ExoMars Status Report

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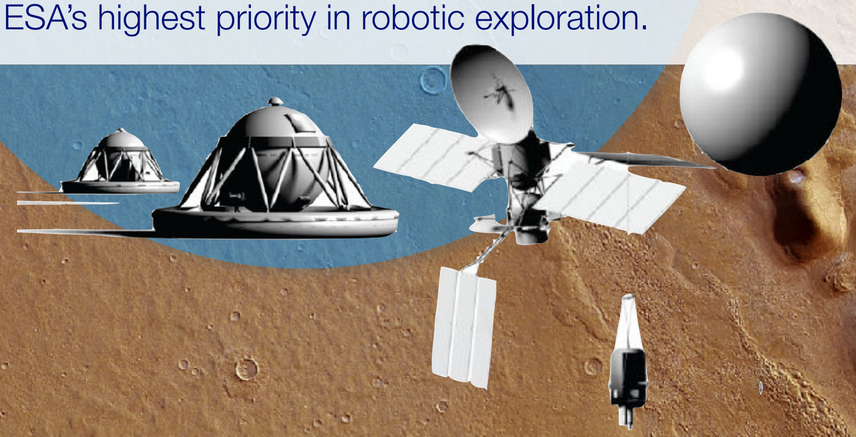
Jorge L. Vago, H. Svedhem, D. Rodionov, ExoMars project and ExoMars science working teams

MEPAG
5 April 2018, Arlington VA (USA)

Cooperation

ExoMars Programme

- Consists of two missions, in 2016 and 2020.
- A cooperation between ESA and Roscosmos (agreement signed in Mar 2013).
- The programme also includes some important contributions from NASA.
- ExoMars constitutes ESA's highest priority in robotic exploration.



Upper Reul Vallis, MEX / HRSC

2016 Mission Objectives

E X O M A R S

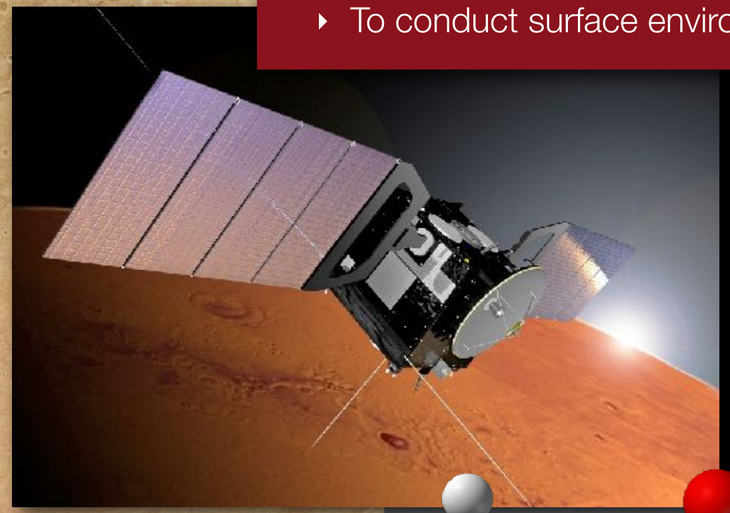
TECHNOLOGY OBJECTIVE

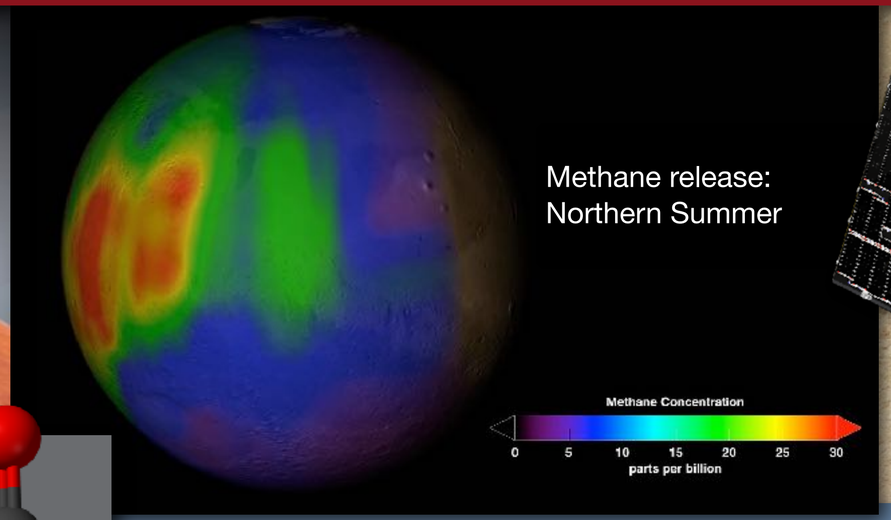
- Entry, Descent, and Landing (EDL) of a payload on the surface of Mars.

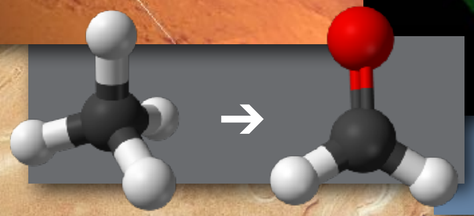
2016

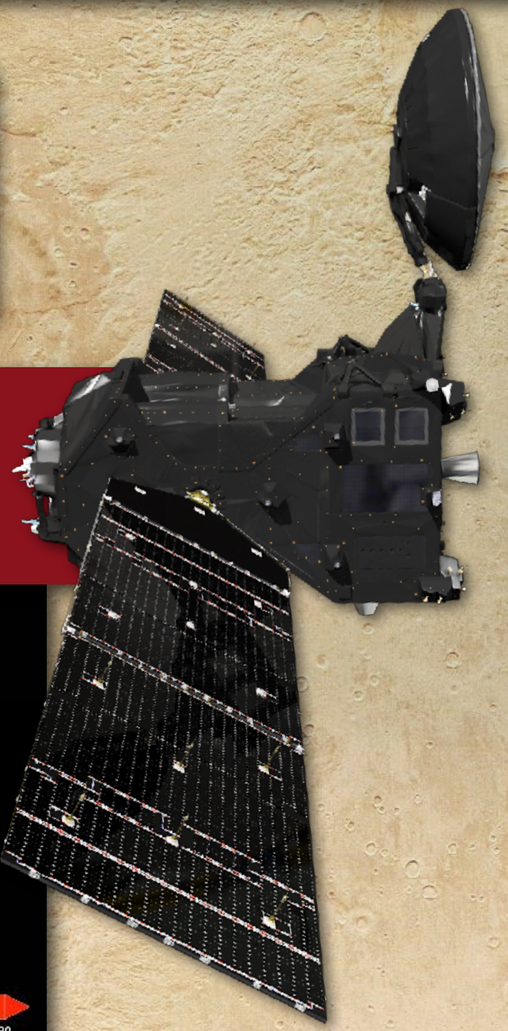
SCIENTIFIC OBJECTIVES

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





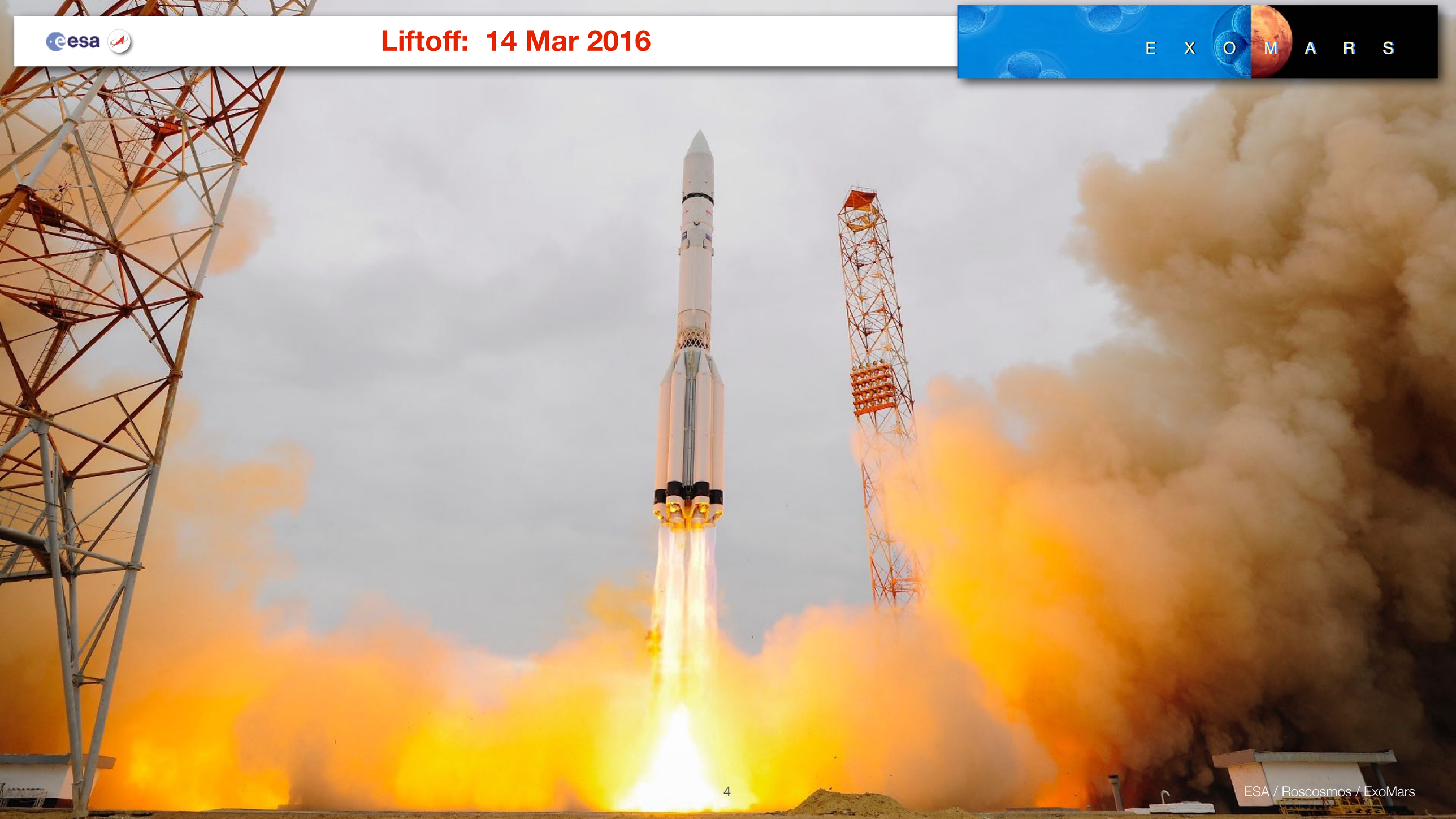




- Data relay services for landed missions until 2022.

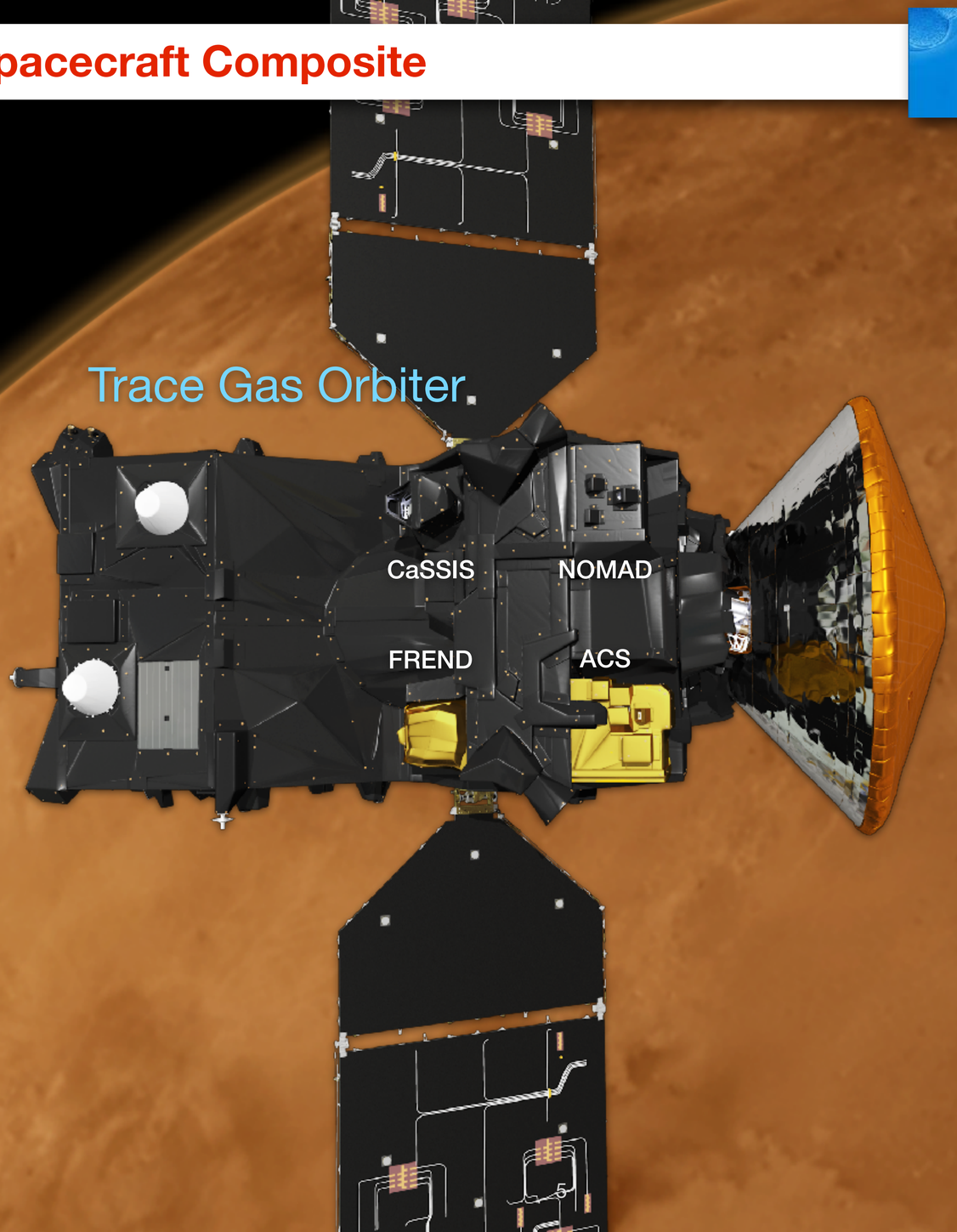
Mamers Valles, MEX / HRSC

Liftoff: 14 Mar 2016



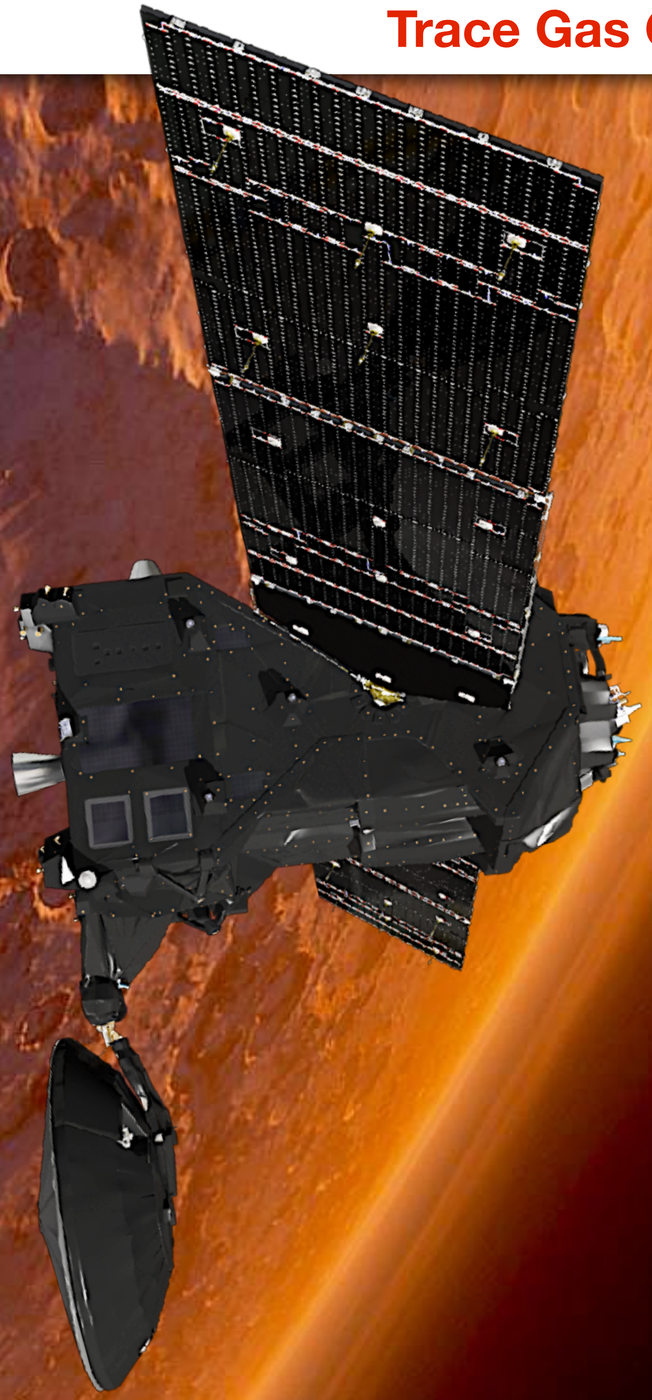
ESA / Roscosmos / ExoMars

Spacecraft Composite



ESA / Medialab

Trace Gas Orbiter



NOMAD

High-resolution occultation and nadir spectrometers

Atmospheric composition (CH_4, 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, Nadir
Mid-IR (2.3 – 4.5 μm) λ/Δλ ~50,000	SO

