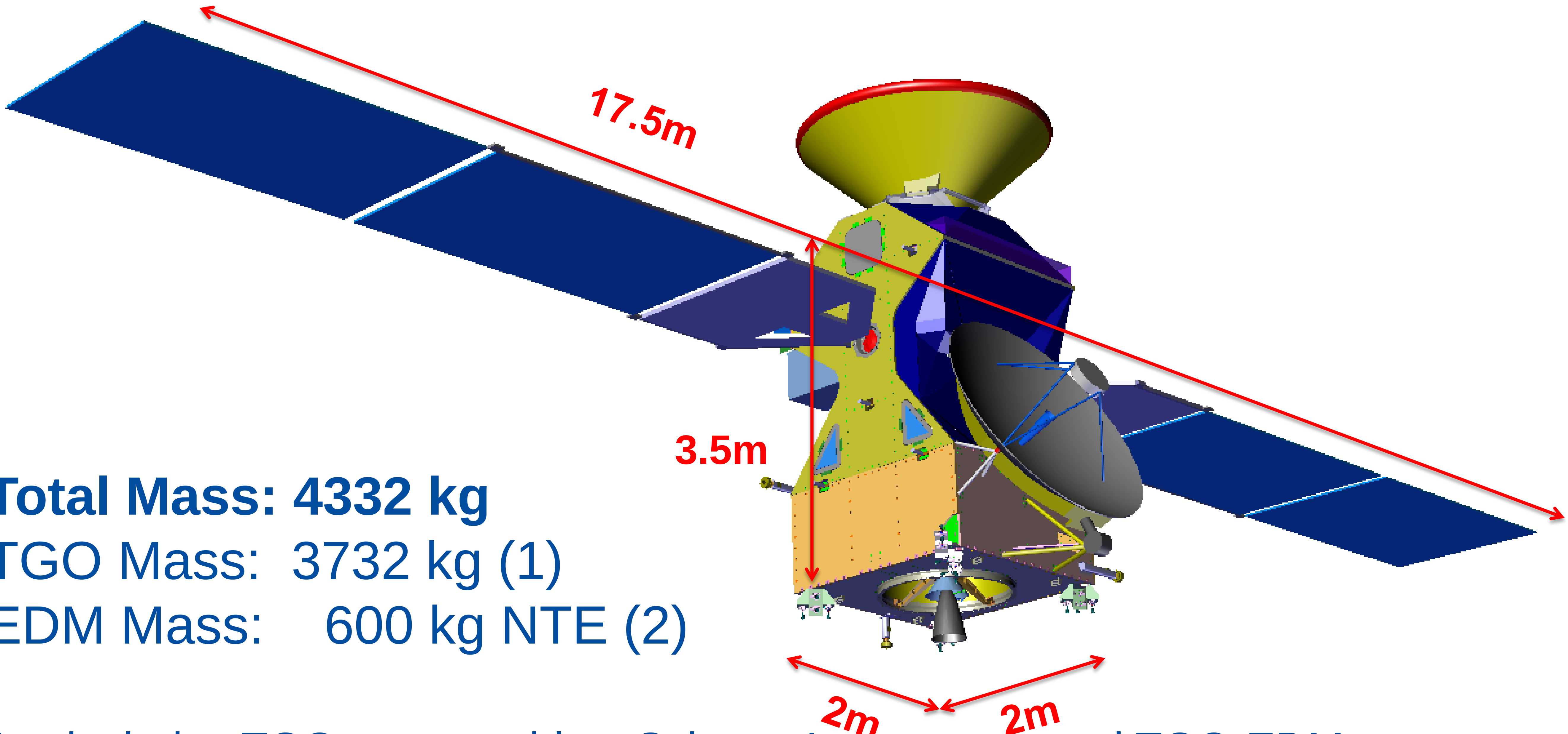
(1) TGO Aerobraking to final orbit
(2) Start of Science Phase

SCIENCE & DATA RELAY PHASE



(1) Data relay for 2018 Rover and Surf Platform starts in Jan 2019
(2) Data relay capability for future Mars surface assets throughout 2022

2016 Spacecraft Composite Overview



Total Mass: 4332 kg

TGO Mass: 3732 kg (1)

EDM Mass: 600 kg NTE (2)

1. includes TGO consumables, Science Instruments and TGO-EDM Separation Assembly
2. includes EDM consumables and EDM Science Instruments

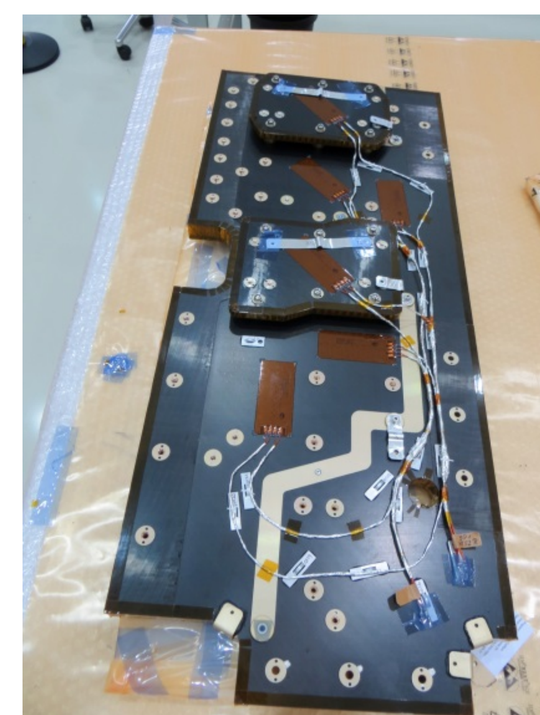
2016 TGO – PFM Structures

Central Tube Static Load Testing

Tanks integration into Central Tube

Panels with Thermal HW

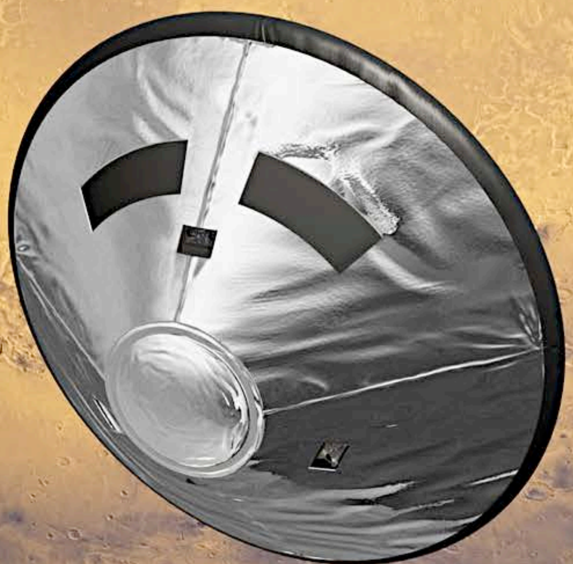
Central Tube with Thermal Hardware →



EDL Demonstrator Module

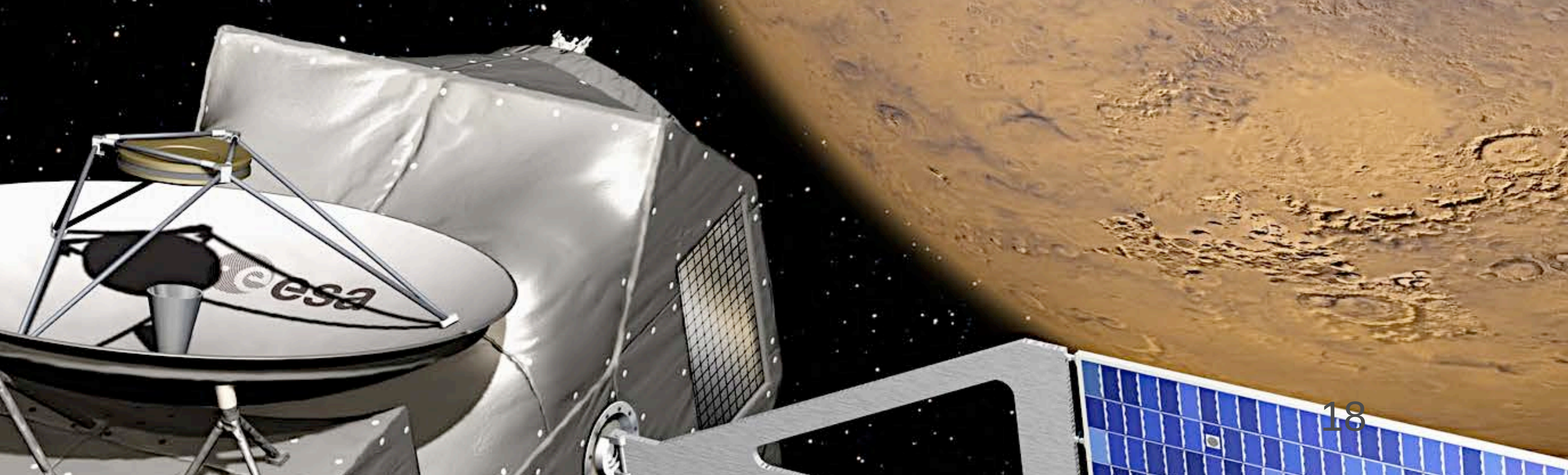
EDM

- A technology demonstrator for landing payloads on Mars;
- A platform to conduct environmental measurements, particularly during the dust storm season.



EDM PAYLOAD

- Integrated mass: 5 kg;
- Surface lifetime: 4–8 sols;
- Measurements:
- •Descent science;
- •P, T, wind speed and direction;
- •Optical depth;
- •Atmospheric charging;
- •Descent camera.