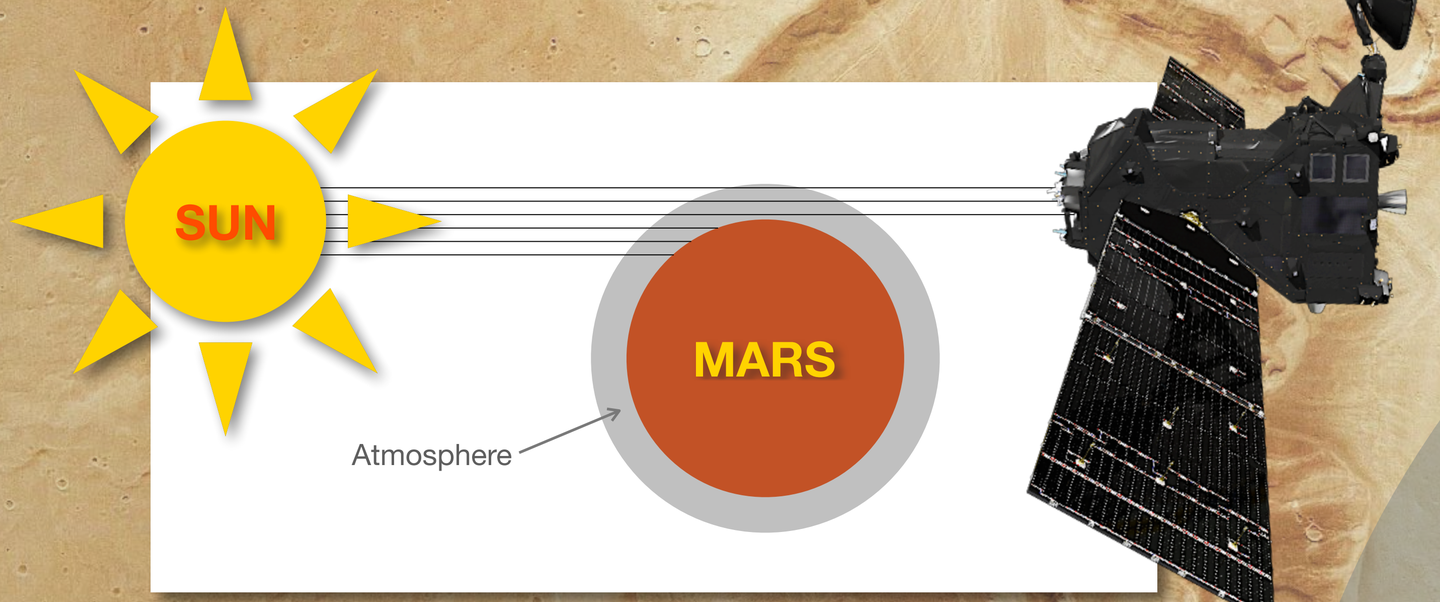
FREND

Collimated neutron detector

Mapping of subsurface water and hydrated minerals

ESA / Medialab, Kees Veenenbos

Modes of Observation



Orbit:

- Altitude: 400 km
- Inclination: 74°
- Period: 2 hours

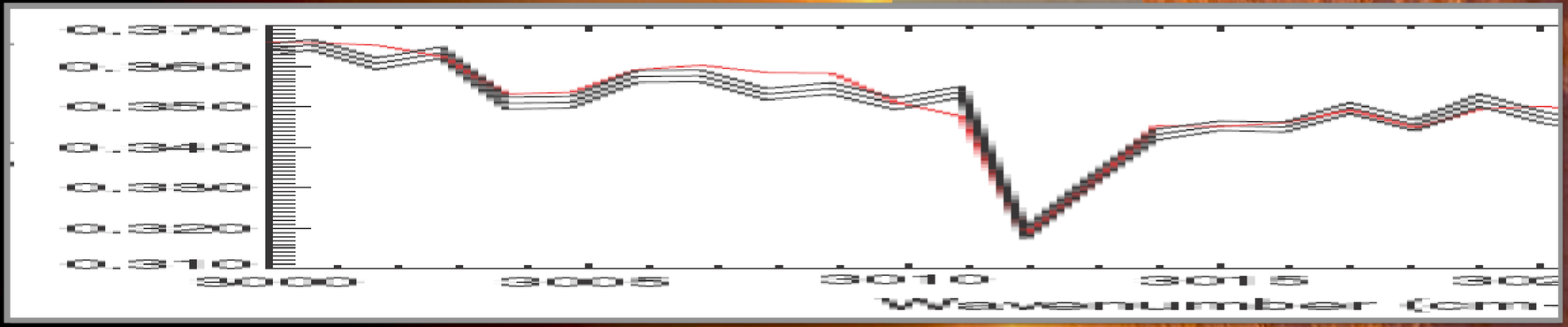
Pointing possibilities:

- **Solar occultation:** Use the sun as bright IR source for high sensitivity observations.
- **Nadir (±5° off-axis):** To correlate atmospheric measurements and surface information.
- **Limb scanning:** For investigating atmospheric vertical structure.

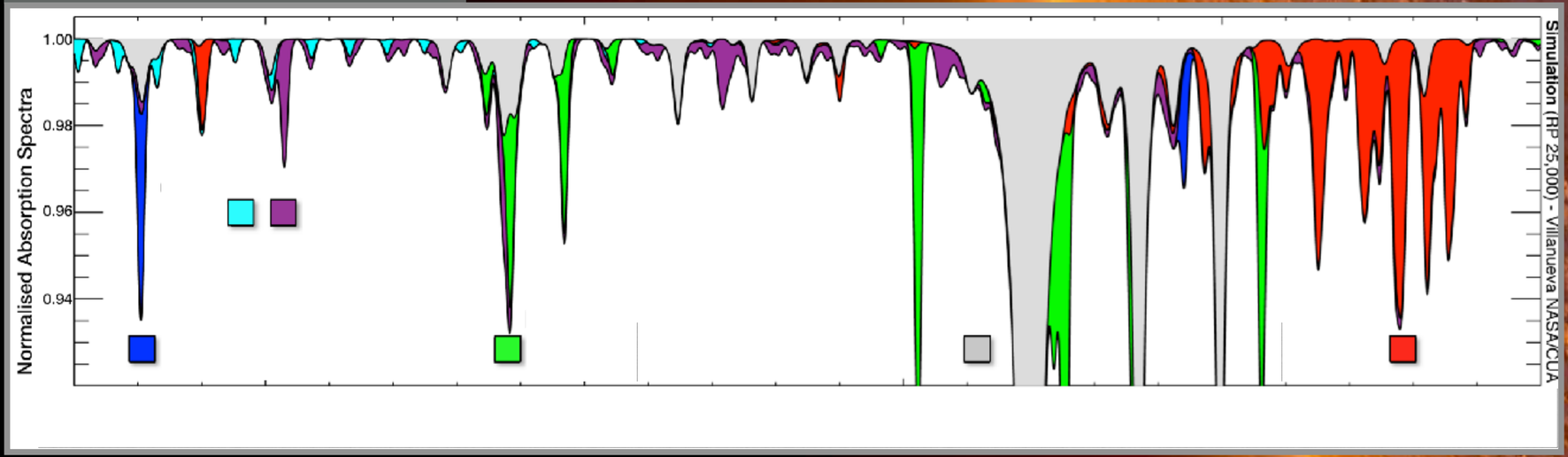
Mamers Valles, MEX / HRSC

TGO and MEX Spectral Resolutions

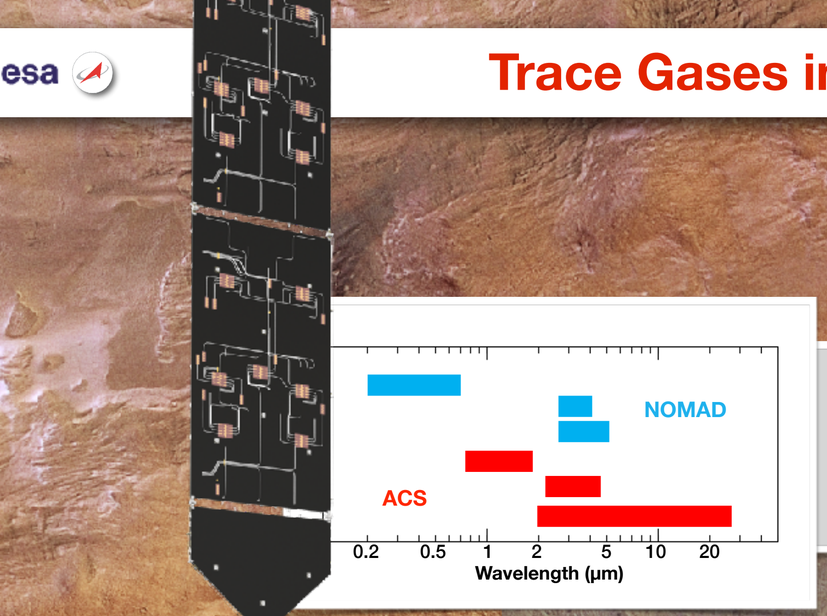
PFS on MEX



NOMAD and ACS on TGO



Trace Gases in IR and UV



- Methane detection can be confirmed (if present) by many absorption bands.
- TGO methane sensitivity is 100 ppt (~1000 times better than Mars Express).
- The ability to also measure other hydrocarbons will help establish its origin.

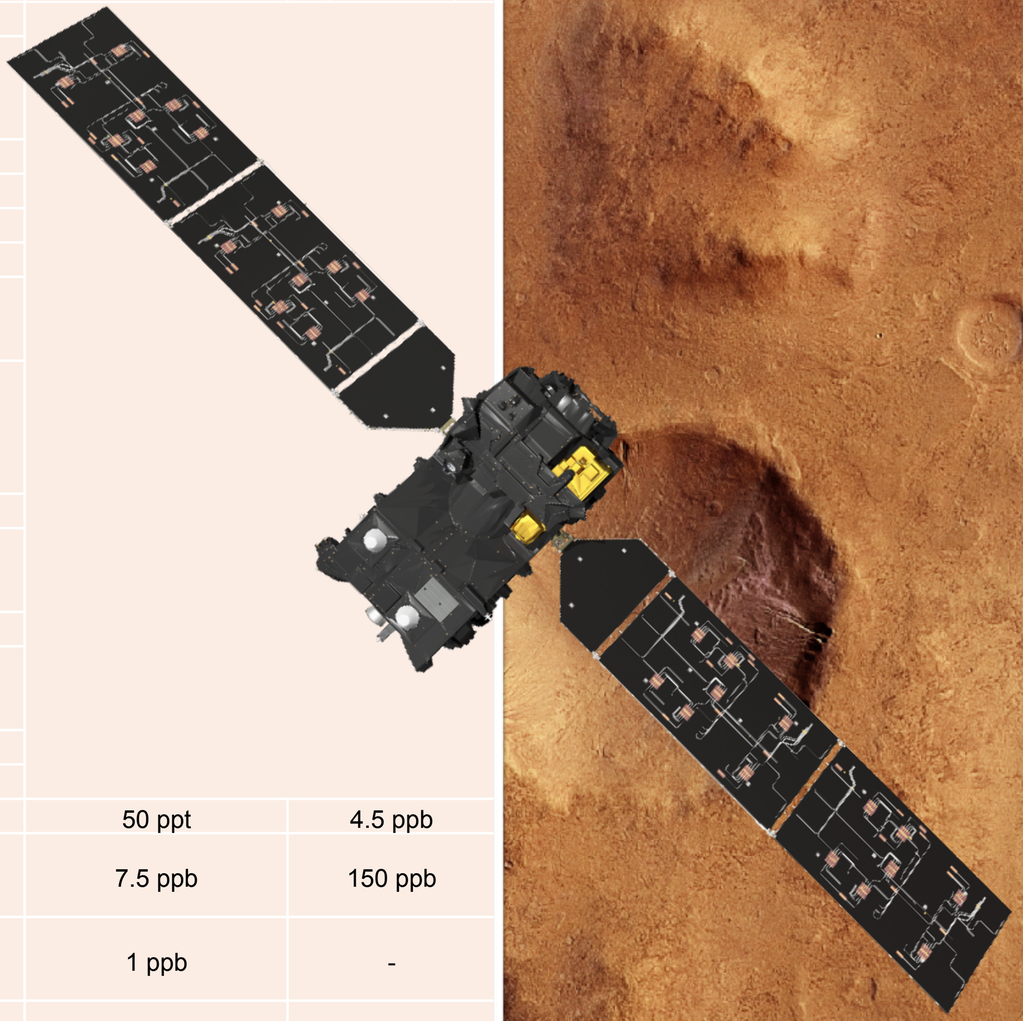
Infrared:
CO_2 (and $^{13}CO_2$, ^{17}OCO, ^{18}OCO, $C^{18}O_2$), CO (and ^{13}CO, $C^{18}O$), H_2O (and HDO), NO_2, N_2O, CH_4 (and $^{13}CH_4$, CH_3D), C_2H_2, C_2H_4, C_2H_6, H_2CO, HCN, OCS, HCl, HO_2, H_2S, aerosols/ice

Ultraviolet:
O_3 and SO_2

Argyre, MEX / HRSC

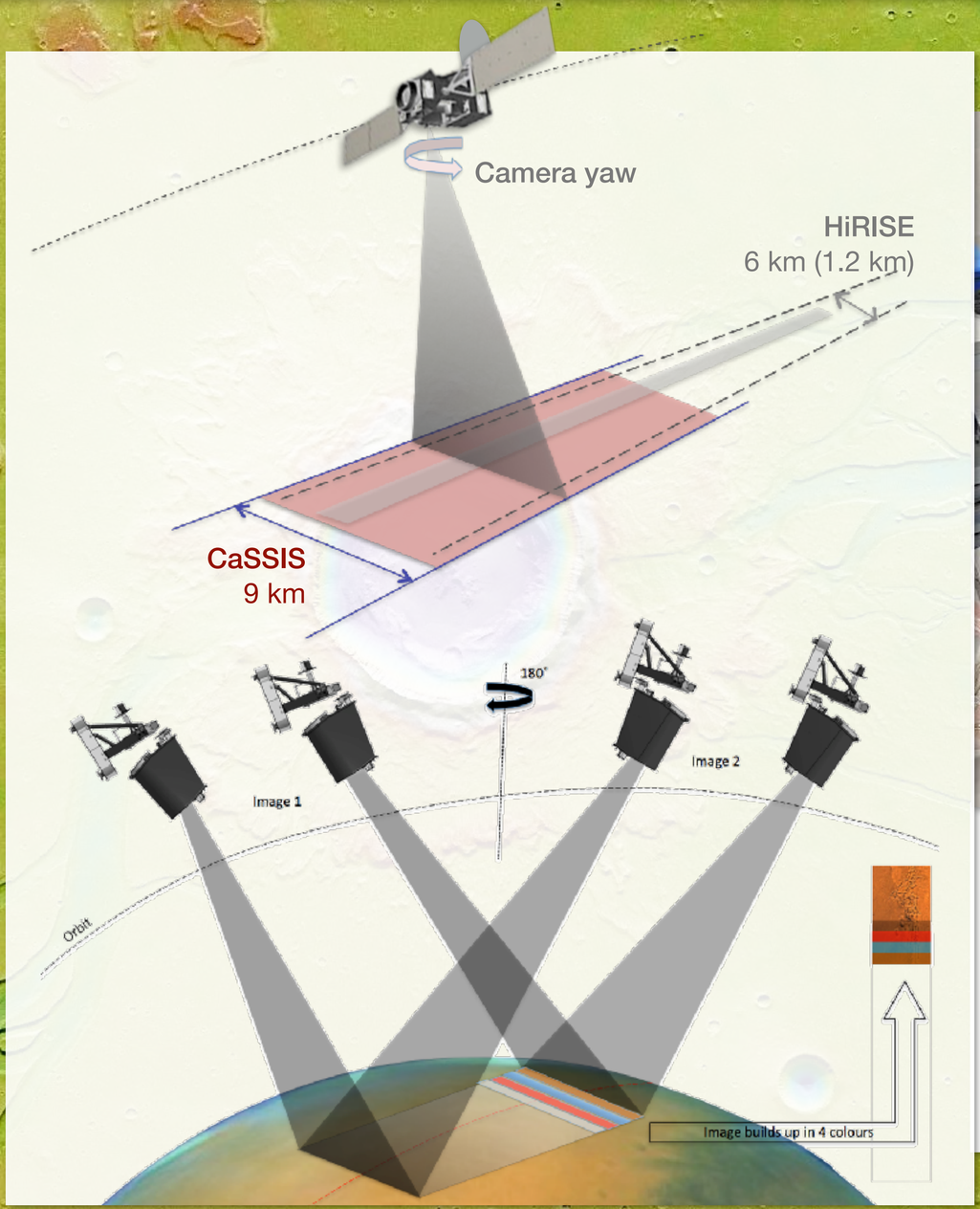
Trace Gases in IR and UV

		SO	LNO		UVIS	
		Solar Occultation (SNR = 2000)	Solar Occultation (SNR = 3000)	Nadir (SNR = 100)	Solar Occultation (SNR = 500)	Nadir (SNR = 500)
CH_4	0-60 ppb [a]	25 ppt	20 ppt	11 ppb		
H_2O	< 300 ppm (variable with season)[b]	0.2 ppb	0.15 ppb	31 ppb		
HDO	D/H =5.6 SMOW[c]	0.7 ppb	0.7 ppb	0.8 ppm		
CO	700 - 800 ppm [d]	5 ppb	4 ppb	1.5 ppm		
C_2H_2	< 2 ppb [g]	0.03 ppb	0.03 ppb	20 ppb		
C_2H_4	< 4 ppb [g]	0.2 ppb	0.15 ppb	70 ppb		
C_2H_6	< 0.2 ppb [e] < 0.7 ppb [g]	0.03 ppb	0.02 ppb	11 ppb		
HCl	< 3 ppb [e] < 0.2 ppb [f] < 0.6 ppb [g]	0.03 ppb	0.025 ppb	31 ppb		
HCN	< 5 ppb [g]	0.03 ppb	0.03 ppb	15 ppb		
HO_2	0.1-6 ppb [l] < 200 ppb [g]	1 ppb	1 ppb	0.5 ppm		
H_2S	< 200 ppm [h]	4 ppb	3 ppb	1.6 ppm		
N_2O	< 100 ppb [h] < 90 ppb [g]	0.2 ppb	0.2 ppb	83 ppb		
NO_2	< 10 ppb [h]	0.14 ppb	0.1 ppb	50 ppb		
OCS	< 10 ppb [h]	0.3 ppb	0.3 ppb	122 ppb		
O_3		2.5 ppb	1.5 ppb	0.8 ppm	50 ppt	4.5 ppb
H_2CO	< 4.5 ppb [e] < 3.9 ppb [g]	0.04 ppb	0.03 ppb	16 ppb	7.5 ppb	150 ppb
NH_3	< 5 ppb [h] < 60 ppb [g]				1 ppb	-
SO_2	< 1 ppb [i] < 2 ppb [j,k]				0.5 ppb	18 ppb

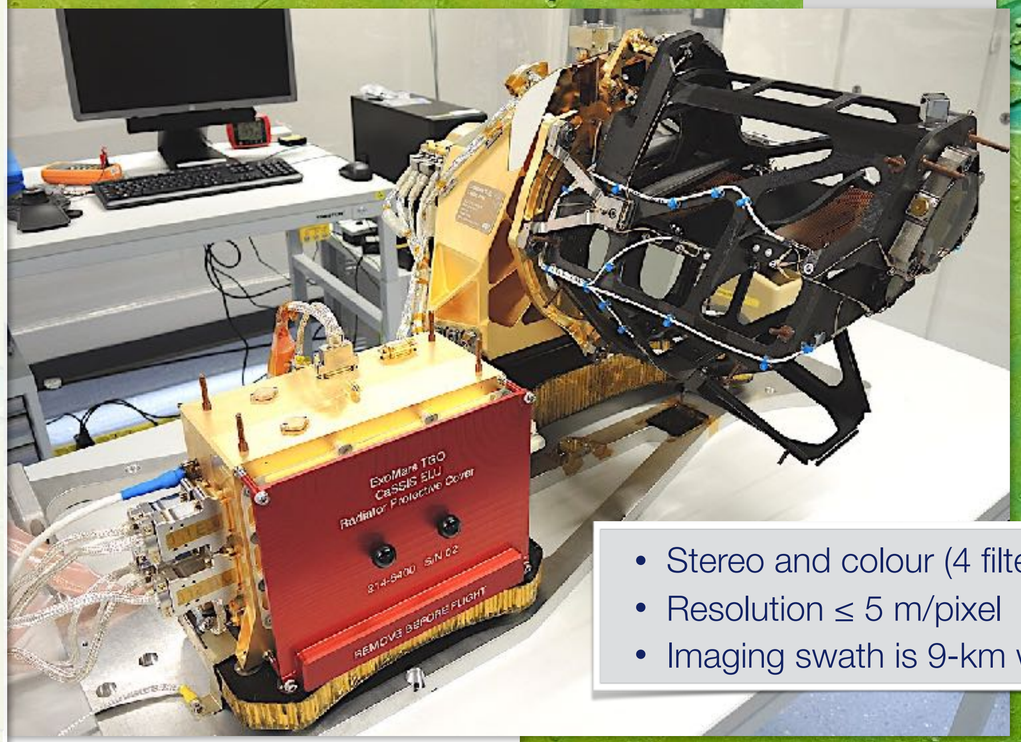


Argyre, MEX / HRSC

Colour, Stereo Camera



CaSSIS



- Stereo and colour (4 filters)
- Resolution ≤ 5 m/pixel
- Imaging swath is 9-km wide

University of Bern

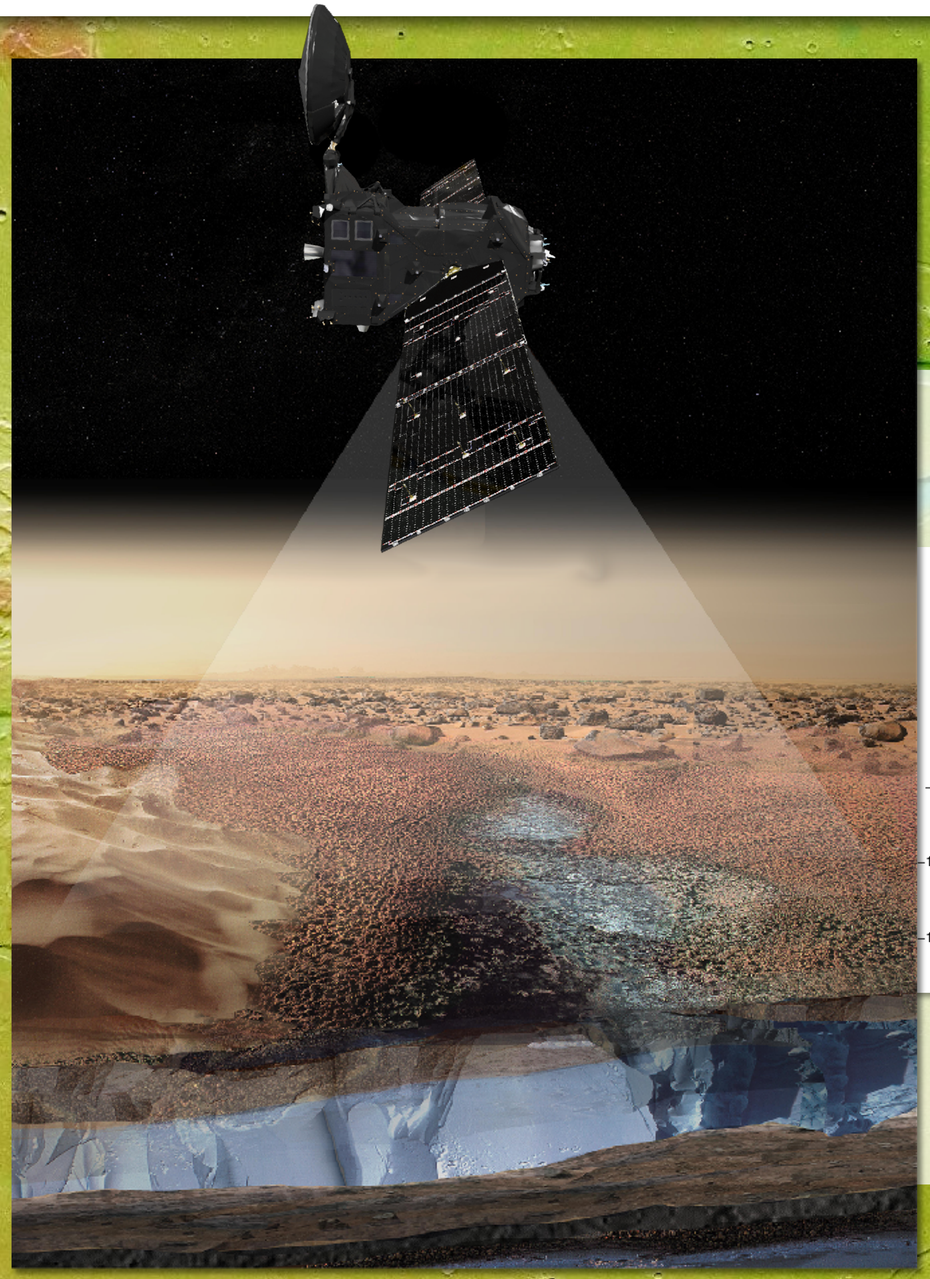
Hephaestus Fossae, MEX / HRSC

500m

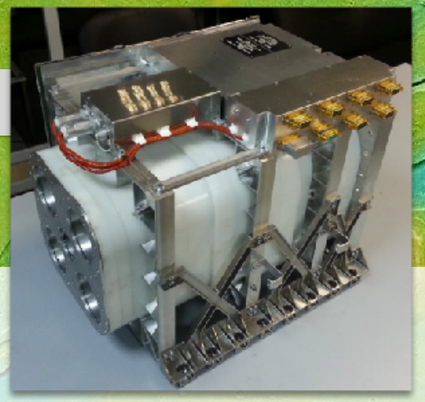
CaSSIS scan imaging of Hebes Chasma from 235km, 2.8m/pixel, 22 Nov 2016

ESA / ExoMars / CaSSIS

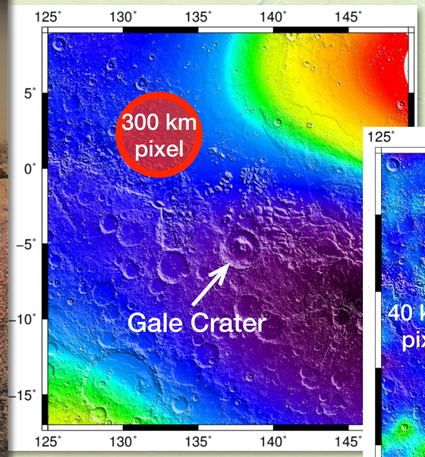
Subsurface Water



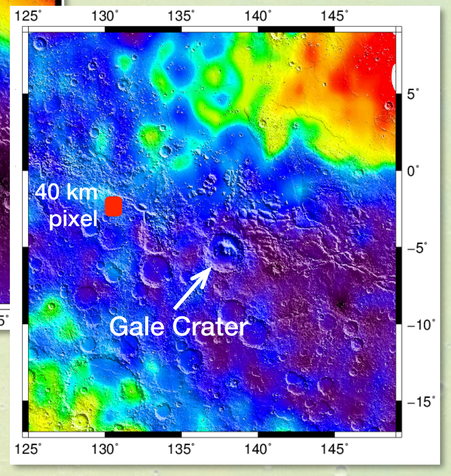
FREND



HEND/Odyssey data,
300-km resolution



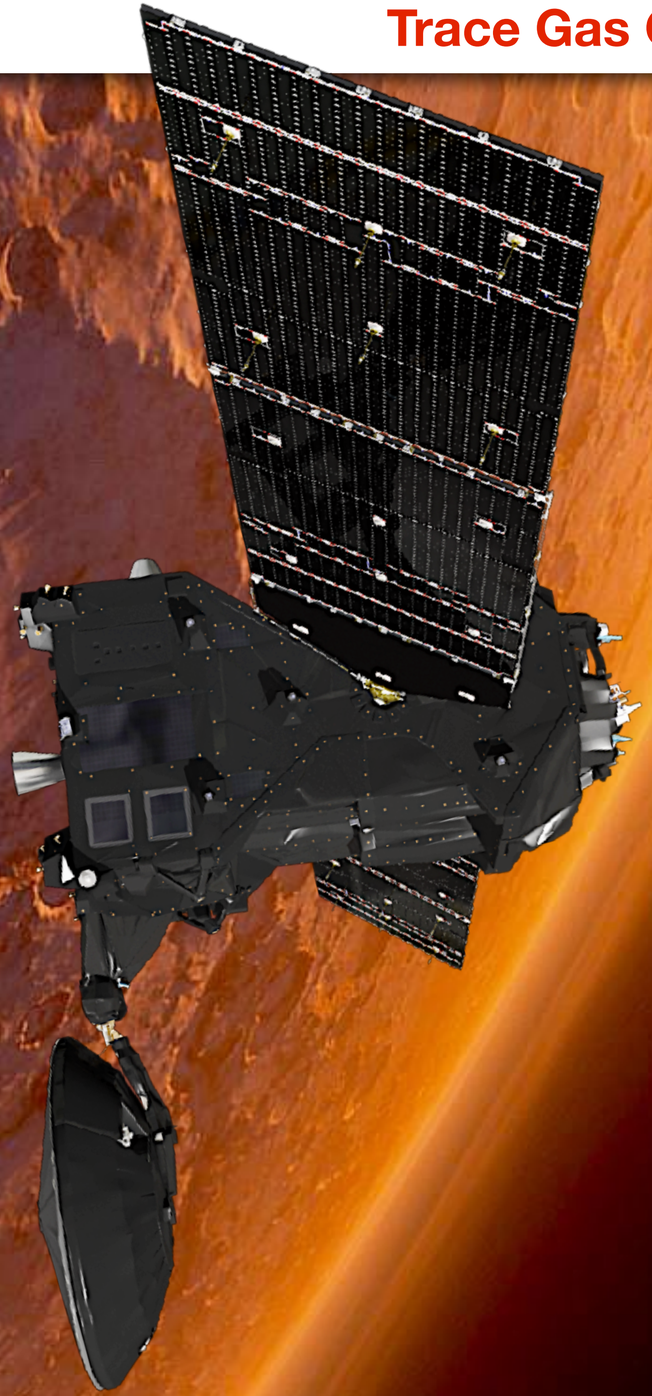
Simulation of FREND/TGO data
based on HEND/Odyssey,
40-km resolution



IKI, Moscow

Hephaestus Fossae, MEX / HRSC

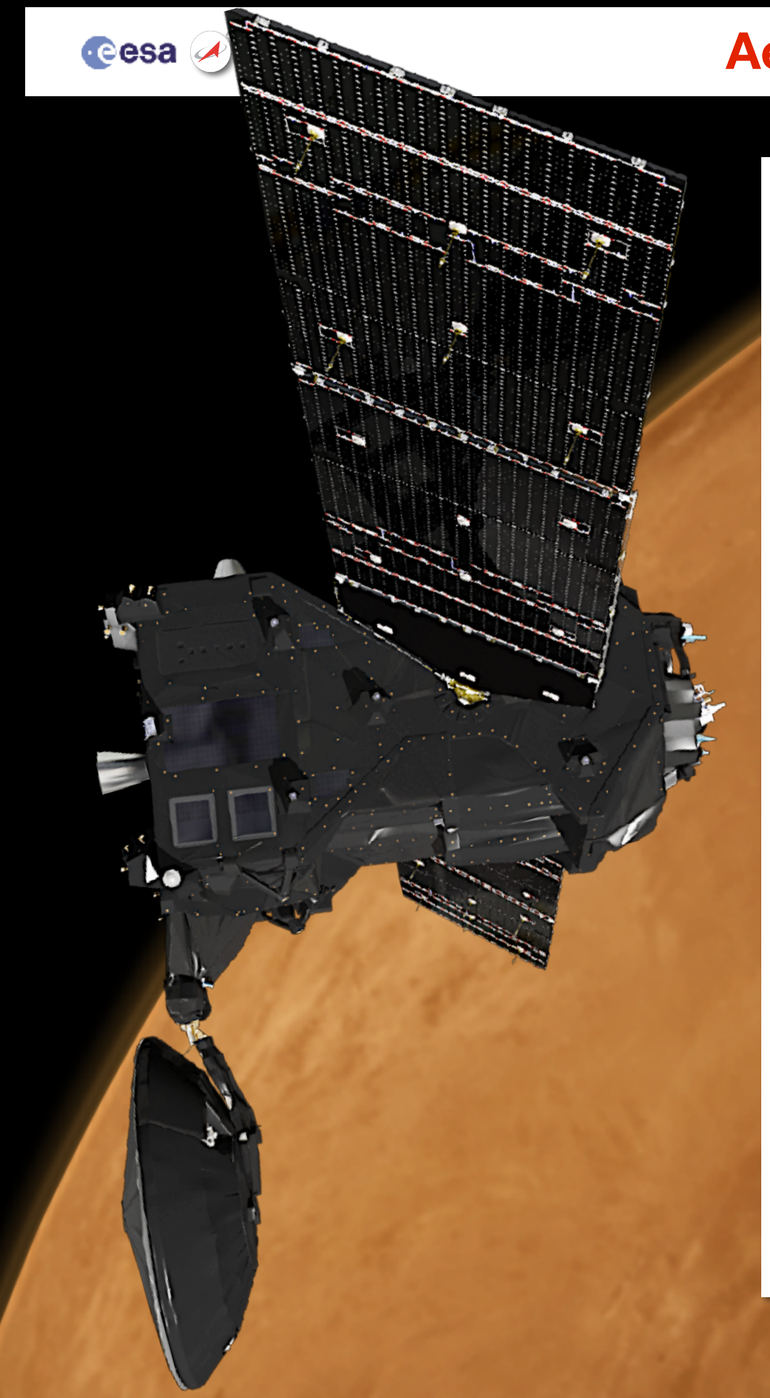
Trace Gas Orbiter

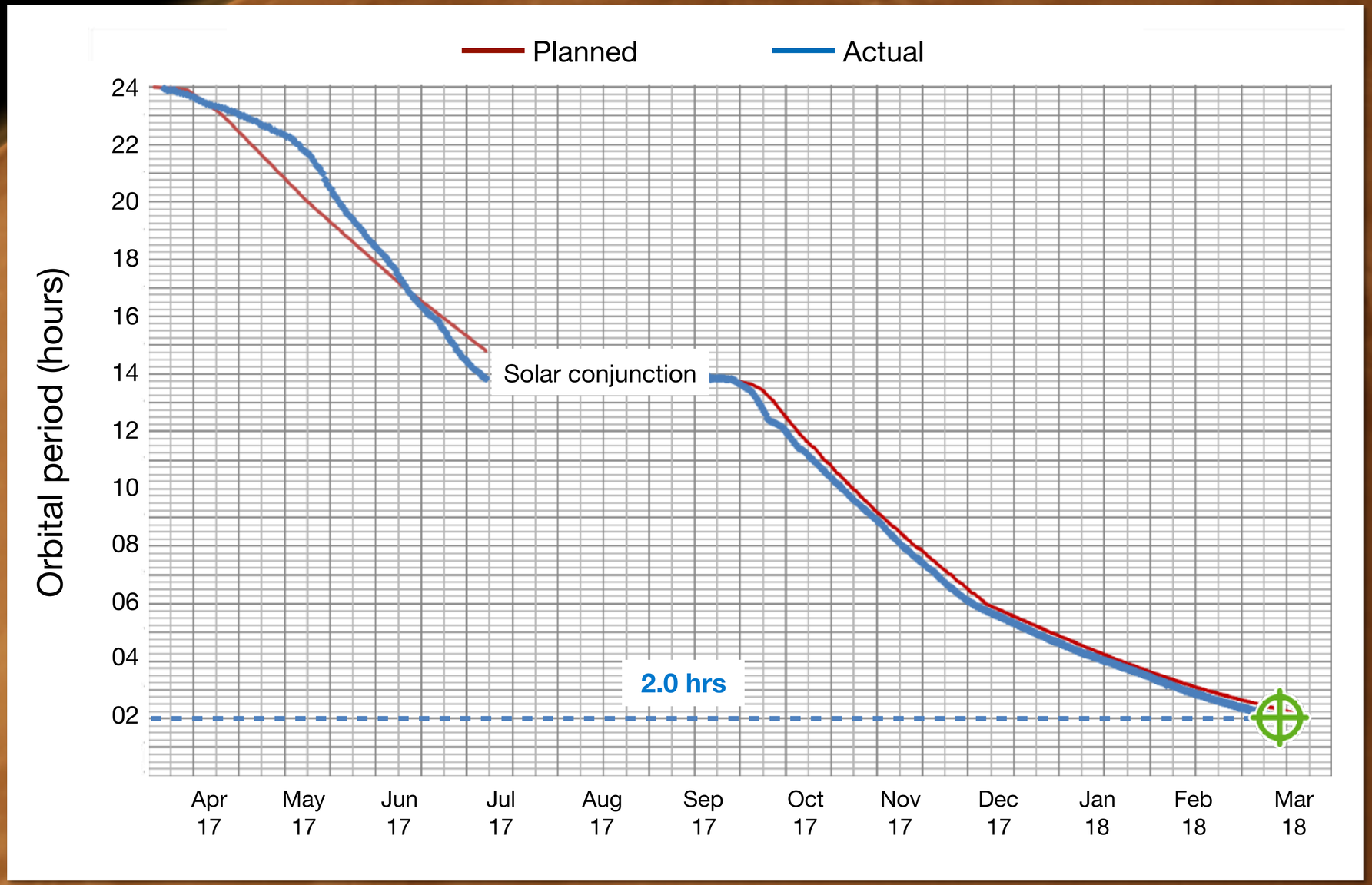


- TGO overall status is excellent.
- All instruments were utilised from the Mars capture orbit (during Nov 2016 and Feb-Mar 2017).
- Aerobraking started with a “walk in” phase on March 2017.
- End of aerobraking was accomplished on 20 Feb 2018.
- The circularisation of the orbit is being performed stepwise. The final orbit will be reached on 7 Apr 2018.
- First atmospheric sun occultation measurements on 21 Apr 2018.