2016 Mission Overview – EDM

1- Separation from TGO on Mars arrival hyperbolic trajectory

- ✓ 3 days before Mars atmospheric entry
- ✓ Spinning at 2.75 rpm for attitude stabilisation

2- Coast Phase

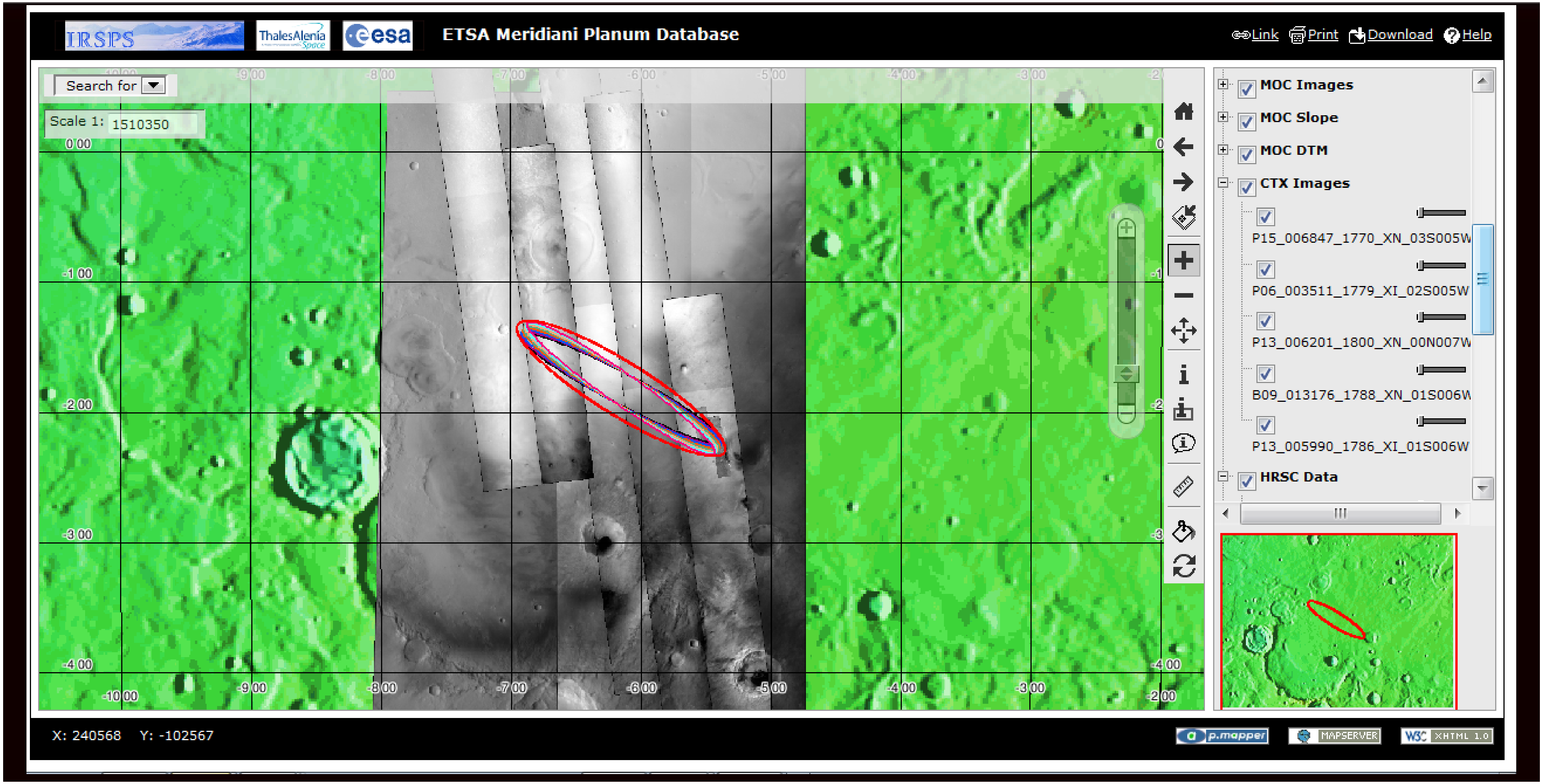
- ✓ On-board systems in hibernation mode shortly after separation, awaken 1 hour prior to Mars atmospheric entry

3- EDL Phase

- ✓ Ls 244 deg, within Global Dust Storm Season
- ✓ Landing at Meridiani Planum (landing ellipse 100 Km x 15 Km, 3-sigma)
- ✓ UHF proximity link with TGO for transmission of EDL essential telemetry

4- Surface Phase

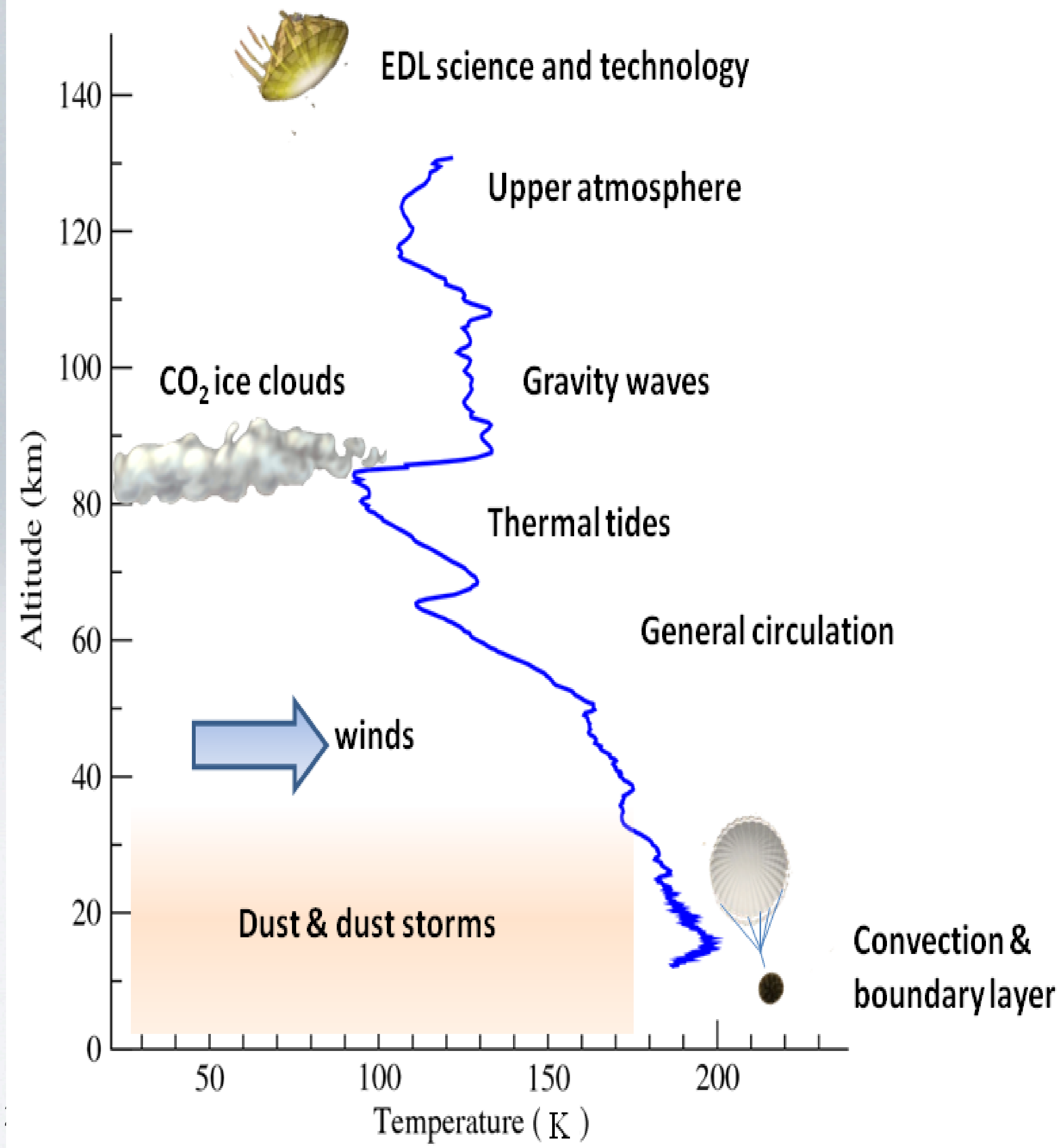
- ✓ EDL and Surface Payload data upload via UHF proximity link with MEX and/or NRO


IRSPS
ThalesAlenia Space
esa
ETSA Meridiani Planum Database
Link
Print
Download
Help
Search for
Scale 1: 1510350
MOC Images
MOC Slope
MOC DTM
CTX Images
P15_006847_1770_XN_03S005W
P06_003511_1779_XI_02S005W
P13_006201_1800_XN_00N007W
B09_013176_1788_XN_01S006W
P13_005990_1786_XI_01S006W
HRSC Data
X: 240568 Y: -102567
p.mapper
MAPSERVER
W3C XHTML 1.0

AMELIA science goals

Rare, high quality *in situ* observations of the Martian atmosphere over a wide altitude range, for the first time during Mars "dust storm season"

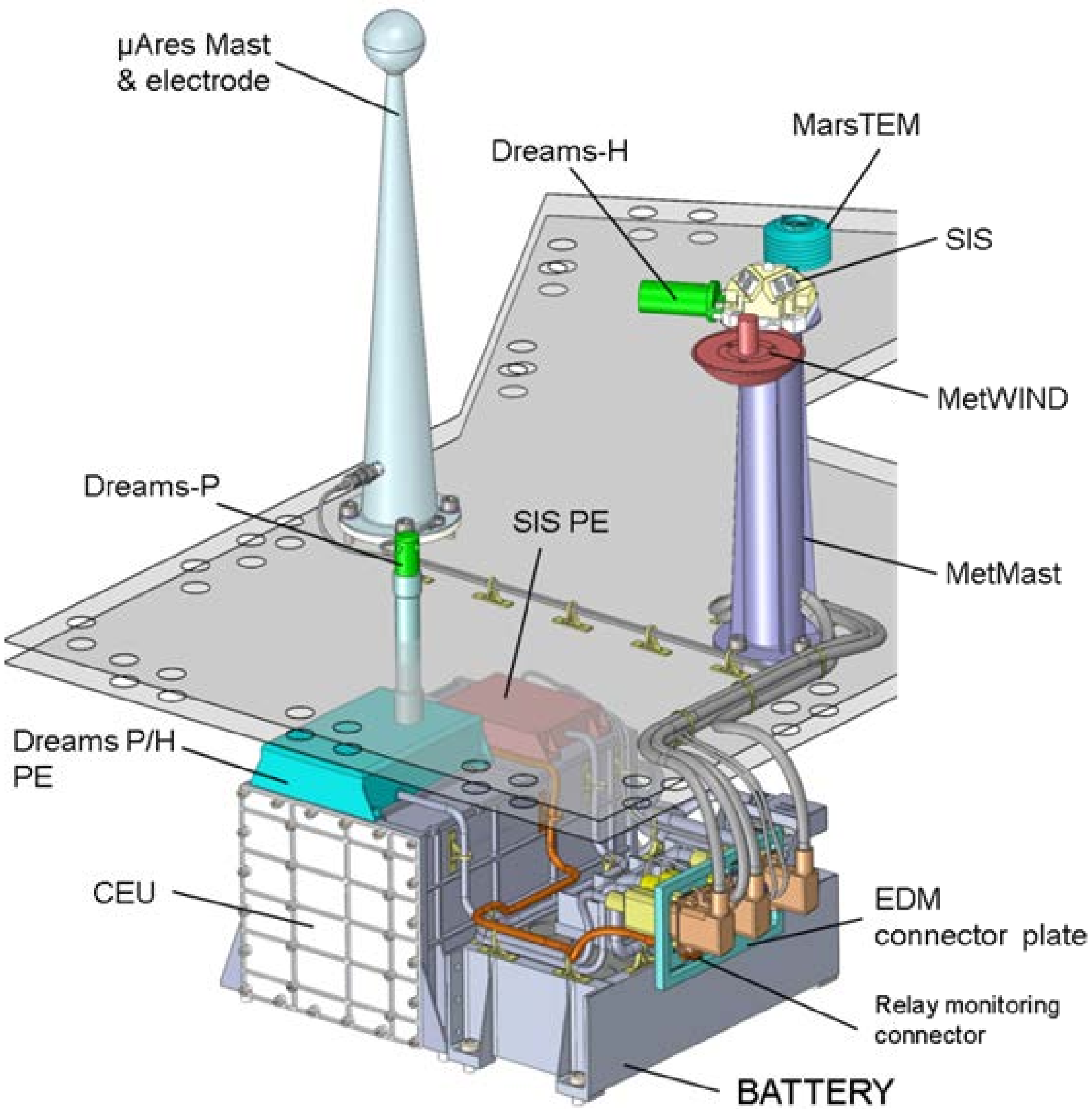
- **Atmospheric general structure**
  - Impact of **dust** on the general circulation
  - Characterize **"thermal tides"** and their sensitivity to dust
  - Observe **gravity waves** and help understand their impact on the mean flow: currently a key question in Mars atmospheric sciences !
- **Boundary layer** (parachute phase)
  - **Detect the top** of the daytime planetary boundary layer (PBL)
  - Observe the scale and intensity of the **turbulence**
  - Tentatively measure horizontal and/or vertical **winds** within the PBL



2016 EDM Science Measurements

- ❑ **Improve our knowledge of Mars atmosphere with in-situ observations (Entry-Descent-Landing phase)**
  - ➢ **AMELIA** experiment

- ❑ **Improve our knowledge of Mars environment at times of high dust loading (Surface Operations phase)**
  - ➢ **DREAMS experiment**



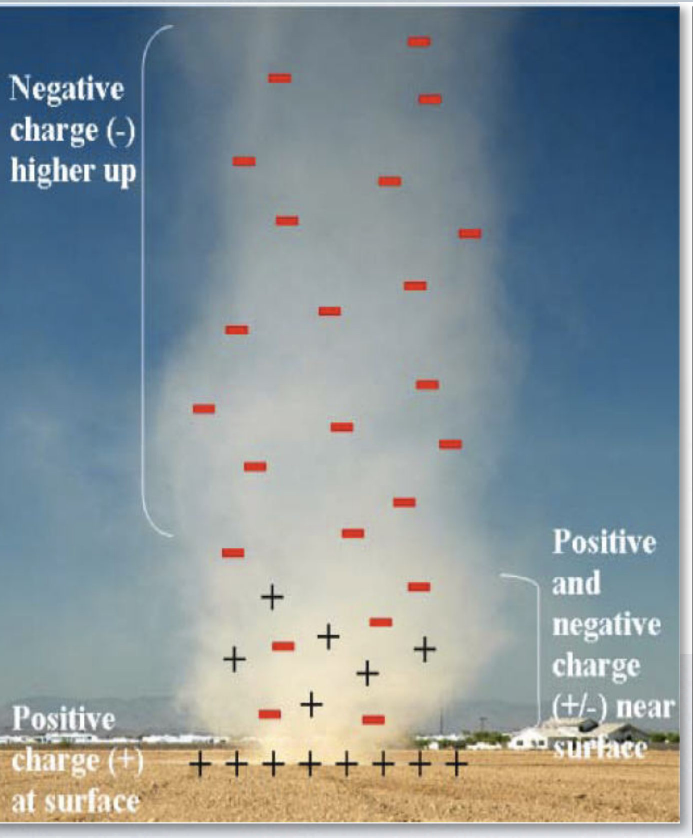
DREAMS / Electricity

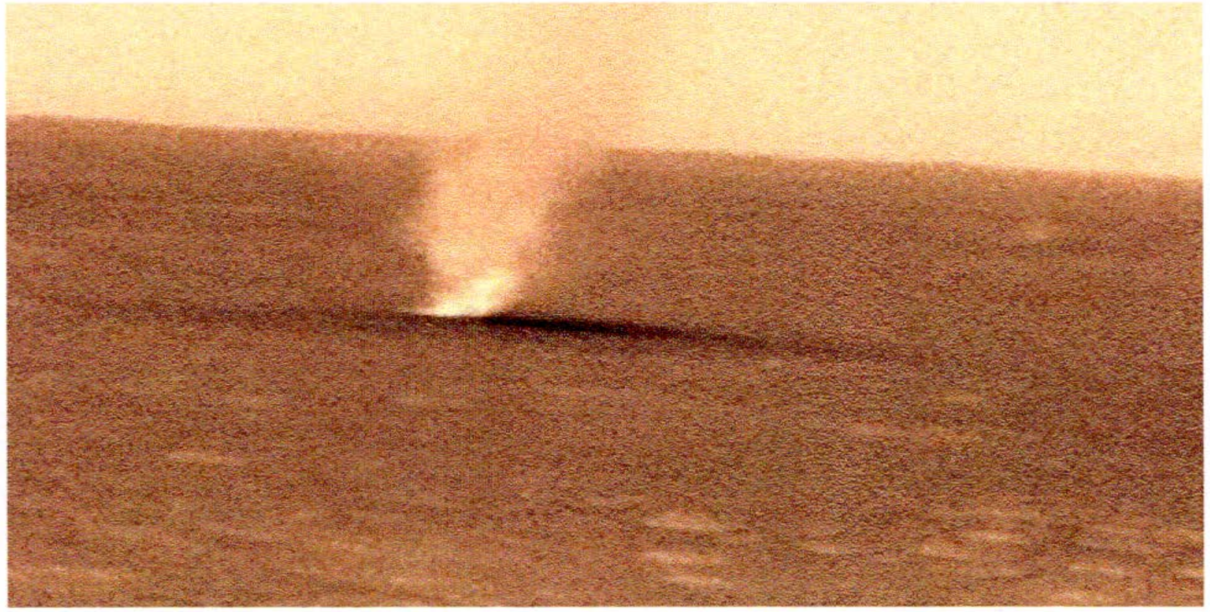
DREAMS shall establish the first ever investigation of atmospheric electric phenomena at Mars

Intense electric fields are expected at times of dust storms and in the vicinity of dust devils.

The "*atmospheric electric fields*" are related to atmospheric charging and discharging processes, possibly creating a global electric circuit on Mars.

Atmospheric electricity could play a significant role in the dust cycle, in chemistry, and shall be considered in the context of human exploration.