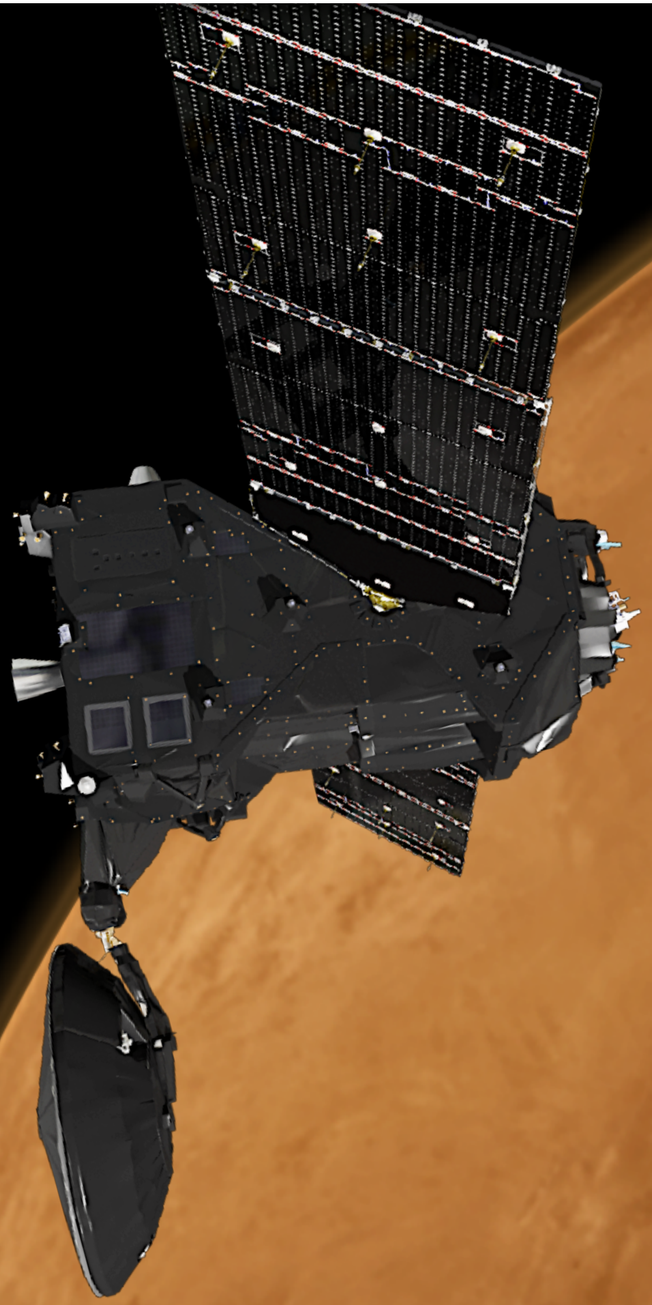
Credit: ESA/Medialab, Kees Veenenbos

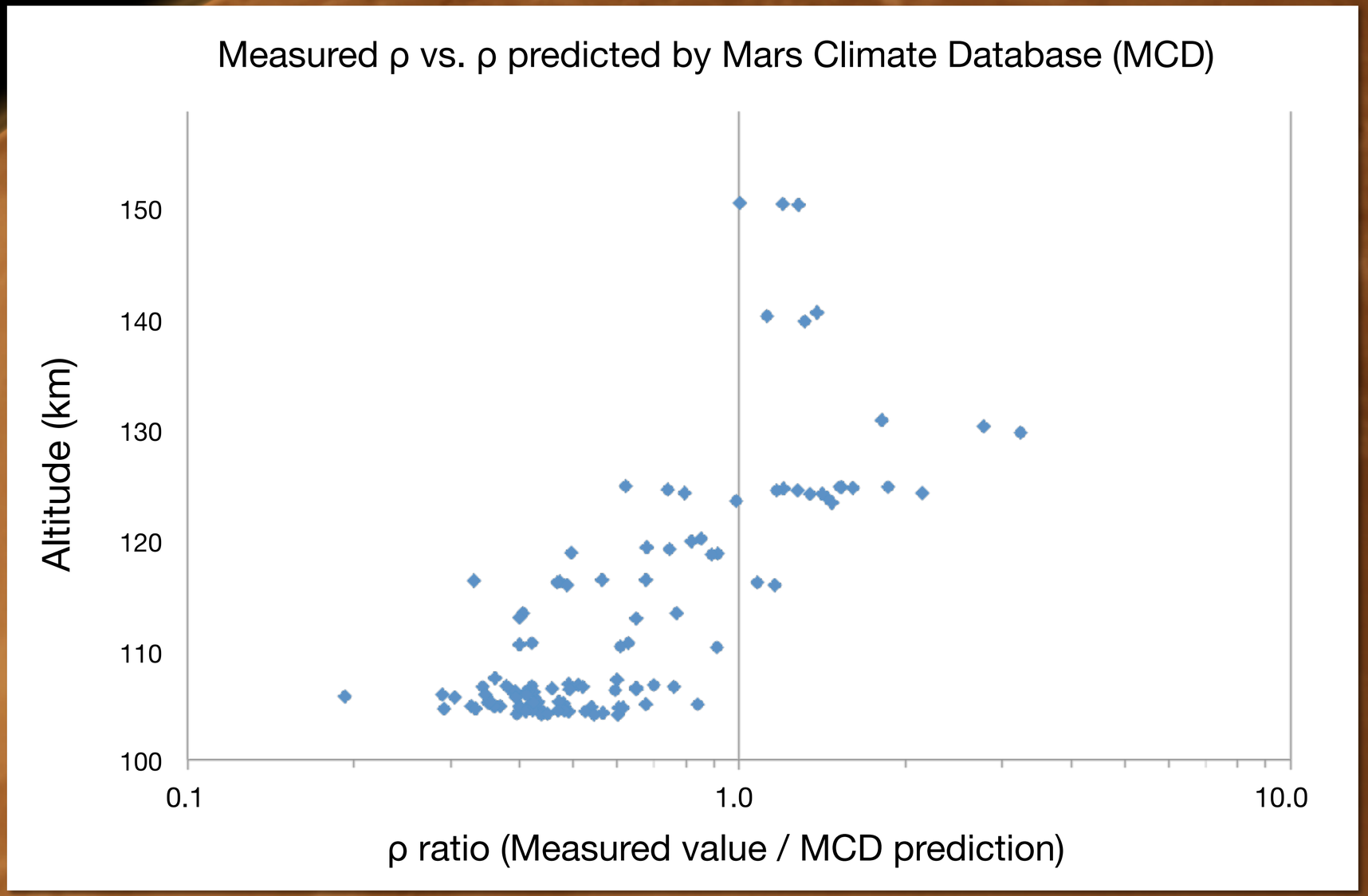
Aerobraking





Measured vs. Predicted Density

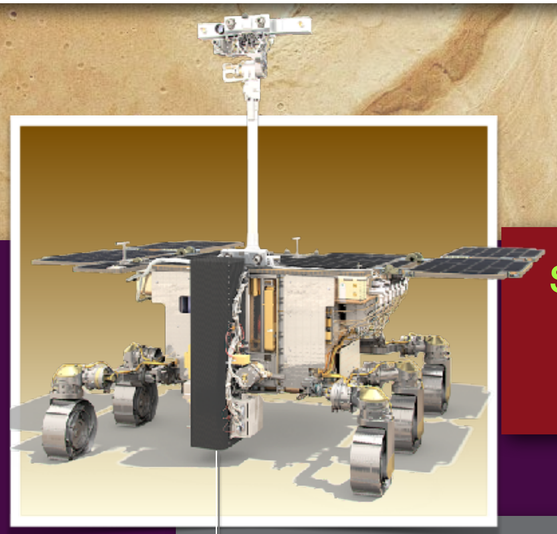




2020 Mission Objectives

EXOMARS

2020



SCIENTIFIC OBJECTIVES

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

TECHNOLOGY OBJECTIVES

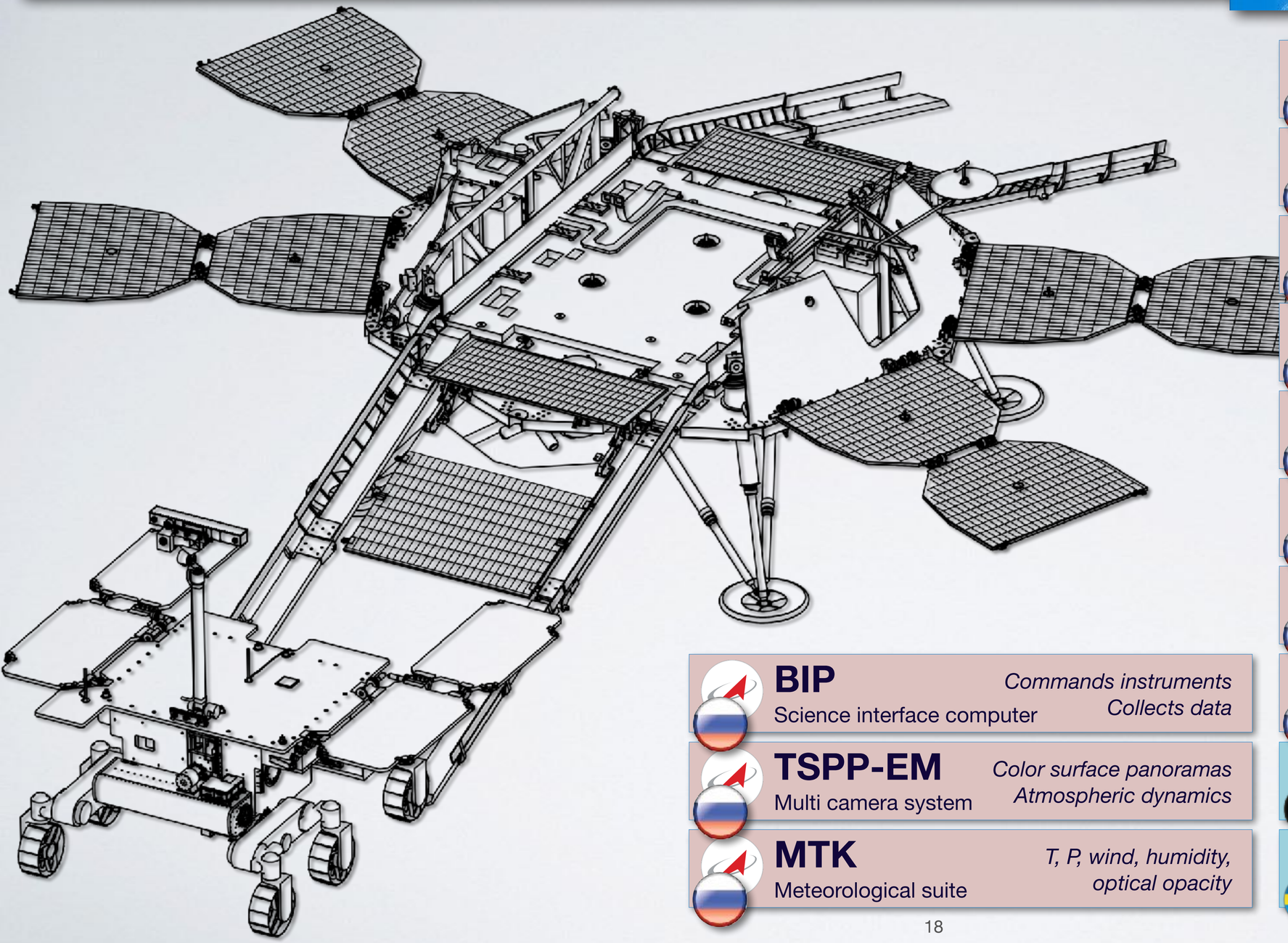
- Surface mobility with a rover (having several kilometres range);
- Access to the subsurface to collect samples (with a drill, down to 2-m depth);
- Sample acquisition, preparation, distribution, and analysis.

- To characterise the surface environment.

- Throttleable braking engines for planetary landing.
- Russian deep-space communications stations working in combination with ESA's ESTRACK.

Mamers Valles, MEX / HRSC

Surface Platform



BIP — Science interface computer
Commands instruments
Collects data

TSPP-EM — Multi camera system
Color surface panoramas
Atmospheric dynamics

MTK — Meteorological suite
T, P, wind, humidity, optical opacity

PK — Dust suite
Dust properties and E field monitoring

FAST — IR Fourier spectrometer
Trace gases, T, and aerosol monitoring

RAT-M — Microwave radiometer
Surface and atmospheric T monitoring

ADRON-EM — Neutron detector
Subsurface water content
Radiation dosimetry

MAIGRET — Magnetometer
Magnetic field measurements

MGAK — GCMS
Atmospheric Analysis

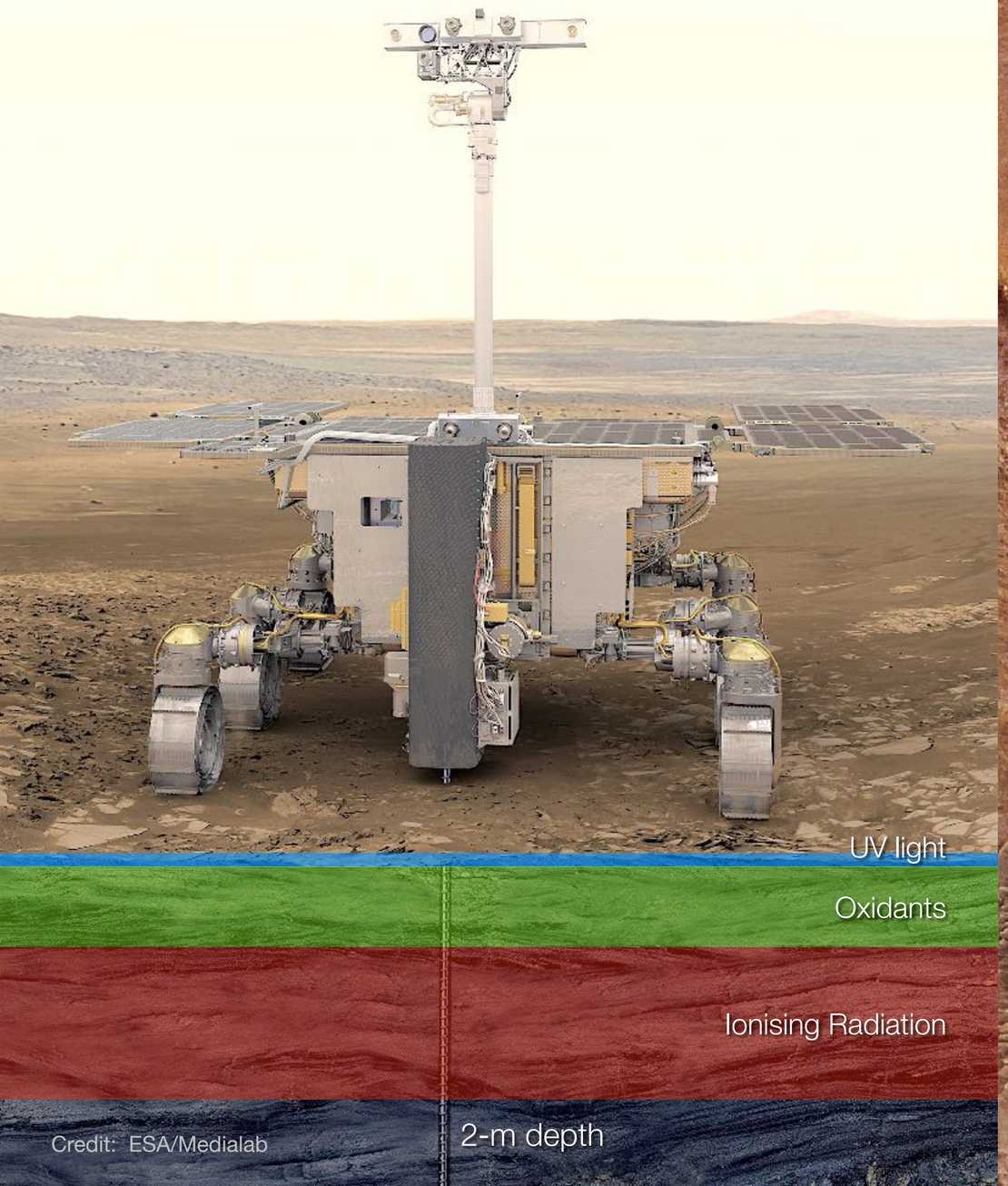
SEM — Seismometer
Internal Mars structure investigations

M-DLS — Diode laser spectrometer
Atmospheric chemical and isotopic composition

LaRa — Coherent transponder
Radio science for internal structure investigations

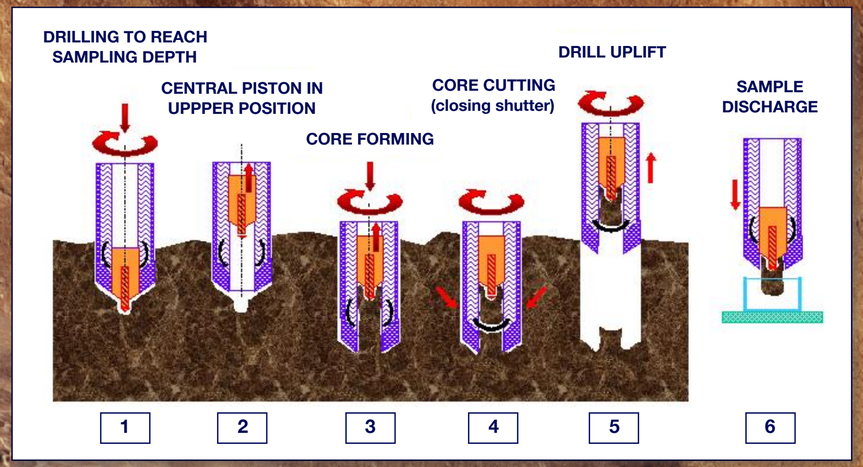
HABIT — Habitability studies
T, UV dose, humidity, salt deliquescence

Mobility + Subsurface Access



Credit: ESA/Medialab

Nominal mission :	218 sols
Nominal science :	6 Experiment Cycles + 2 Vertical Surveys
EC length :	16–20 sols
Rover mass :	300-kg class
Mobility range :	Several km

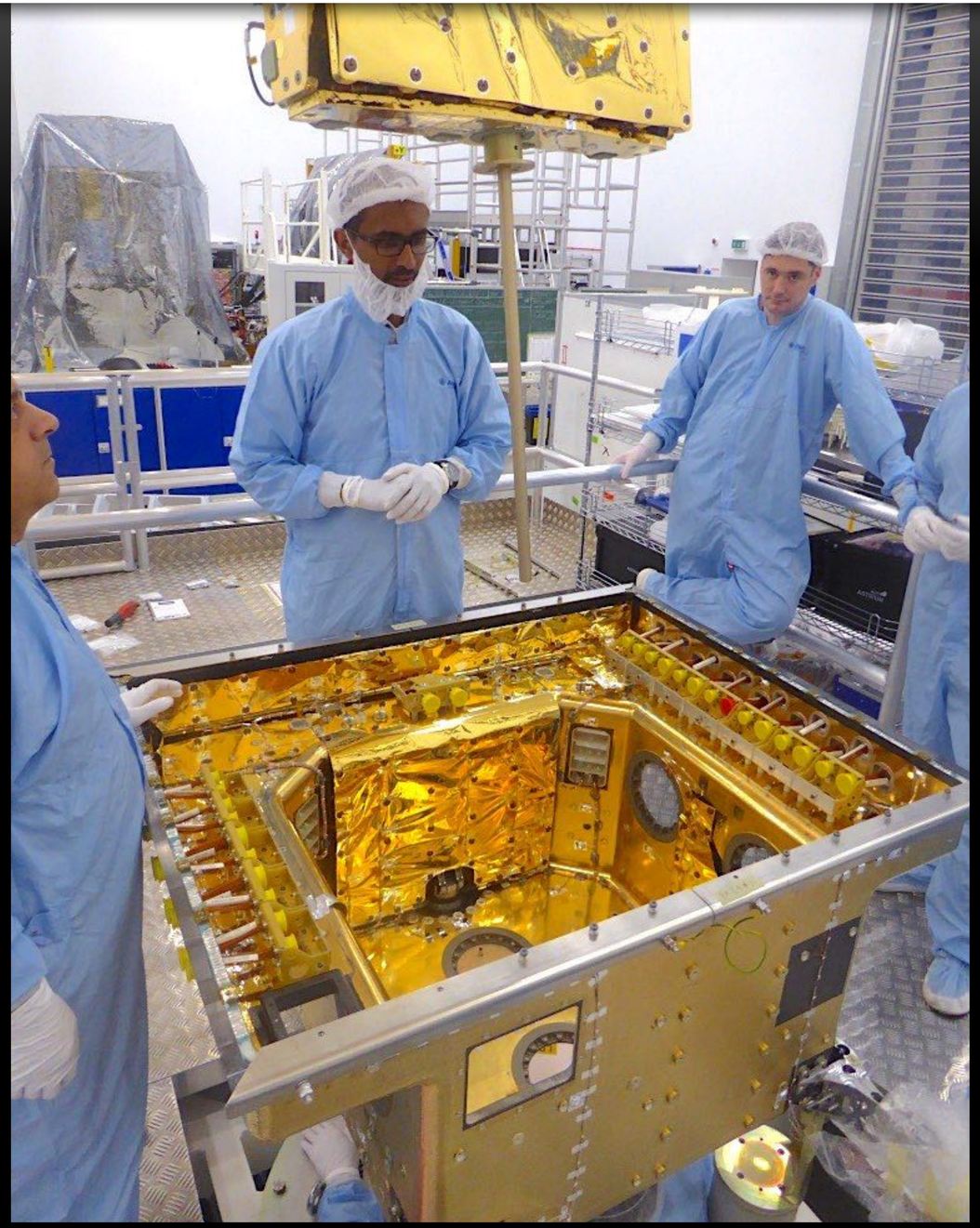


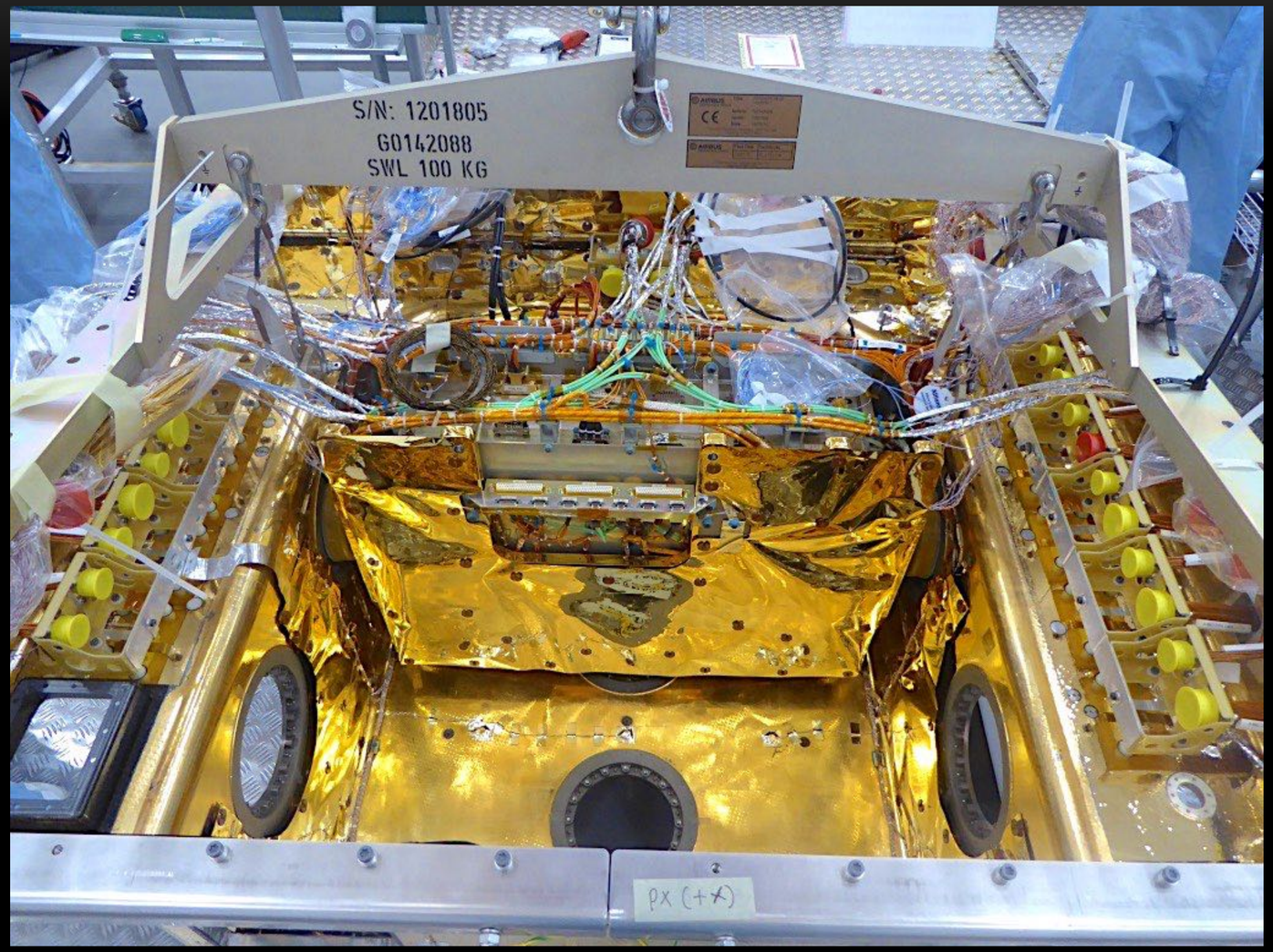
Argyre, MEX / HRSC

Mobility + Subsurface Access

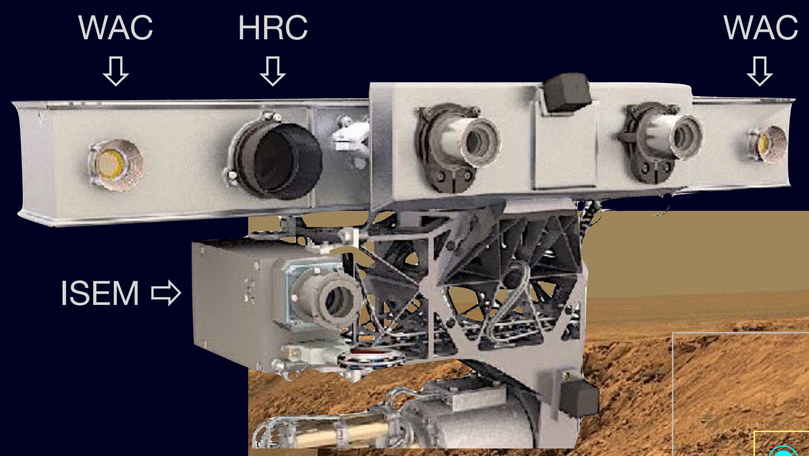
ESA / Medialab

Integration of Service Module



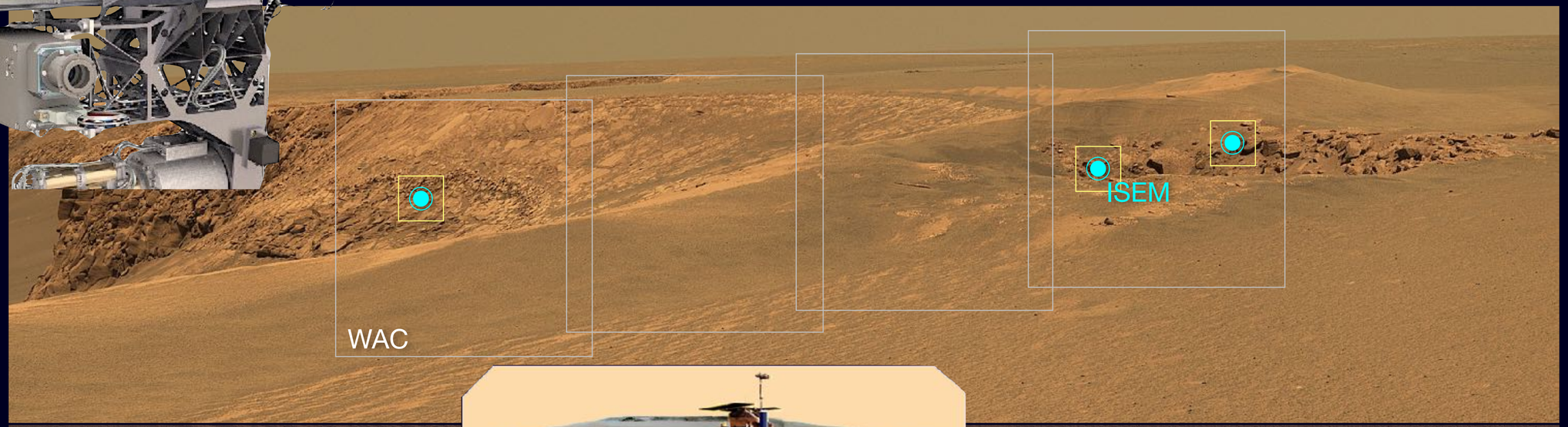


Site Characterisation

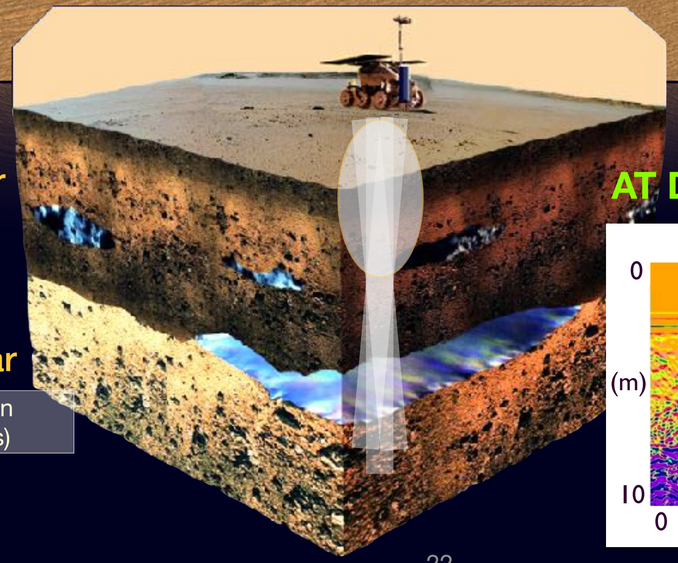


AT PANORAMIC SCALE: To establish the geological context

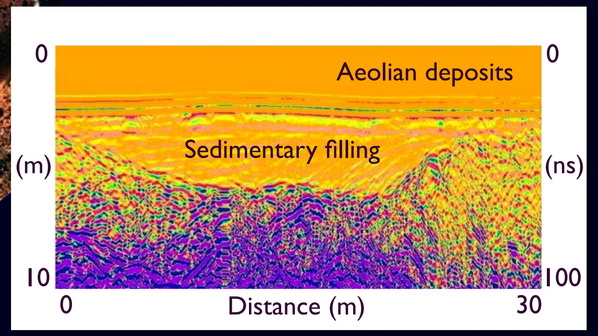
Two Wide Angle Cameras (WAC): Colour, stereo, 35° FOV;
One High-Resolution Camera (HRC): Colour, 5° FOV
One IR spectrometer (ISEM): 1° FOV.



Neutron Detector



AT DEPTH: To study the stratigraphy for drilling



Heggy et al. 2007

Ground Penetrating Radar

~3-m penetration, with ~2-cm resolution
(depends on subsurface EM properties)

Outcrop Characterisation

AT ROCK SCALE: To ascertain the past presence of water
For a more detailed morphological examination

High-Resolution Camera

Close-Up Imager

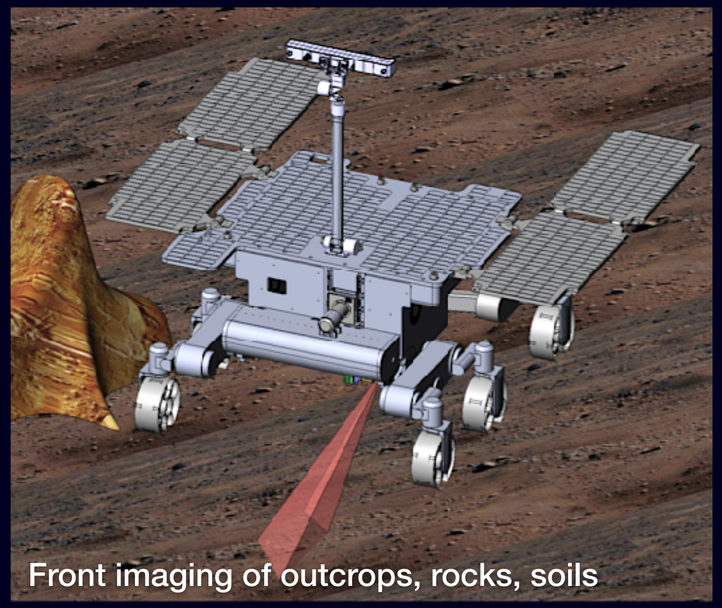
Colour, 20–100-µm/pixel resolution, 19° FOV,
Focusing range: 10 cm to ∞