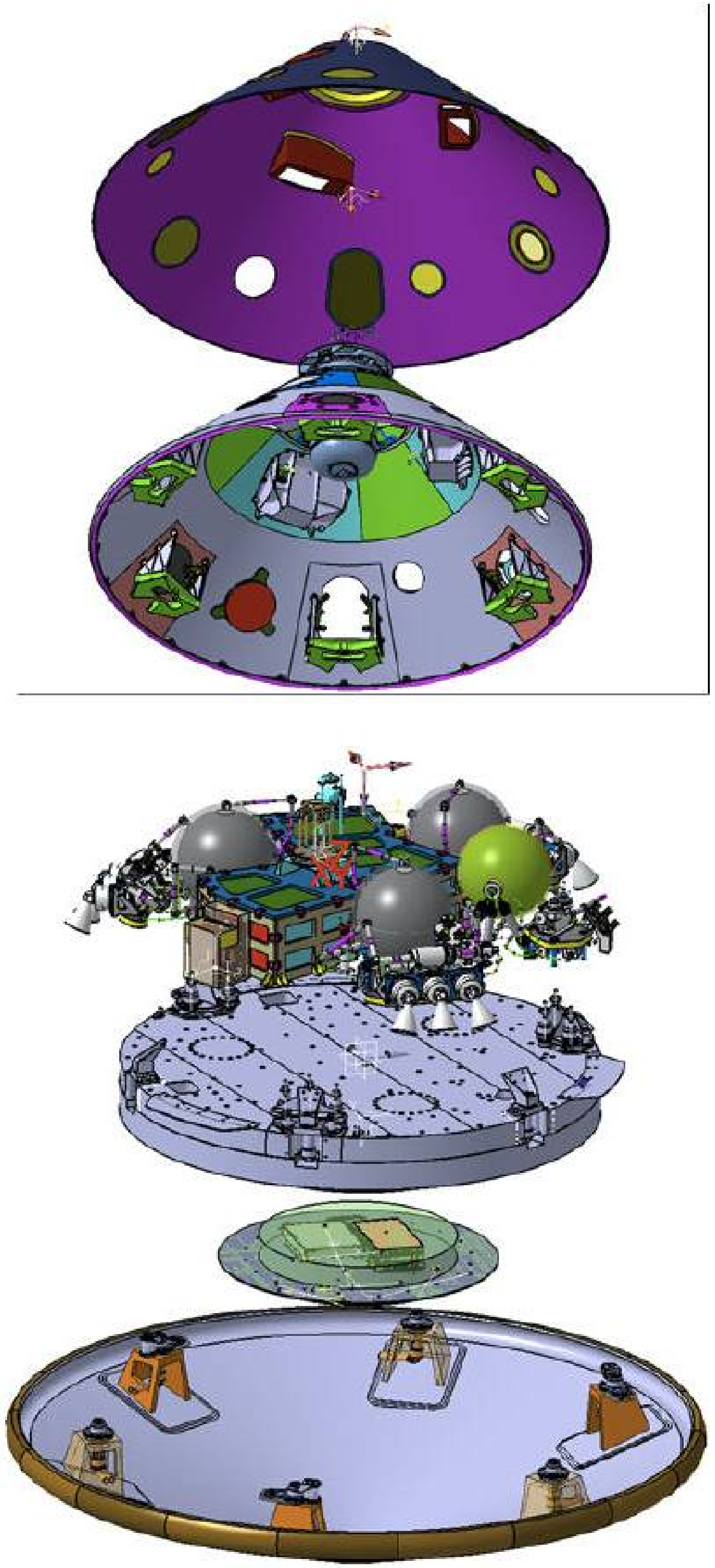




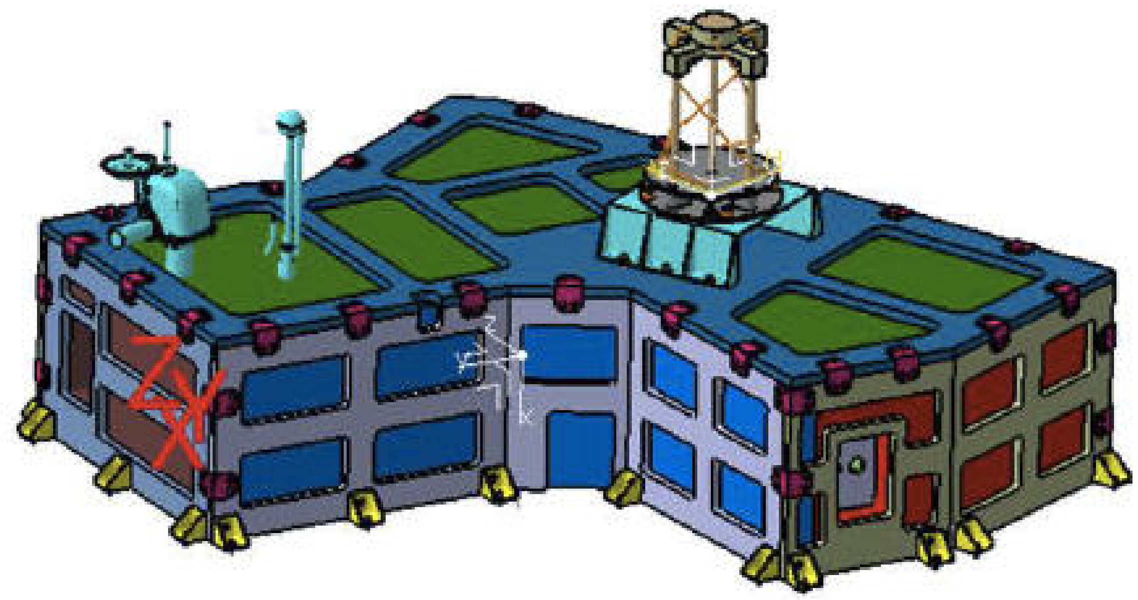
*High voltages can be generated in dust devil vortex, they are theoretically limited by **electrical breakdown** to ~25 kV/m.*

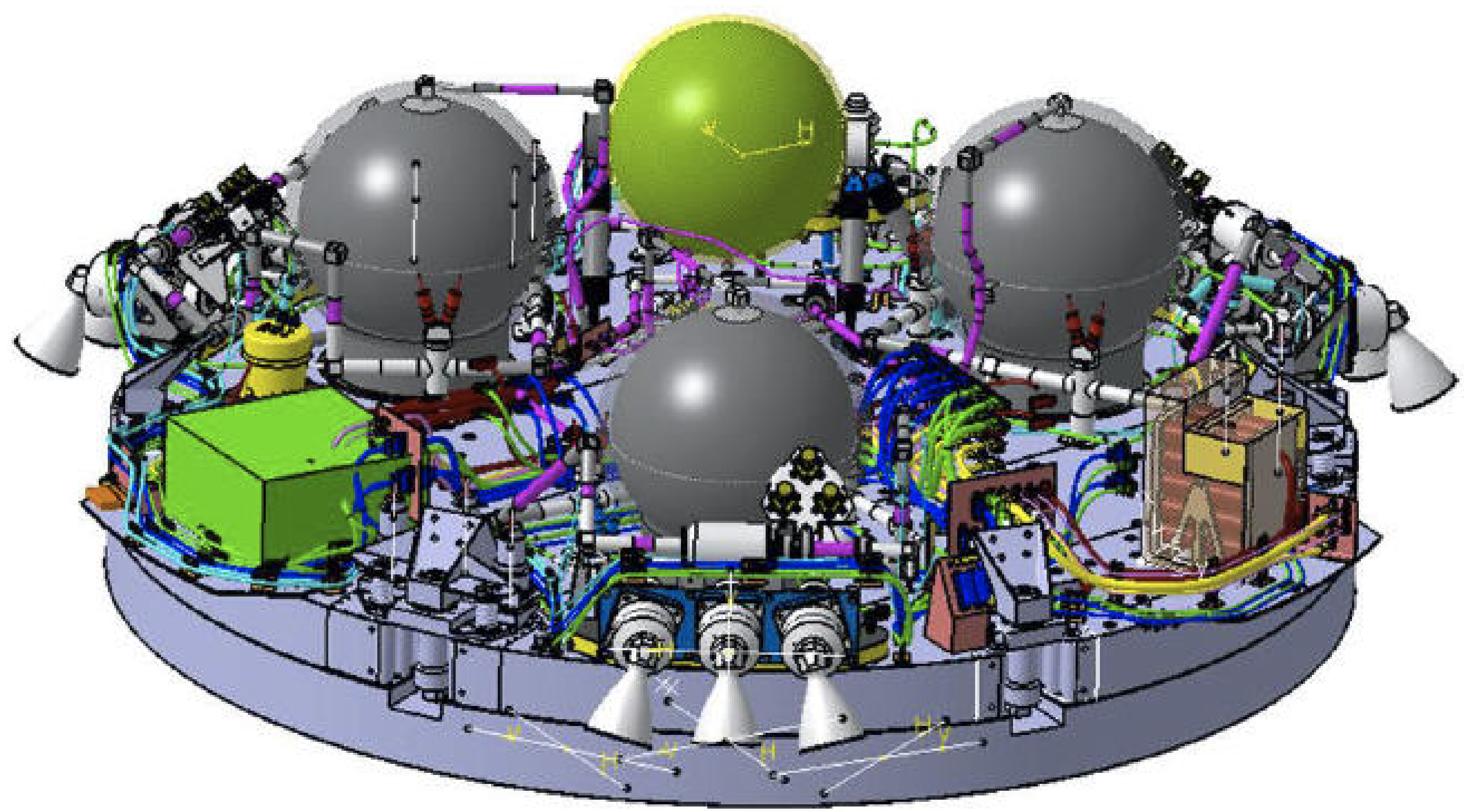
Entry and Descent Module

EDM exploded view



Central Bay (top) and Main Panel

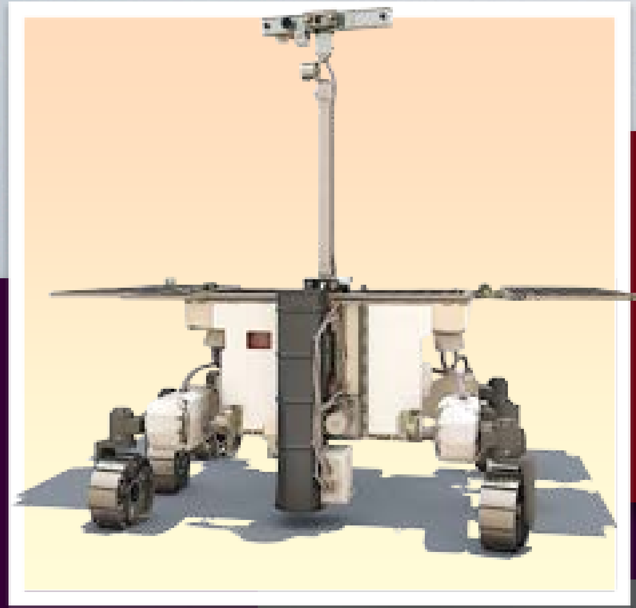




2016 EDM – SM Aeroshell Leak Tightness Check

2016 EDM – SM Sine Vibration Testing

2018 Mission Objectives



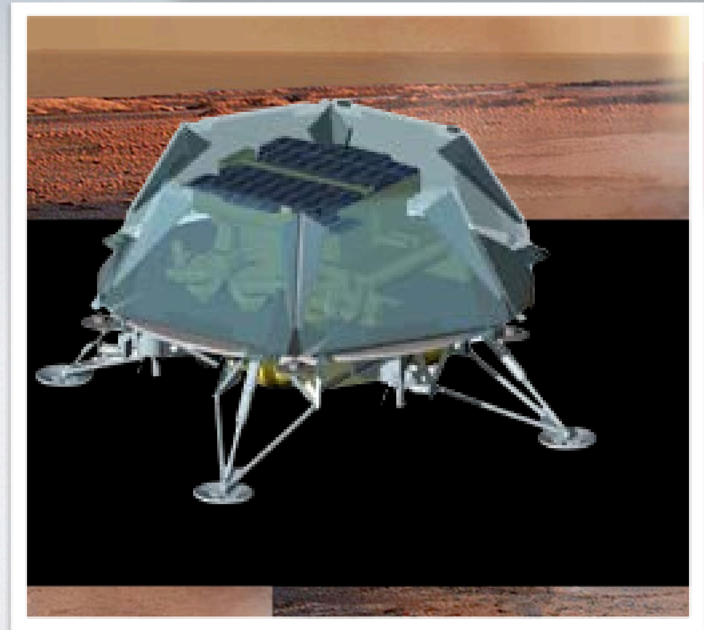
2018

SCIENTIFIC OBJECTIVES

- To search for signs of past and present life on Mars;
- To characterise the water/subsurface environment as a function of depth in the shallow subsurface.

TECHNOLOGY OBJECTIVES

- Surface mobility with a rover (having several kilometres range);
- Access to the subsurface to acquire samples (with a drill, down to 2-m depth);
- Sample acquisition, preparation, distribution, and analysis.



- To study the surface and subsurface environment.