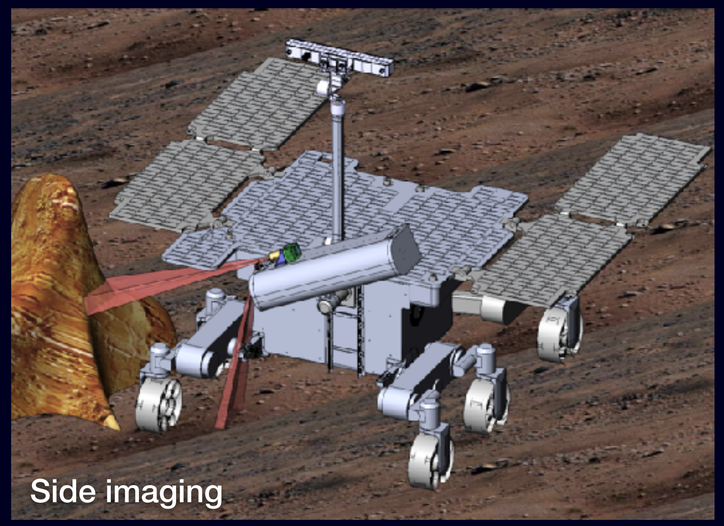
Next step: **ANALYSIS**

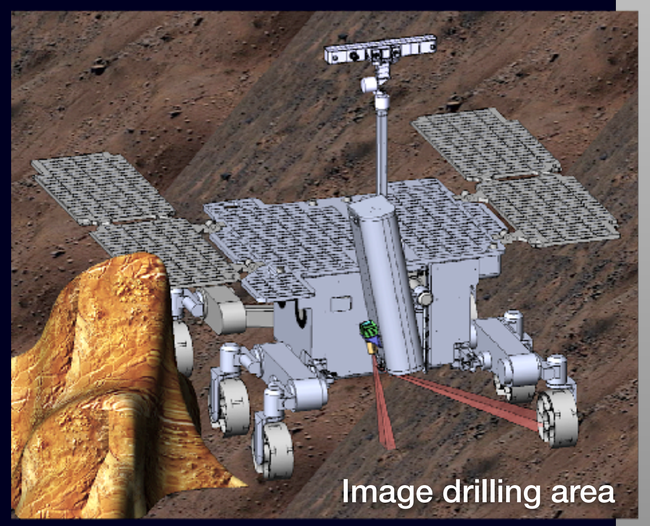
Use the drill to collect a sample

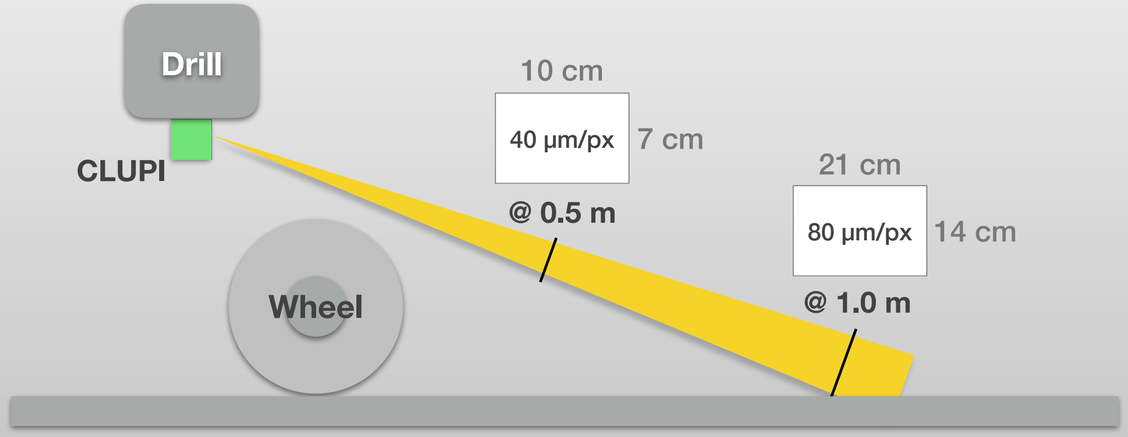
- From an outcrop
- From the subsurface

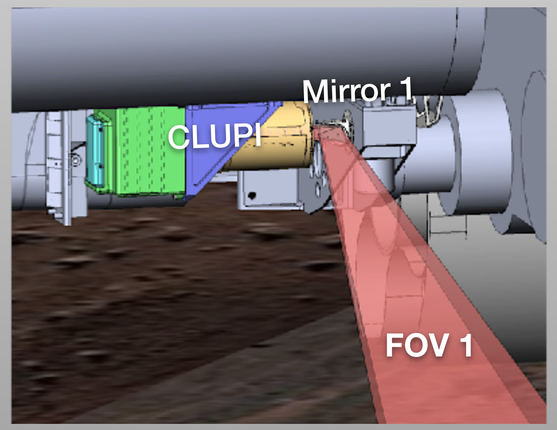
Close-Up Imager

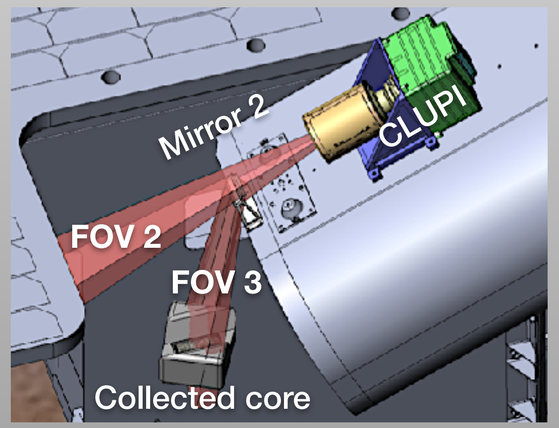


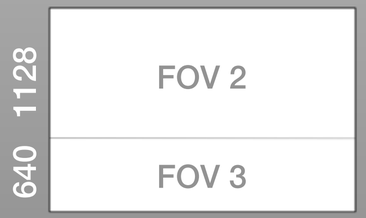






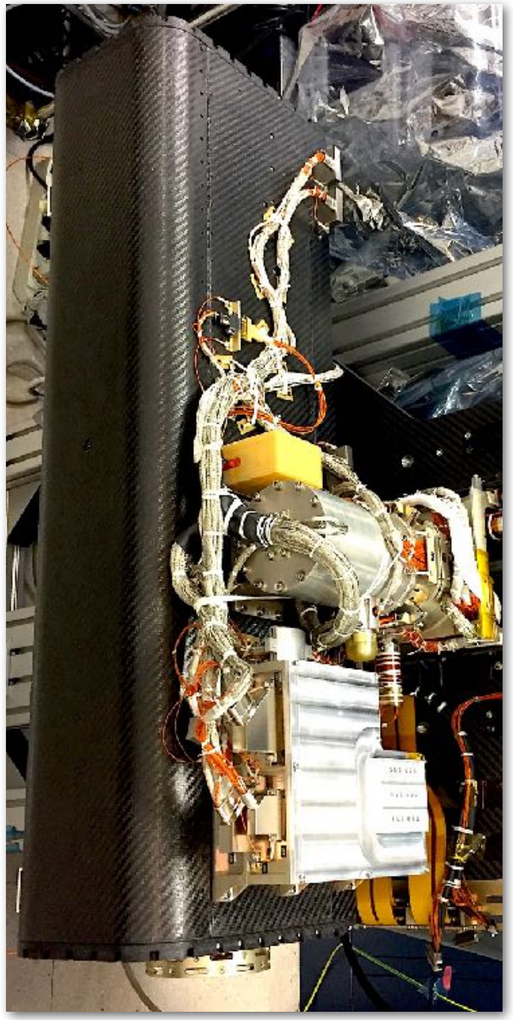


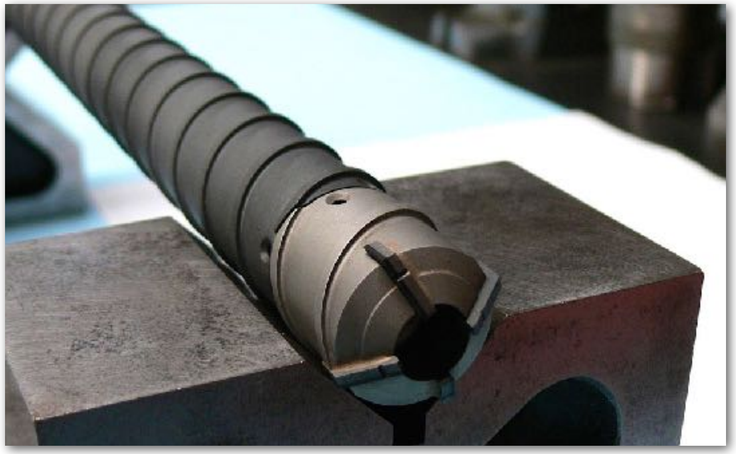




Subsurface Drill

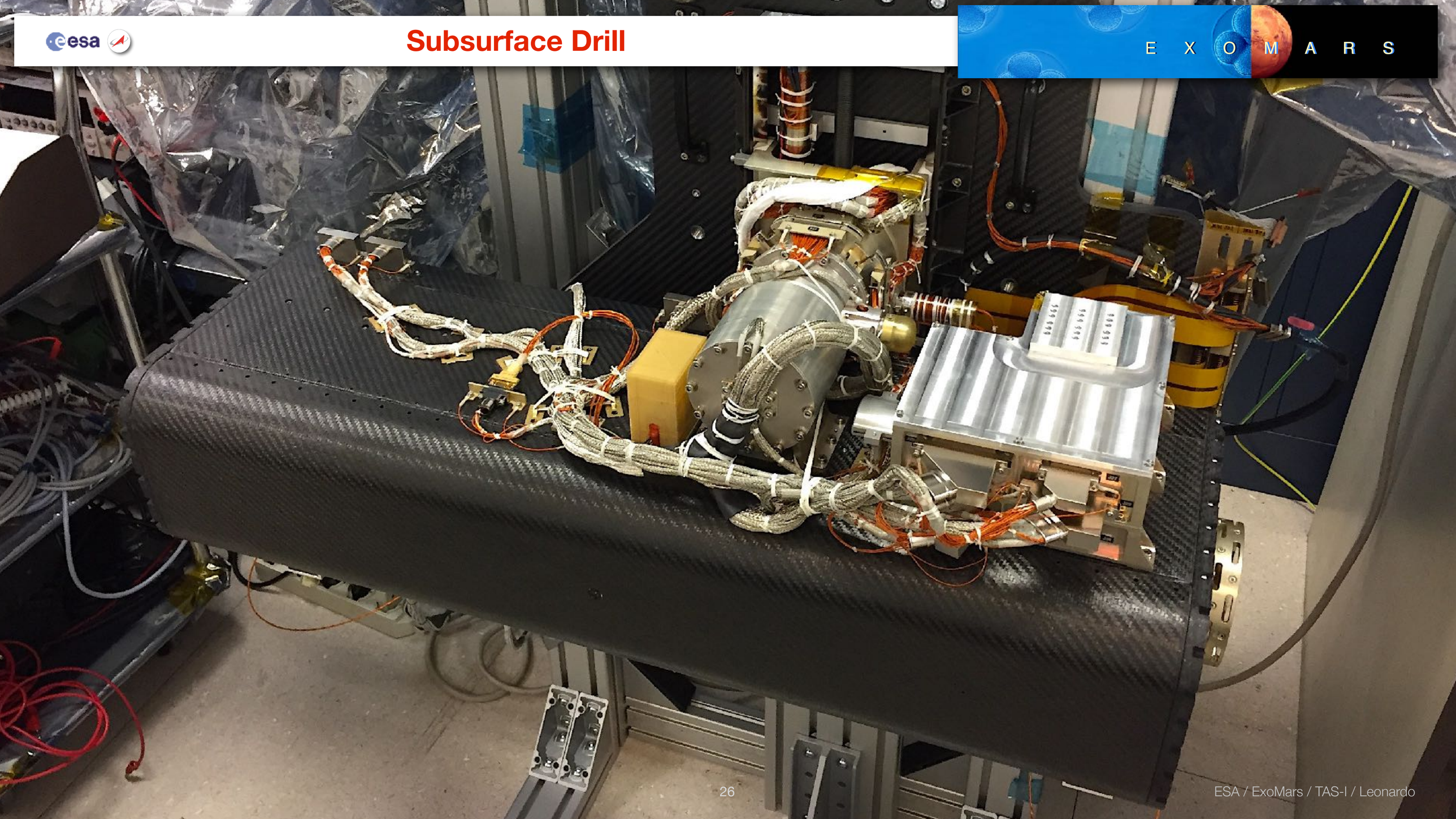
OBTAIN SAMPLES FOR ANALYSIS: From 0 down to 2-m depth





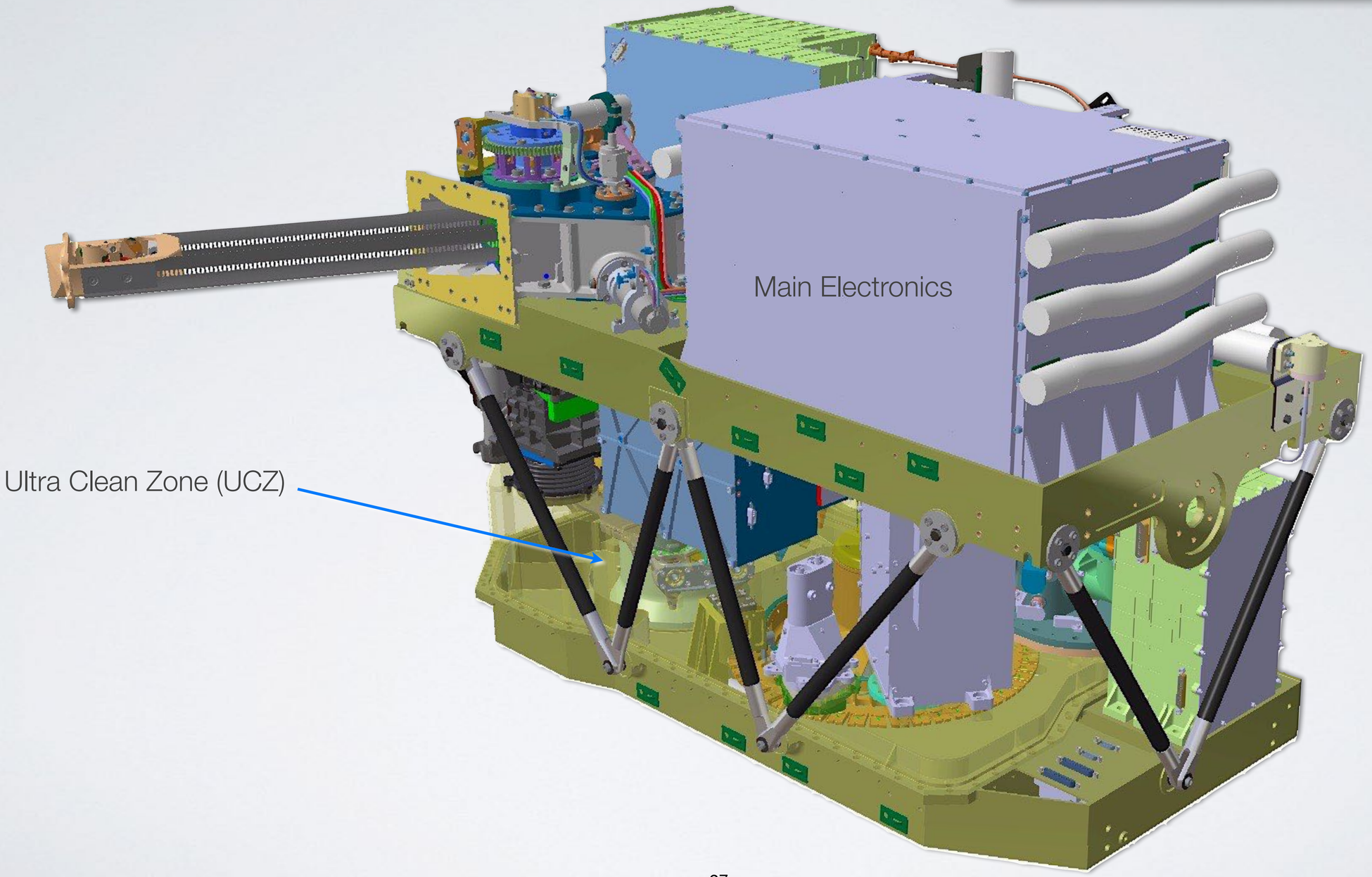
Subsurface drill includes a miniaturised IR spectrometer for borehole investigations.