Credit: MEX/HRSC

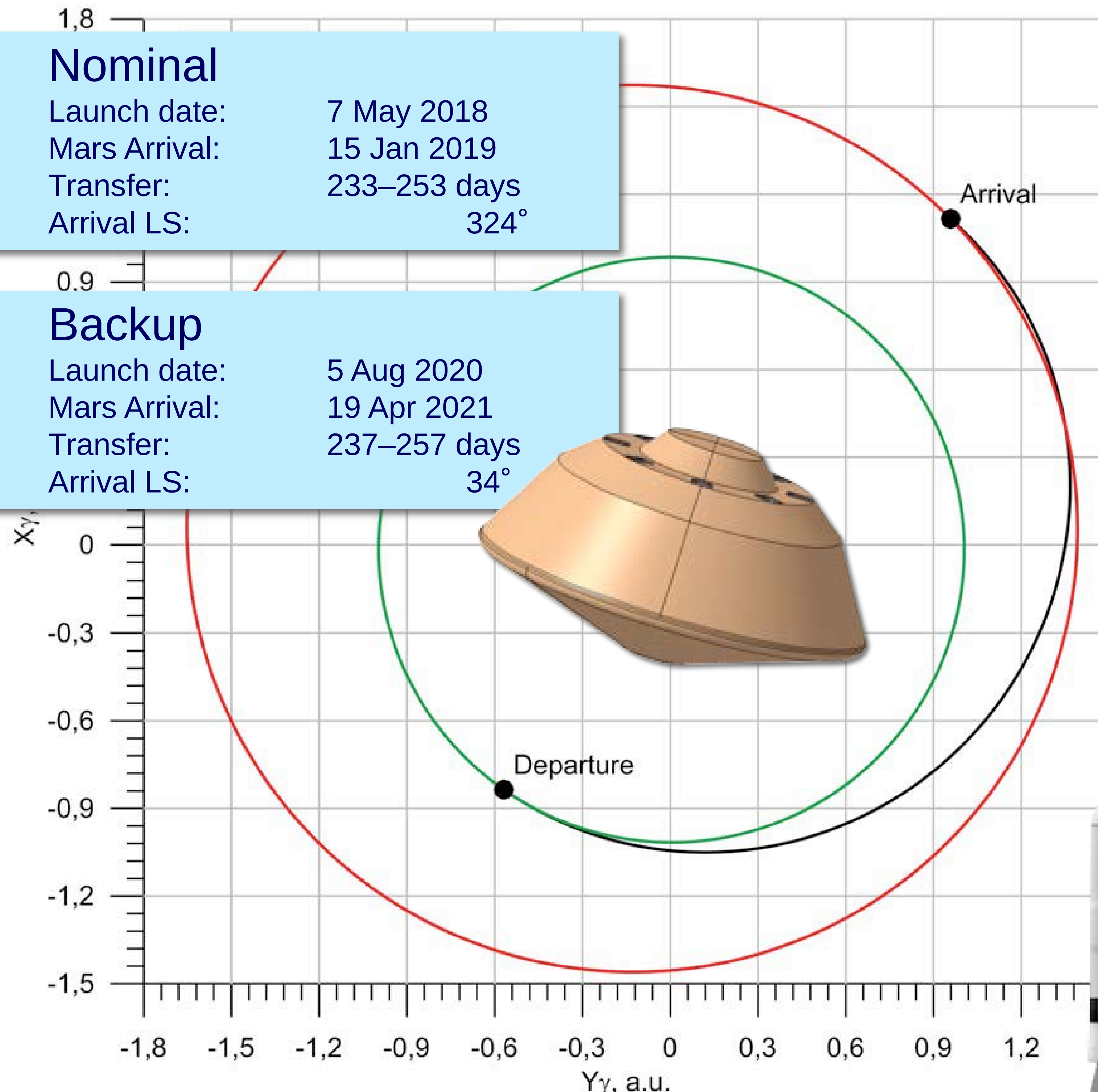
Launch

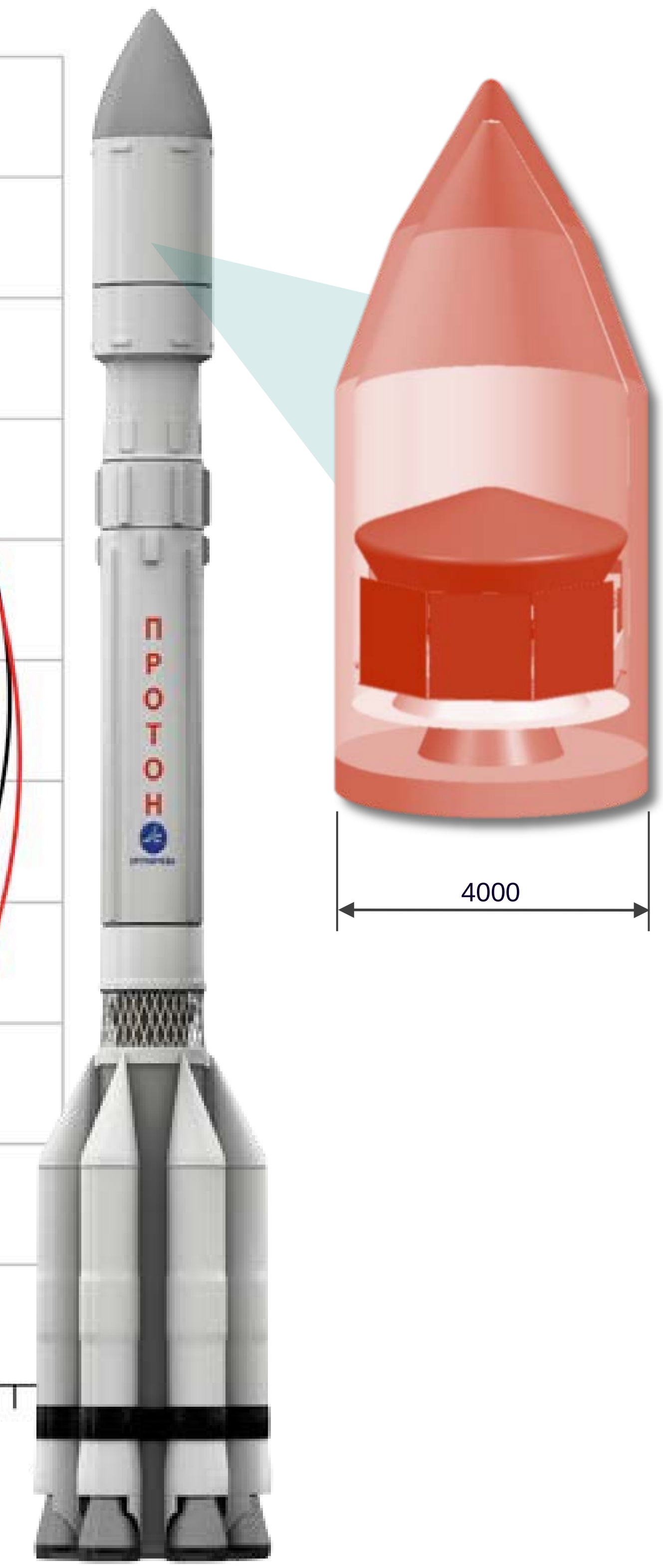
Nominal

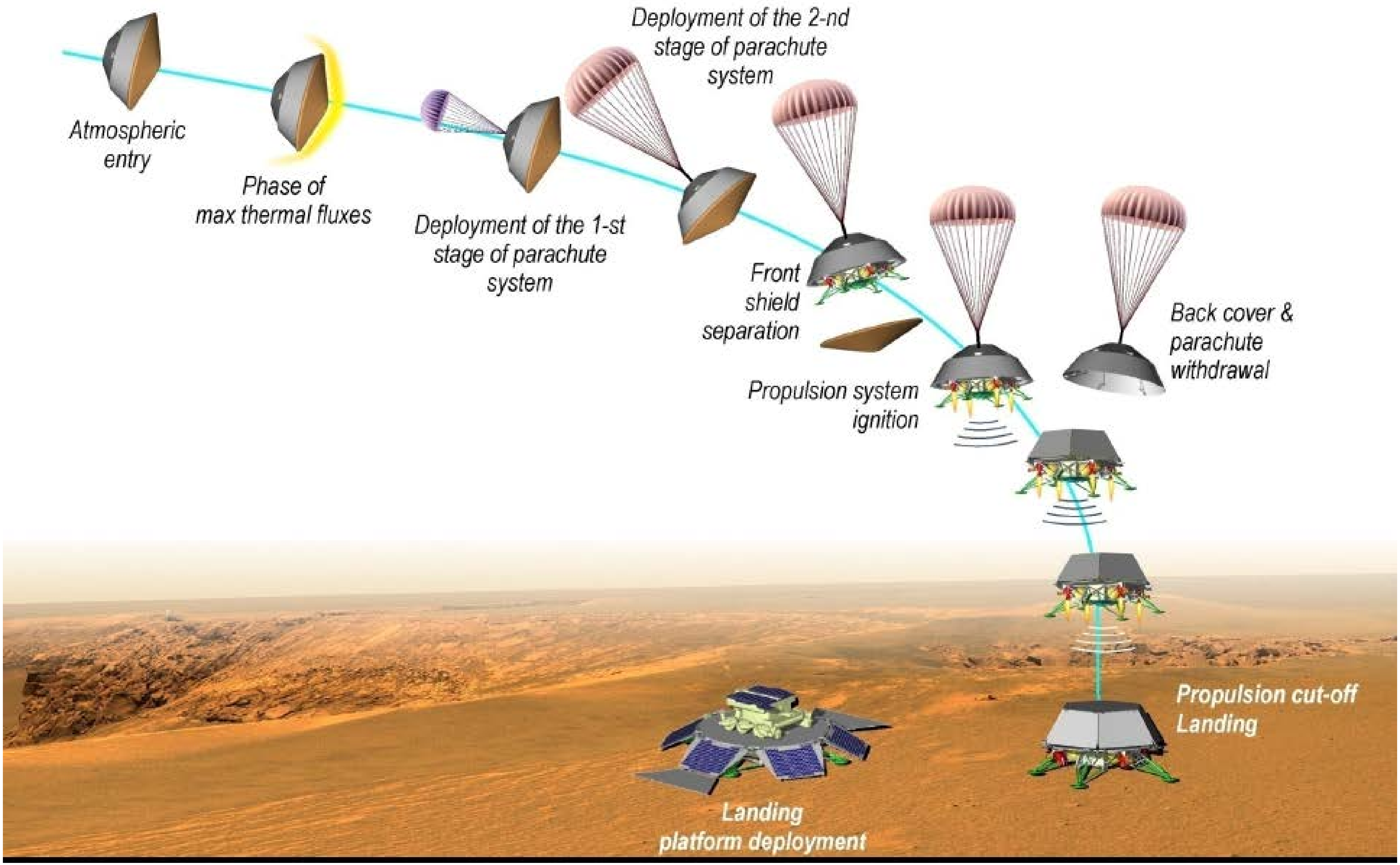
Launch date: 7 May 2018
Mars Arrival: 15 Jan 2019
Transfer: 233–253 days
Arrival LS: 324°

Backup

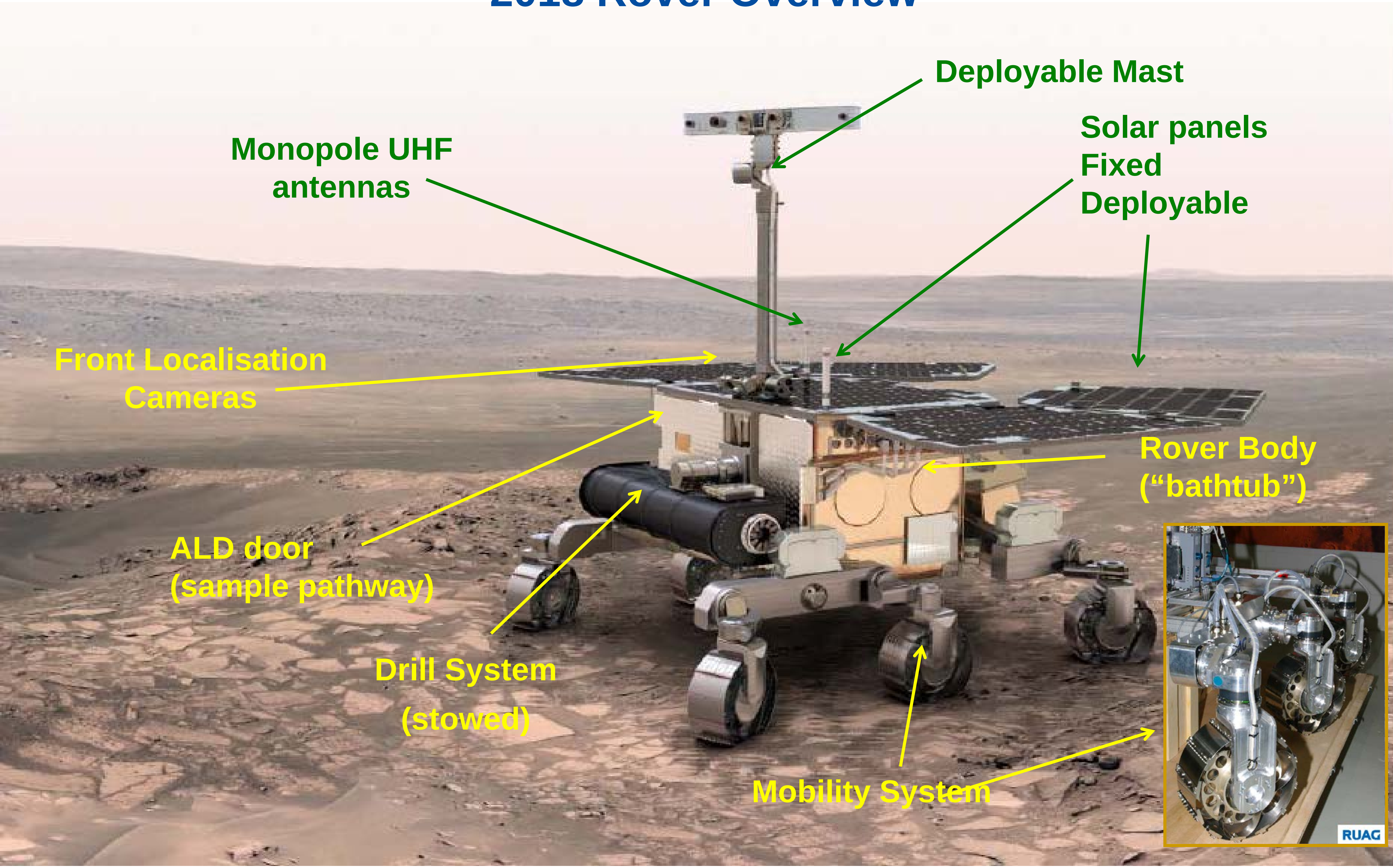
Launch date: 5 Aug 2020
Mars Arrival: 19 Apr 2021
Transfer: 237–257 days
Arrival LS: 34°



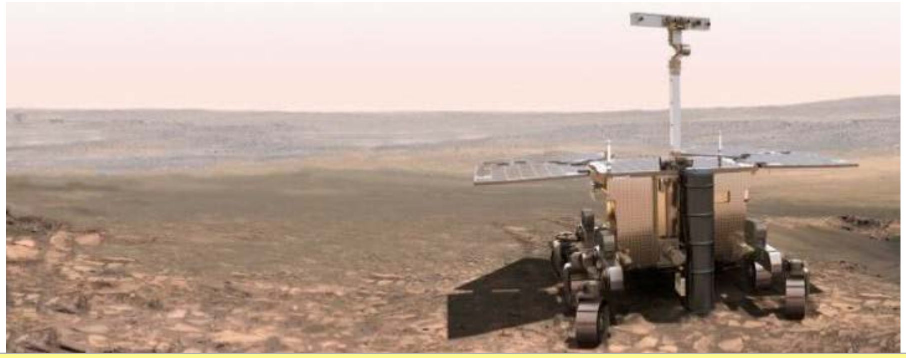



Atmospheric entry
Phase of max thermal fluxes
Deployment of the 1-st stage of parachute system
Deployment of the 2-nd stage of parachute system
Front shield separation
Propulsion system ignition
Back cover & parachute withdrawal
Propulsion cut-off
Landing
Landing platform deployment

2018 Rover Overview



2018 Rover Science Instruments



PanCam
Wide-angle stereo camera pair
High-resolution camera
Geological context
Rover traverse planning
Atmospheric studies
WAC: 35° FOV, HRC: 5° FOV

ISEM
IR spectrometer on mast
Bulk mineralogy of outcrops
Target selection
λ = 1.15 – 3.3 µm, 1° FOV

CLUPI
Close-up imager
Geological deposition environment
Microtexture of rocks
Morphological biomarkers
20-µm resolution at 50-cm distance, focus: 20 cm to ∞

WISDOM
Ground-penetrating radar
Mapping of subsurface stratigraphy
3 – 5-m penetration, 2-cm resolution

ADRON
Passive neutron detector
Mapping of subsurface
Water and hydrated minerals

Drill + Ma_MISS
IR borehole spectrometer
In-situ mineralogy information
λ = 0.4 – 2.2 µm

Analytical Laboratory Drawer

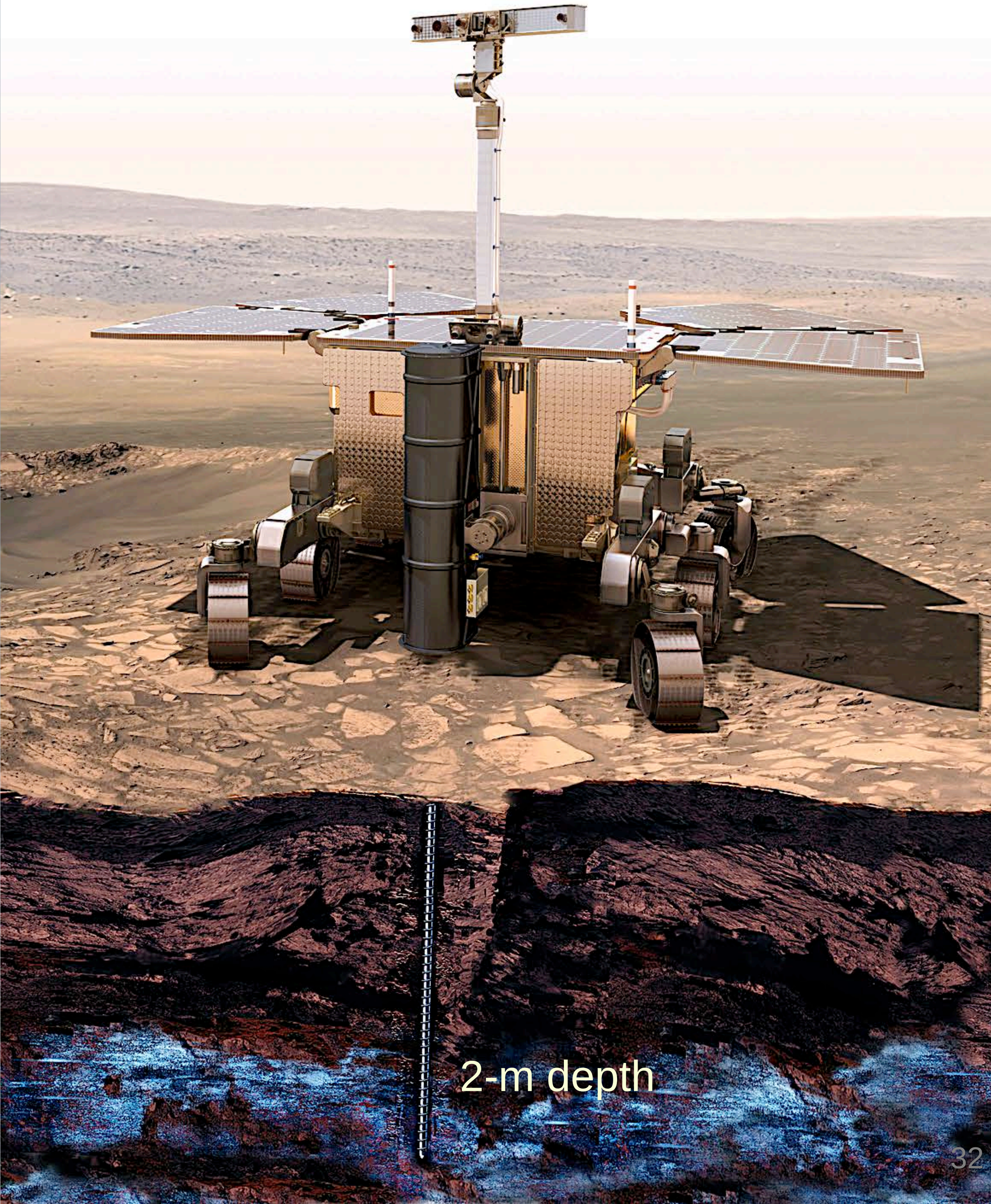
MicrOmega
VIS + IR Spectrometer
Mineralogical characterization of crushed sample material
Pointing for other instruments
λ = 0.9 – 3.5 µm, 256 x 256, 20-µm/pixel, 500 steps