Subsurface Drill

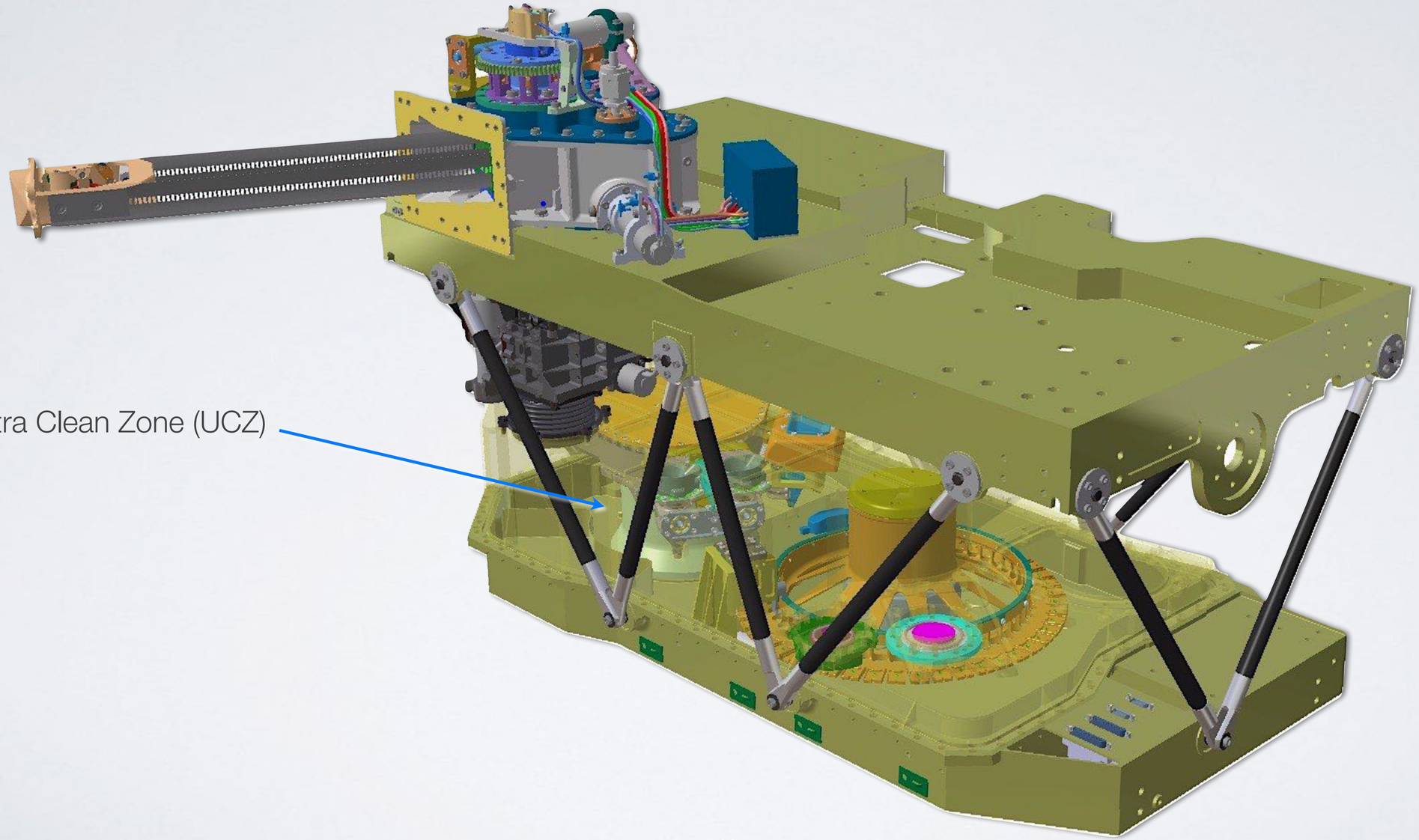


ESA / ExoMars / TAS-I / Leonardo

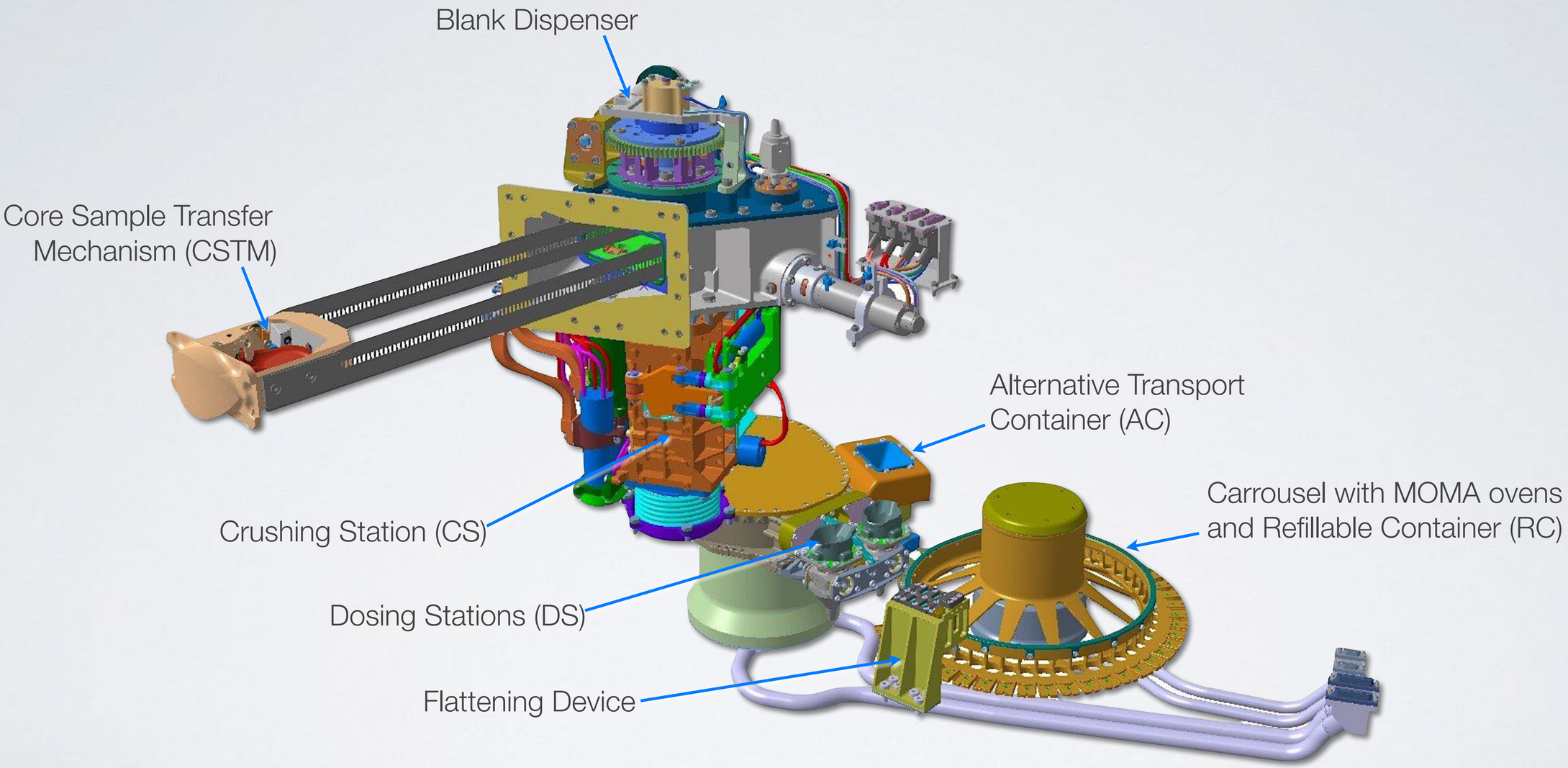
Analytical Laboratory Drawer



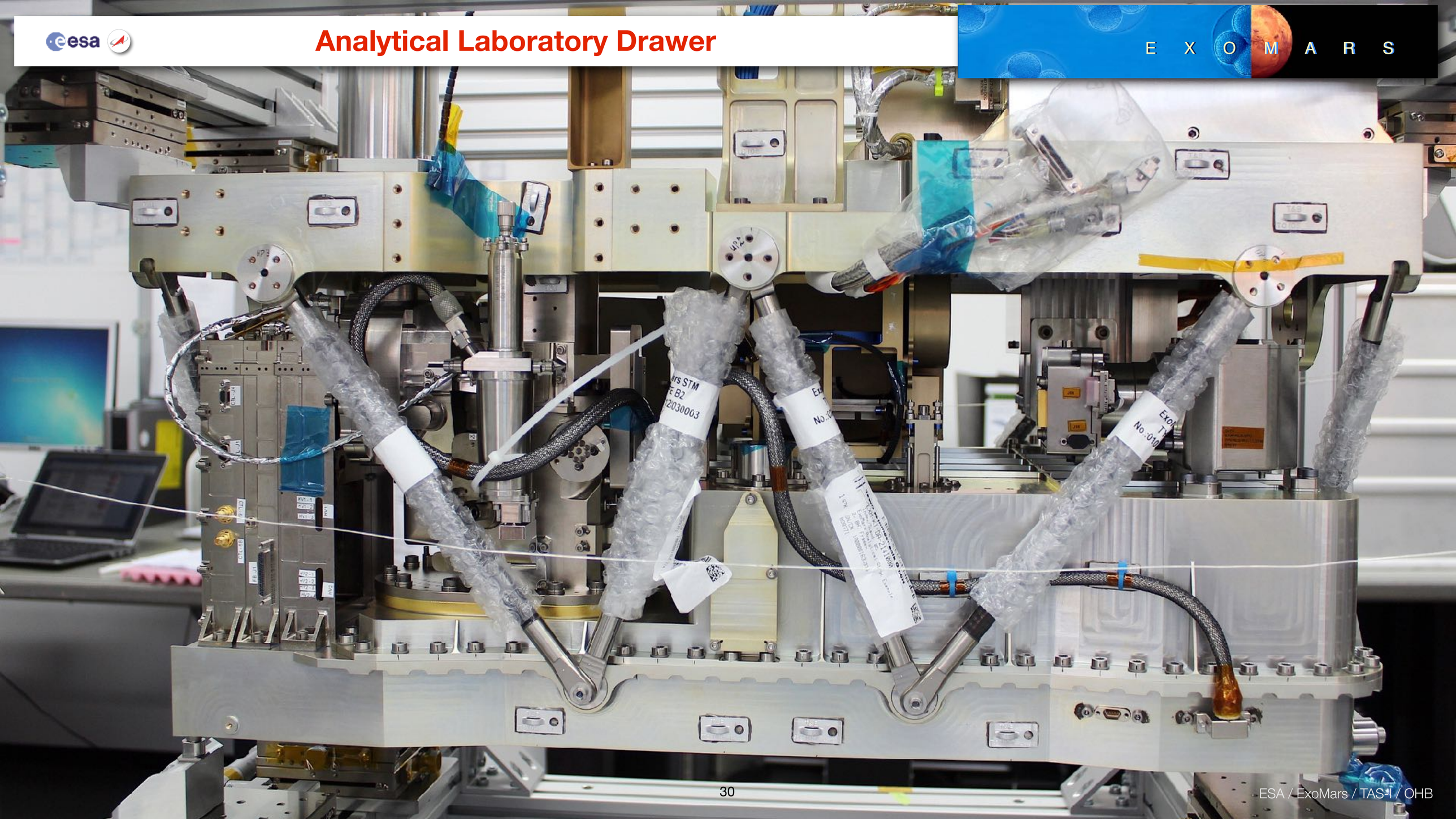
Analytical Laboratory Drawer



Analytical Laboratory Drawer

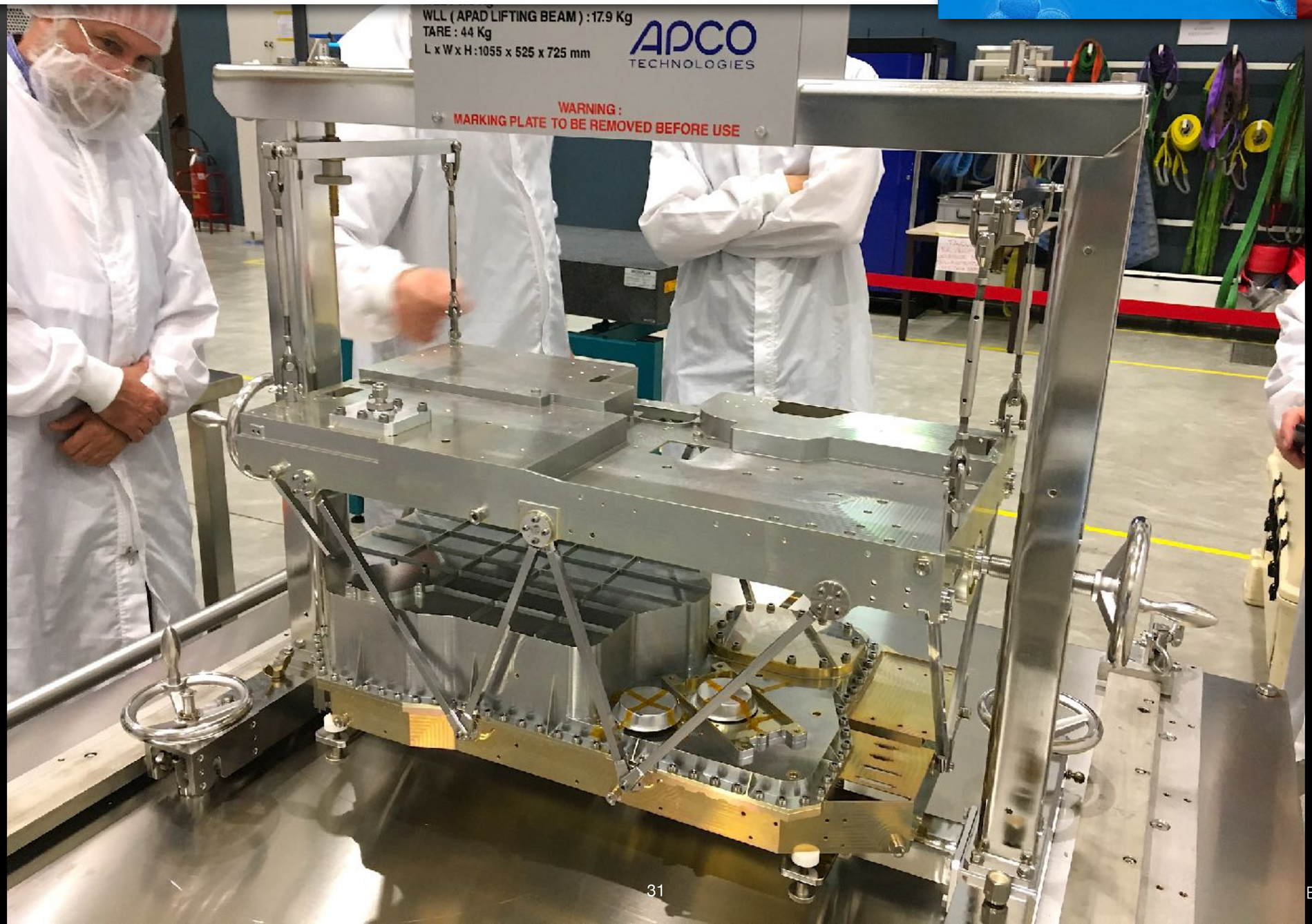


Analytical Laboratory Drawer

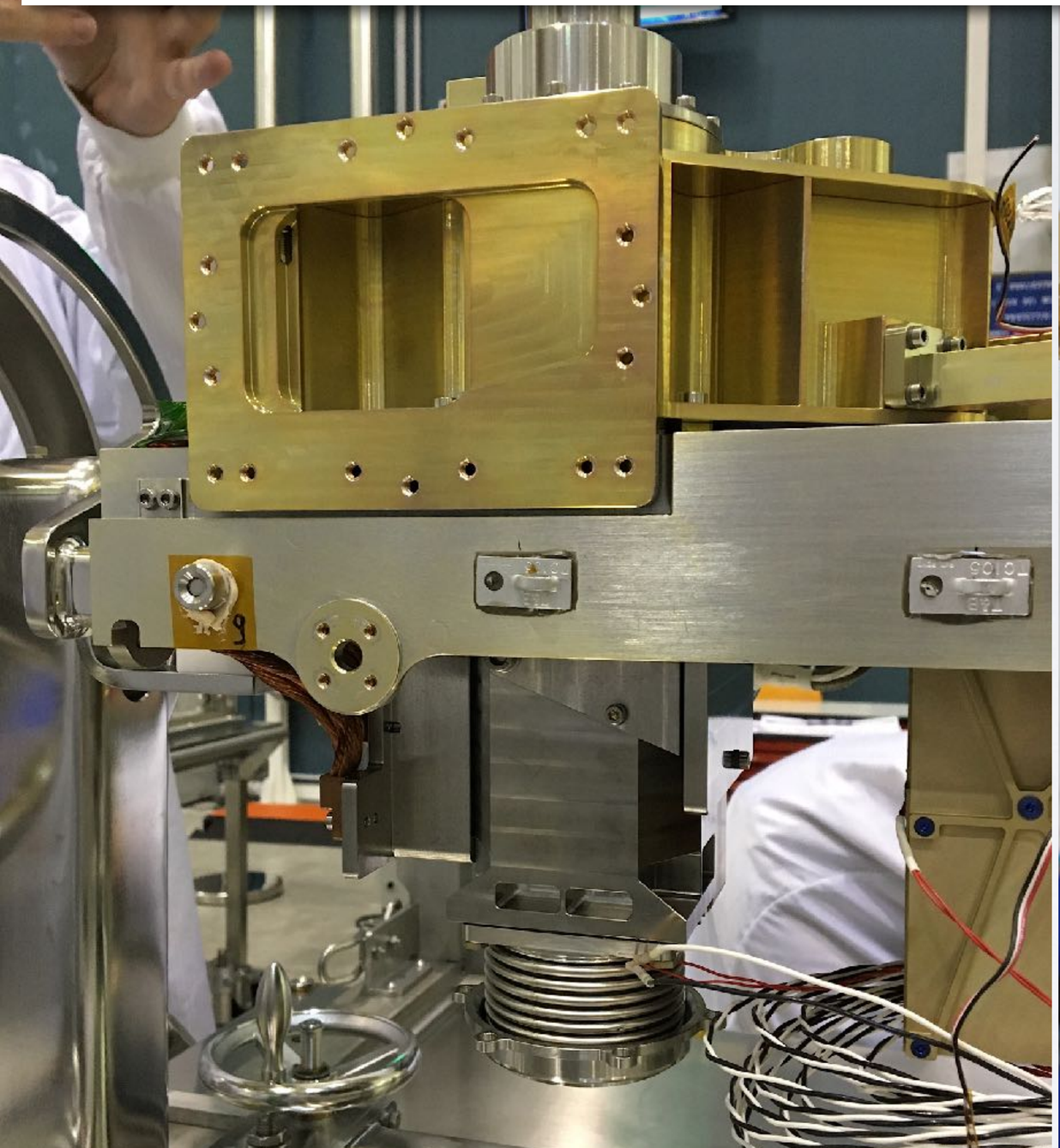


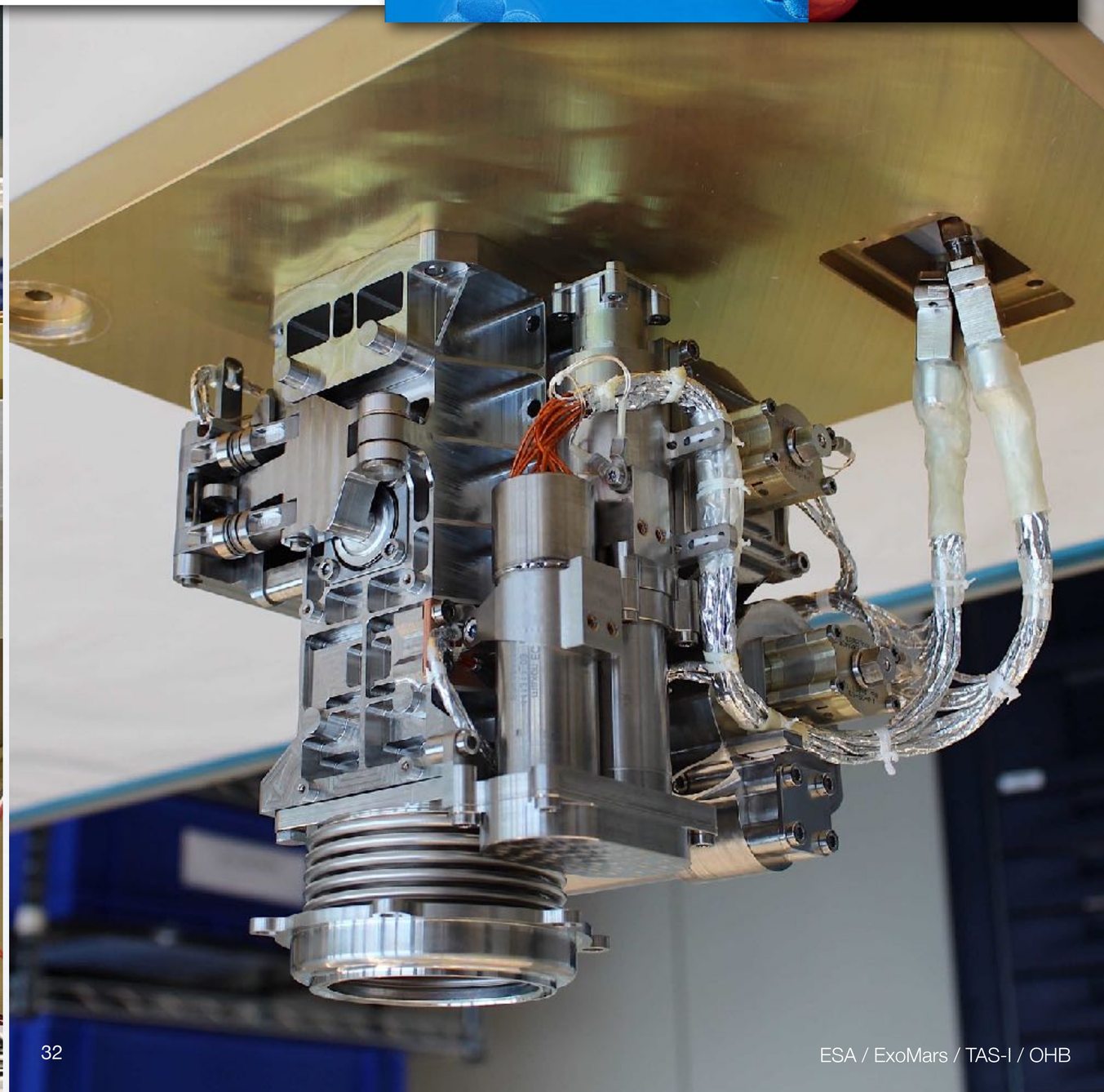
ESA / ExoMars / TAS-I / OHB

Analytical Laboratory Drawer



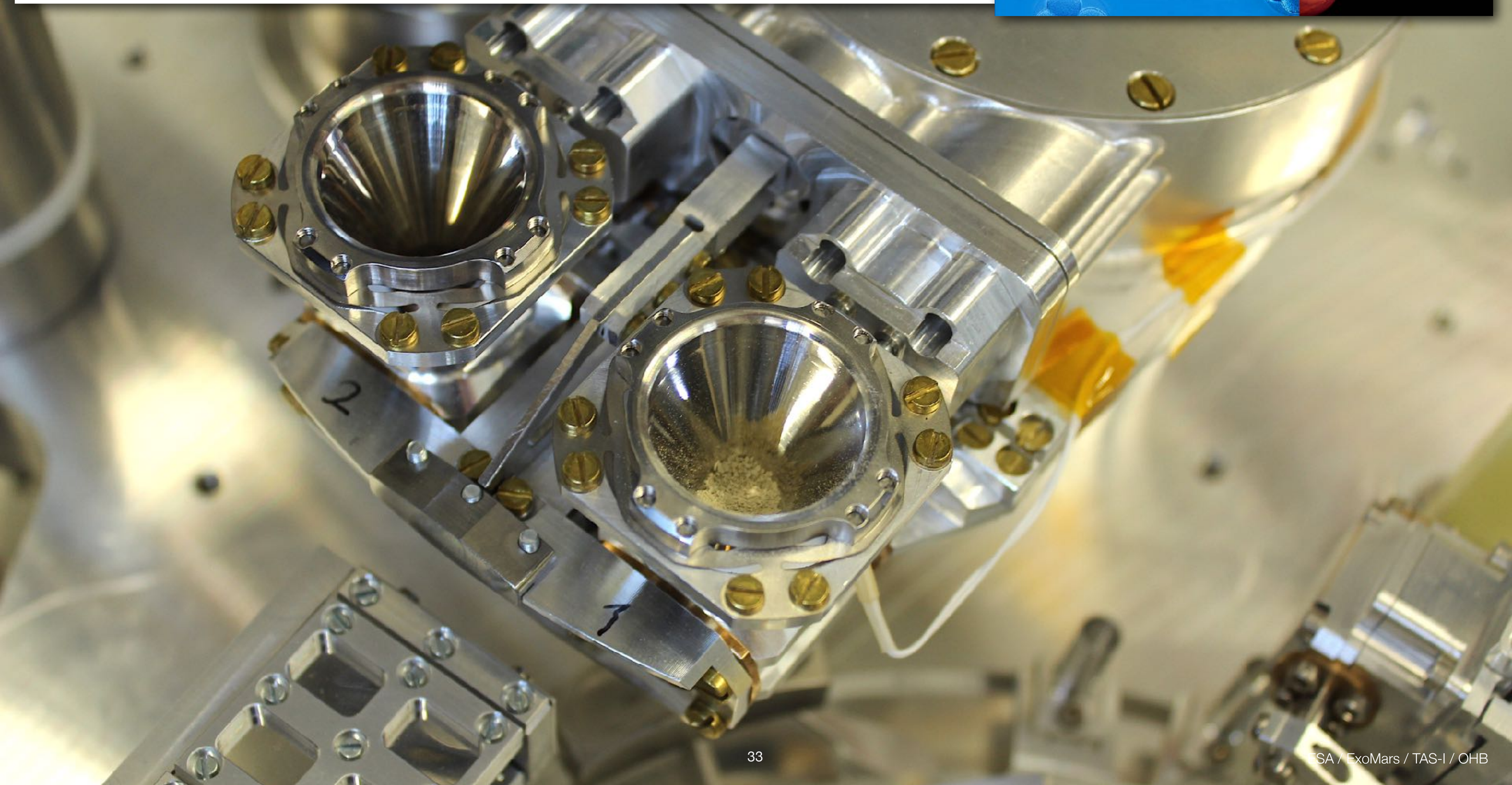
Rock Crushing Station





ESA / ExoMars / TAS-I / OHB

Powder Sample Dosing

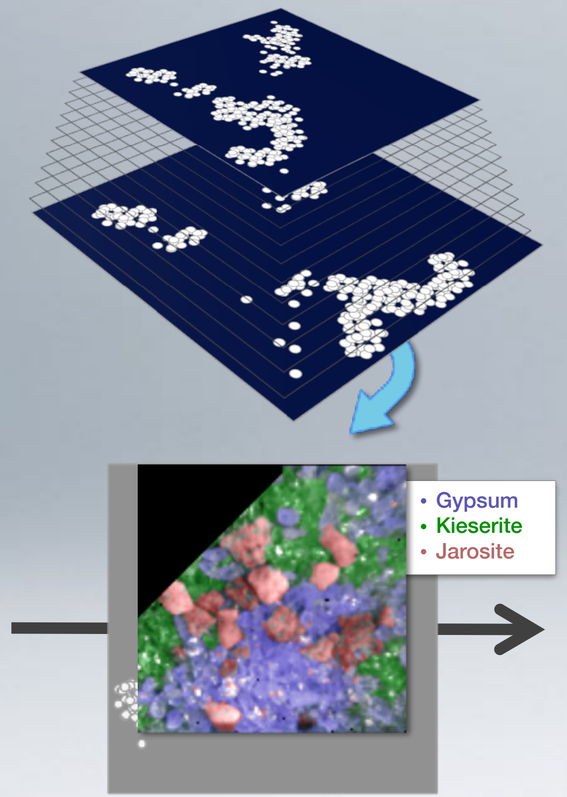


ESA / ExoMars / TAS-I / OHB

Sample Analysis

Use mineralogical + image information from μΩ to identify targets for Raman and MOMA-LDMS.

Imaging VIS + IR spectrometer:
256 x 256 pixels, 20 μm/pixel resolution,
0.95–3.65 μm spectral range, 320 steps

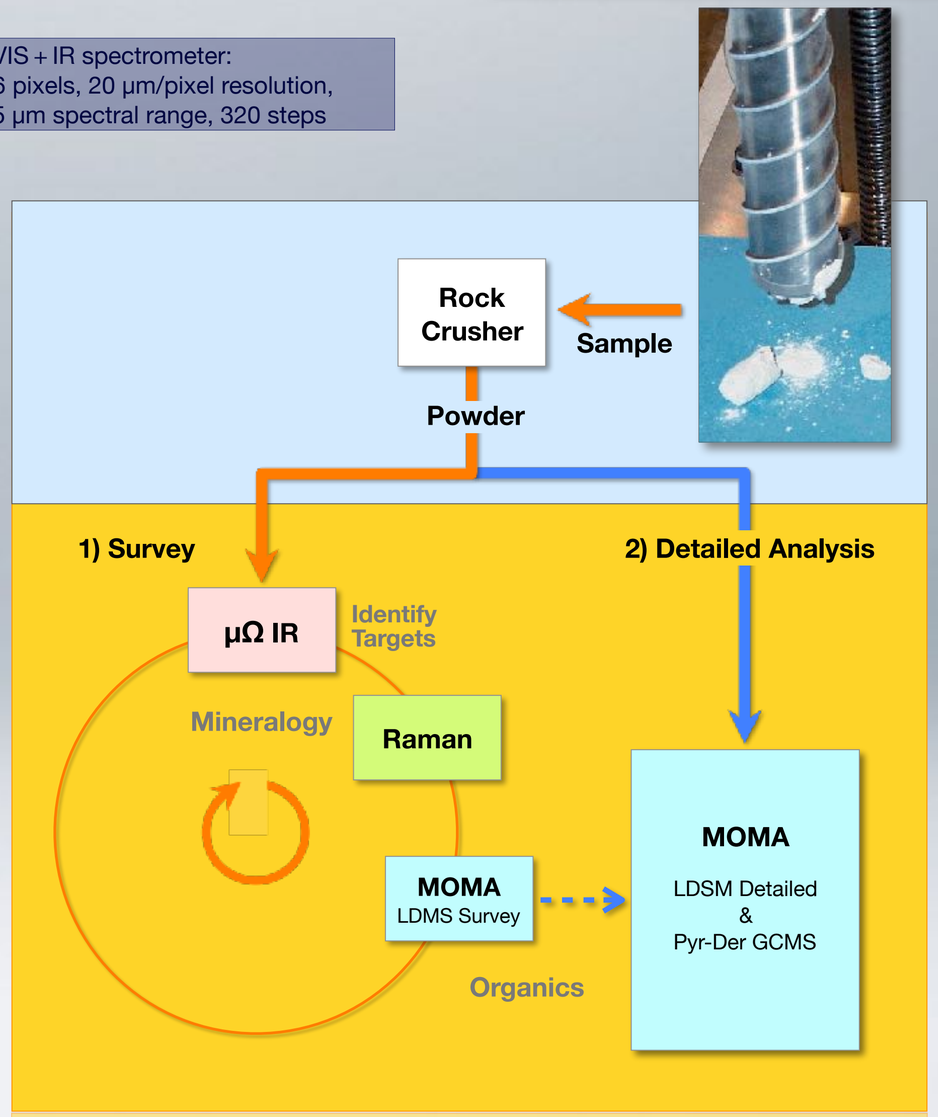


μΩ = 20 μm

Raman = 50 μm

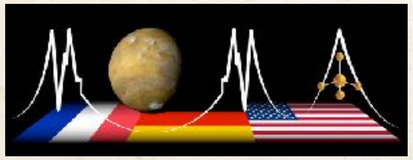
LDMS = 200 x 400 μm

Raman: Spectral shift range 200–3800 cm^{-1}
Spectral resolution: 6 cm^{-1}



LDMS = Laser Desorption Mass Spectrometry
GCMS = Gas Chromatograph Mass Spectrometer

What Can MOMA Do ?



IDENTIFICATION
Dual-source, linear-ion-trap mass spectrometry

Electron-impact ionisation

EXTRACTION
UV laser desorption and ionisation

MARS SAMPLE
All molecules

GC SEPARATION
Gas chromatography

EXTRACTION
Wet chemistry +DMF-DMA 140 °C

MARS SAMPLE
Chiral amino acids

EXTRACTION
Wet chemistry +MTBSTFA 250 °C

MARS SAMPLE
Polar molecules

EXTRACTION
Wet chemistry +TMAH ≤ 600 °C

MARS SAMPLE
Fatty acids

EXTRACTION
Pyrolysis 800 °C

MARS SAMPLE
Non-polar volatiles

ORGANIC MATERIAL

Soluble
Low molecular weight
High polarity
Volatile

→

Insoluble
High molecular weight
Low polarity
Solid

TEMPERATURE

O^- release from (per)chlorates

140 °C 250 °C 600 °C 1000 °C

Mamers Valles, MEX / HRSC

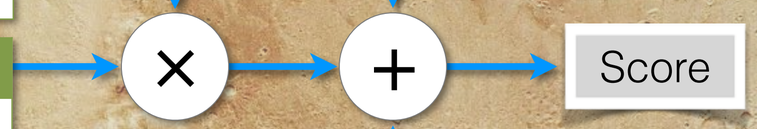
ExoMars Biosignature Score

Morphological biosignatures:	Σ points
Multilayer organosedimentary structures (*e.g.* stromatolites)	20
Other candidate biomediated textures (*e.g.* MISS)	10
Features suggestive of (fossil) microorganisms	20

Result of first blank chemical check: (prior to beginning sample analysis)	Factor
No organics, clean background	1.0–0.9
OR Few, well known spacecraft organics in background	0.8–0.5