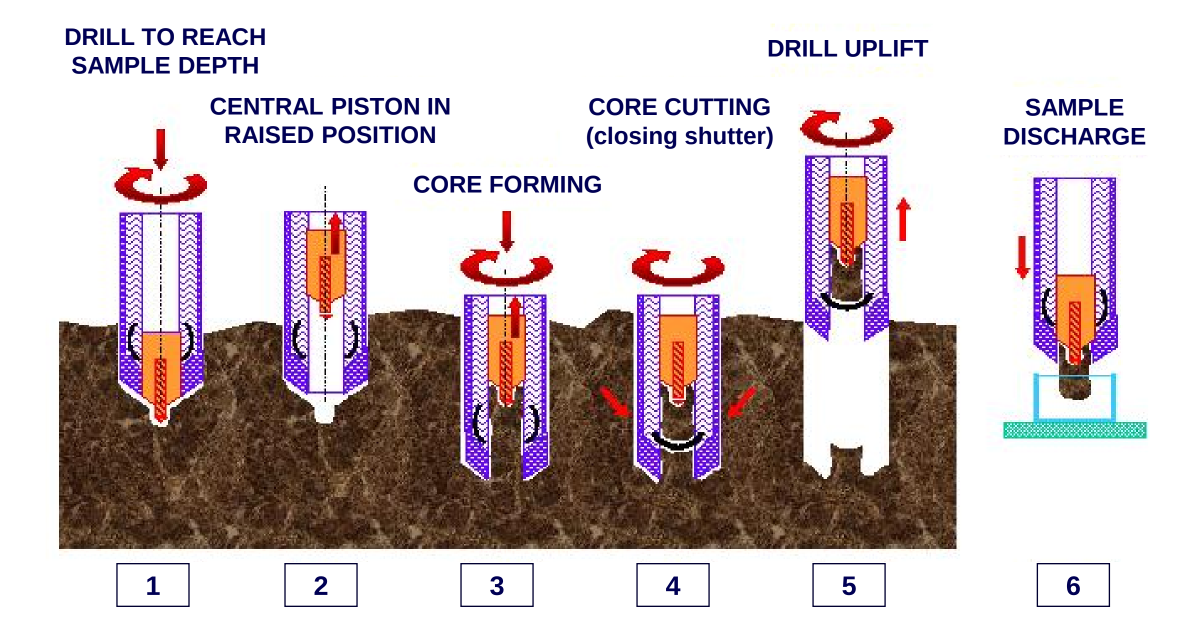
RLS
Raman LIB spectrometer
Geochemical composition
Detection of organic pigments
spectral shift range 200–3800 cm^{-1}, resolution ≤ 6 cm^{-1}

MOMA
LDMS + Pyr-Dev GCMS
Broad-range organic molecules at high sensitivity (ppb)
Chirality determination
Laser-desorption extraction and mass spectroscopy
Pyrolisis extraction in the presence of derivatisation agents, coupled with chiral gas chromatography, and mass spectroscopy

Rover mission : 3D mobility

Nominal mission:	220 sols
Nominal science:	6 Experiment Cycles + 2 Vertical Surveys
EC length:	16–20 sols
Rover mass:	300-kg class
Mobility range:	Several km

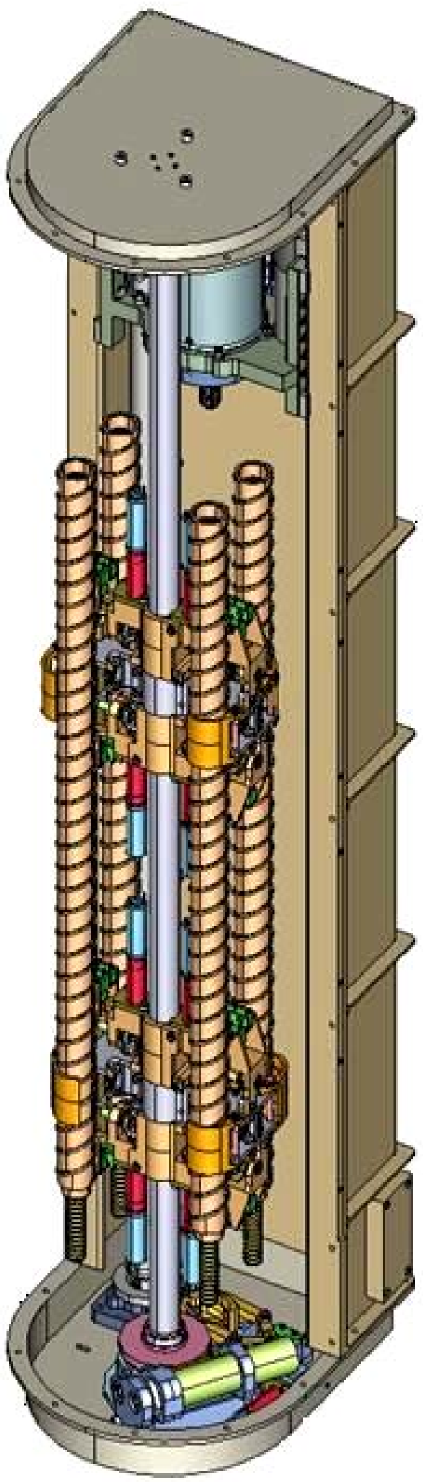


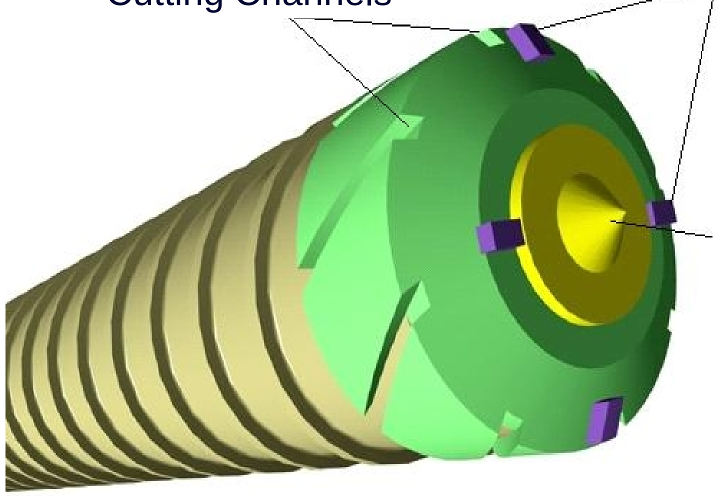


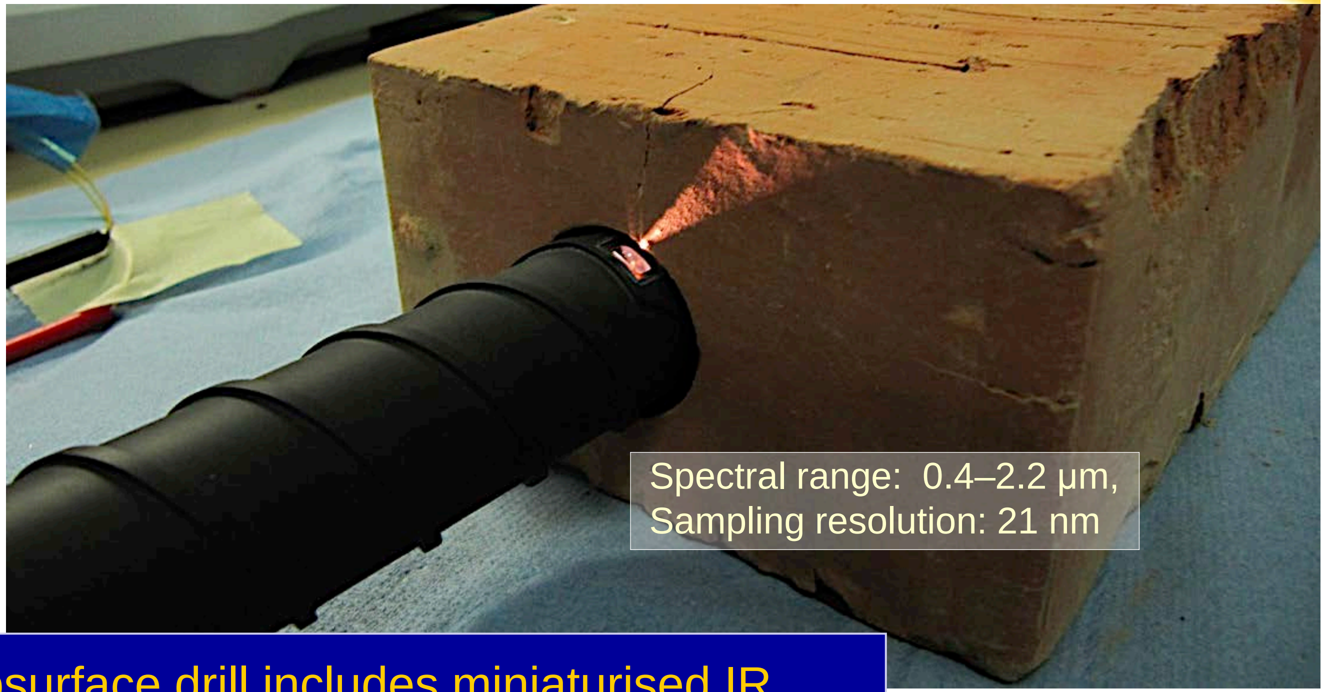
Credit: ESA/Medialab

Subsurface Drill

OBTAIN SAMPLES FOR ANALYSIS: From 0 to 2-m depth





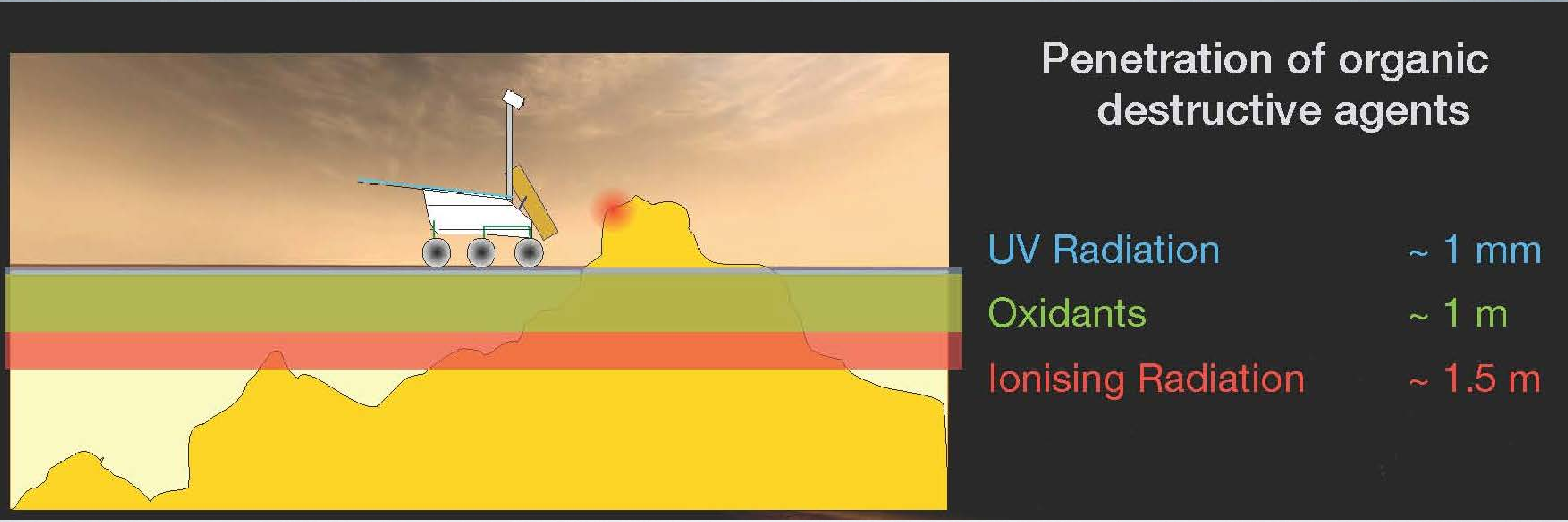


Subsurface drill includes miniaturised IR spectrometer for borehole investigations.

Mission Objectives

Even if Life never arose on Mars, some of the key question are:

- Why?
- Where are the organics ? What is their distribution?



Correlation between :

- organic and inorganic inventories in the sample
- chemical composition and morphology
- concentration of organics as a f(depth)

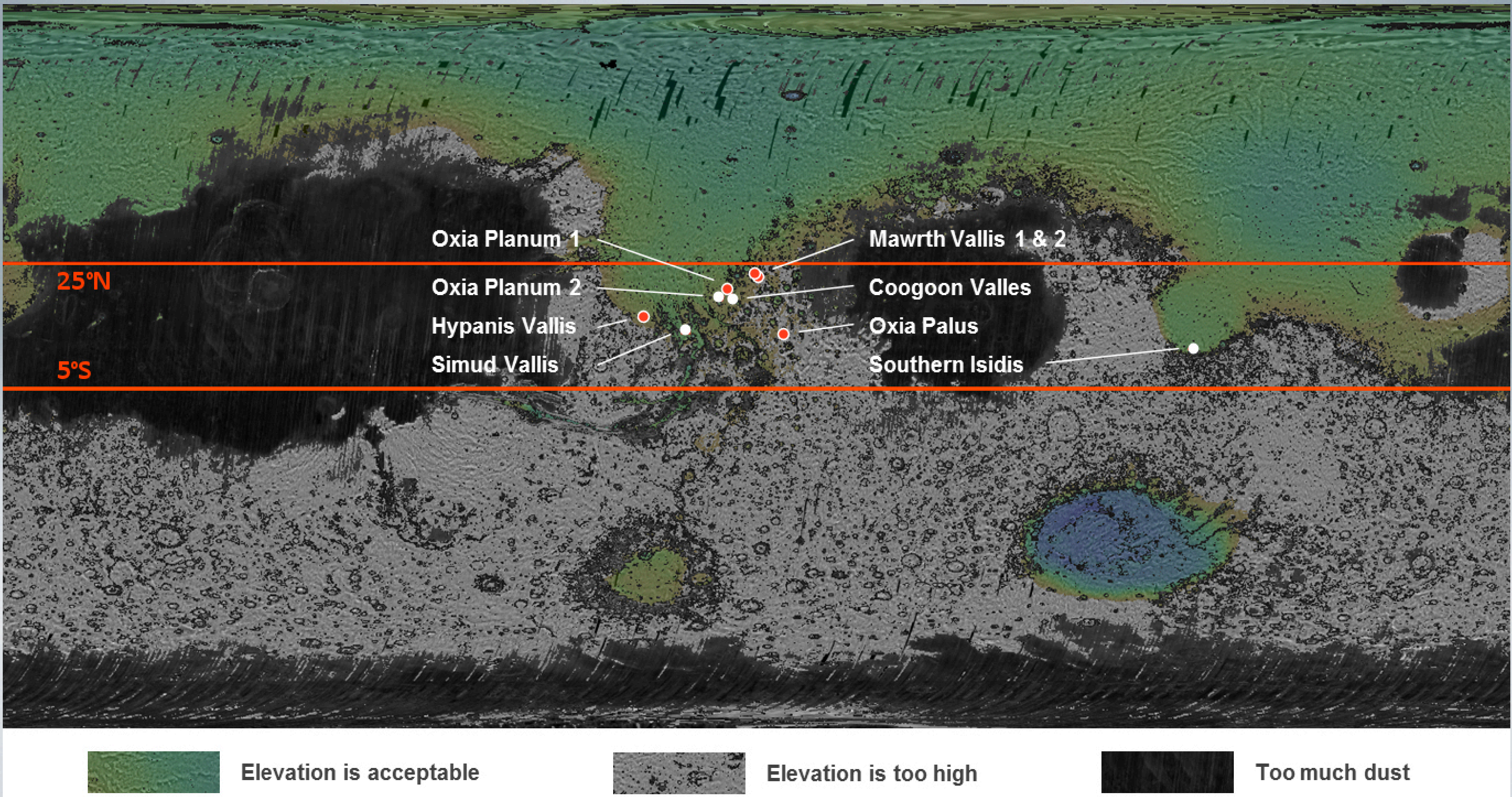
- From a science point of view, a landing site satisfying the Rover mission's search-for-life requirements would also be extremely interesting for the Surface Platform Science.

For the ExoMars Rover to achieve results regarding the possible existence of biosignatures, the mission has to land in a **scientifically appropriate setting:**

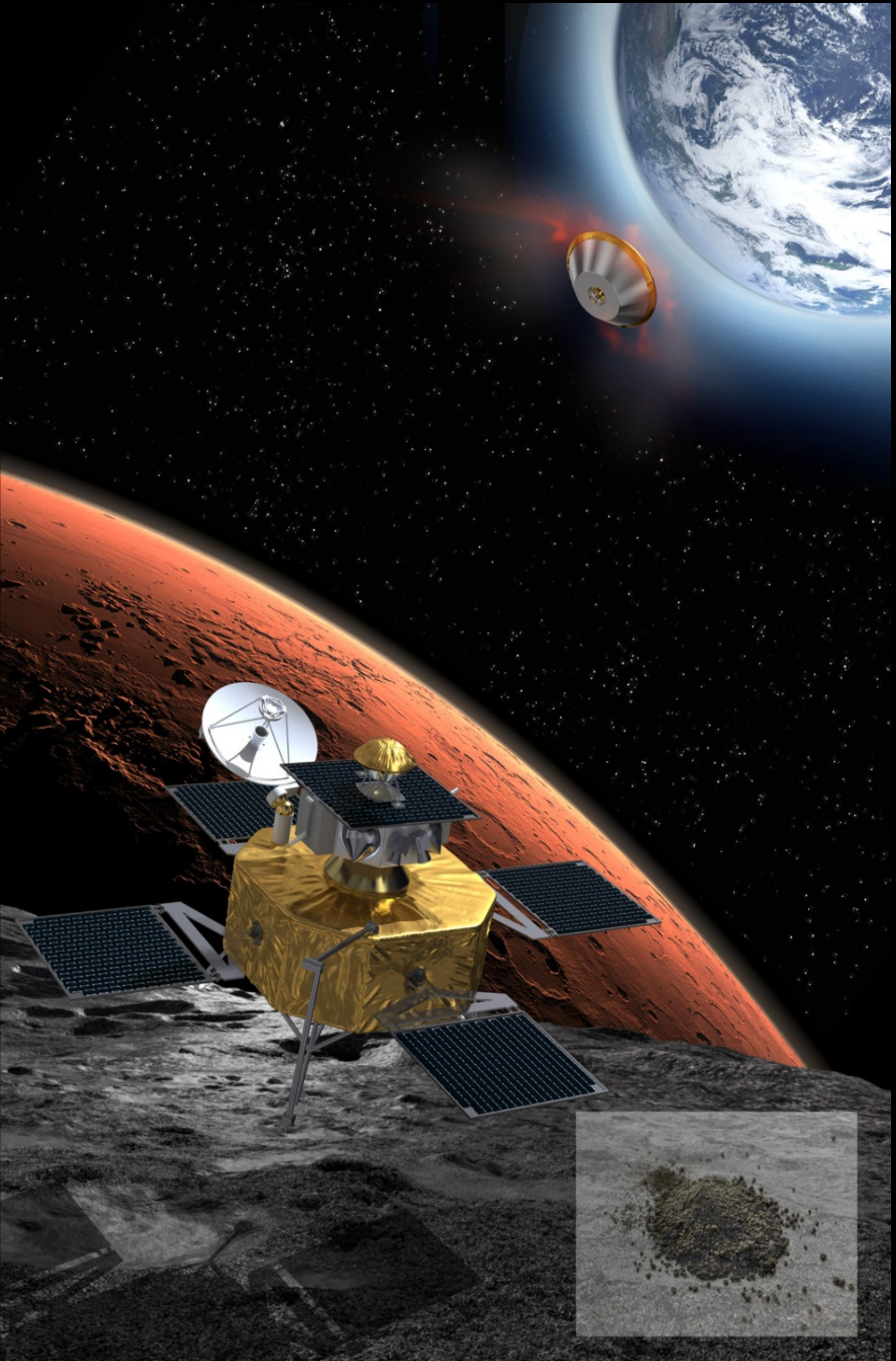
1. The site must be **ancient** (older than 3.6 Ga) — from Mars' early, habitable period: Pre- to late Noachian (Phyllosian), possibly extending into the Hesperian;
2. The site must show abundant morphological and mineralogical evidence for long-duration, or frequently reoccurring, **aqueous activity**;
3. The site must include numerous **sedimentary rock outcrops**;
4. Outcrops must be **distributed** over the landing ellipse to ensure the rover can get to some of them (the expected rover traverse range during the 218-sol nominal mission is a few km);
5. The site must have **little dust** coverage.

Identify a suitable landing site for the ExoMars 2018 mission:

- **Scientifically compelling** — high probability of achieving the science objectives.
- **Safe for landing** — no safe landing, no science.
- **Safe for surface operations** — energy generation, locomotion, etc.
- **Planetary Protection** — no landing on or access to Mars special regions.



MARS ROBOTIC EXPLORATION PROGRAMME



Phobos
Sample
Return

Network