OR Background heavily compromised by contamination	0.2–0.0

Chemical biosignatures:	Σ points
Detection of primary biomolecules or their degradation products	20
Enantiomeric excess (or other isomer selectivity)	30
Molecular weight clustering of organic compounds	20
Evidence of repeating constitutional subunits	20
Systematic isotopic ordering at molecular (group) level	20
Bulk isotopic fractionation	10

Geological context:	Σ points
Long-lived water or hydrothermal setting (morphology)	15–10
Long-lived water or hydrothermal setting (mineralogy)	15–10



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Pasteur Payload

ExoMars Rover Issue

- Astrobiology, June–July 2017
- Introduction paper describing the ExoMars rover science and mission.
- A dedicated paper for each of the nine instruments.

Sand dunes near the north pole, MRO / HiRISE

Pasteur Payload

E X O M A R S

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

λ = 0.4 – 2.2 μm

Analytical Laboratory

MicrOmega
VIS + IR spectrometer

Mineralogy characterisation of crushed sample material
Pointing for other instruments

λ = 0.9 – 3.5 μm, 256 x 256, 20-μm/pixel, 500 steps

RLS
Raman spectrometer

Geochemical composition
Detection of organic pigments

spectral shift range 200–3800 cm^{-1}, resolution ≤ 6 cm^{-1}

MOMA
LDMS + Pyr-Der GCMS

Broad-range, high sensitivity search for organic molecules

Laser desorption extraction and mass spectroscopy

Pyrolisis extraction, with or without derivatisation agents, coupled with chiral gas chromatography, and mass spectroscopy

Reference Surface Mission

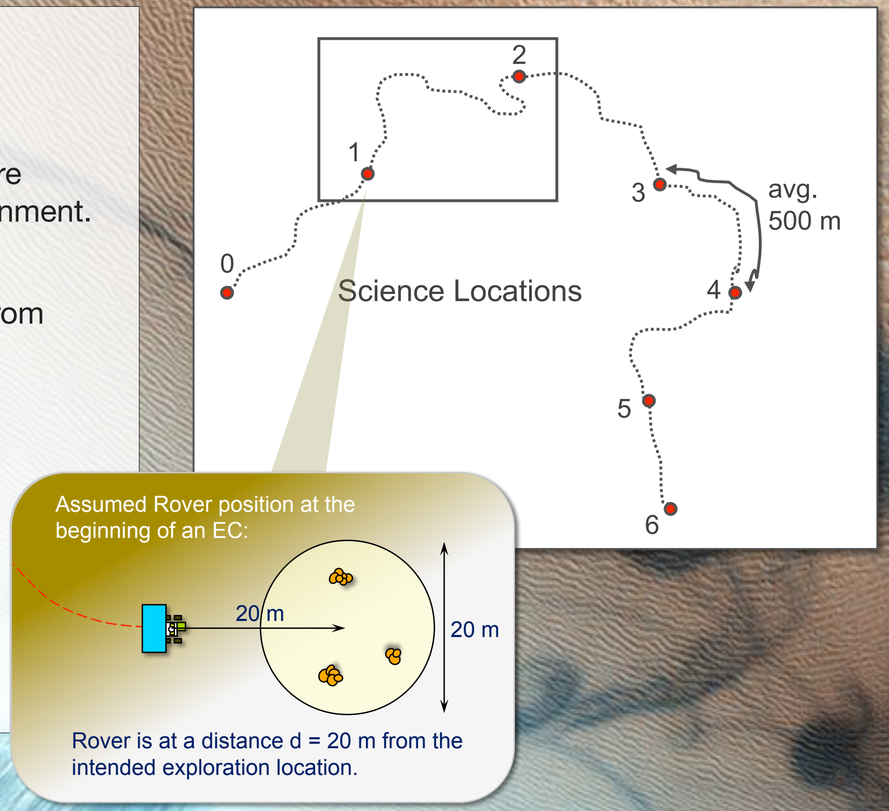
The rover reference surface mission includes:

a) **EXIT LANDING AREA:**
Get away from any rocket organic contamination before opening the analytical laboratory to the martian environment.

b) **BLANK ANALYSIS RUNS:**
Demonstrate that the rover's sample pathway is free from organic contamination.

c) **6 EXPERIMENT CYCLES:**
Combined surface and subsurface exploration.
6 surface and 6 subsurface samples.

d) **2 VERTICAL SURVEYS:**
At one location, collect and analyse samples at depths of 0, 50, 100, 150, and 200-cm.
10 additional subsurface samples.

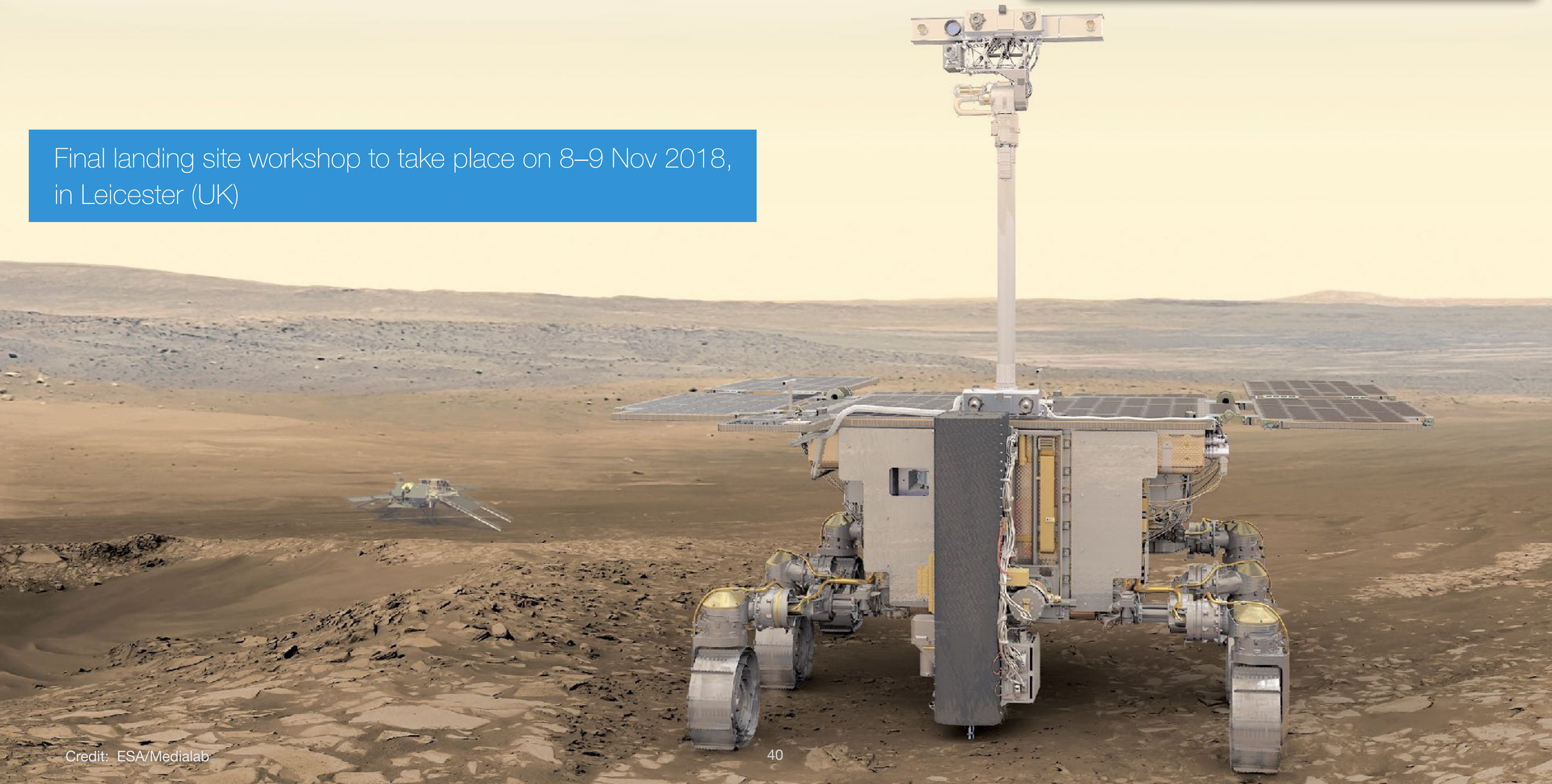


The quality of the landing site is fundamental for achieving the mission's science objectives.

Dust devil tracks, MRO / HiRISE

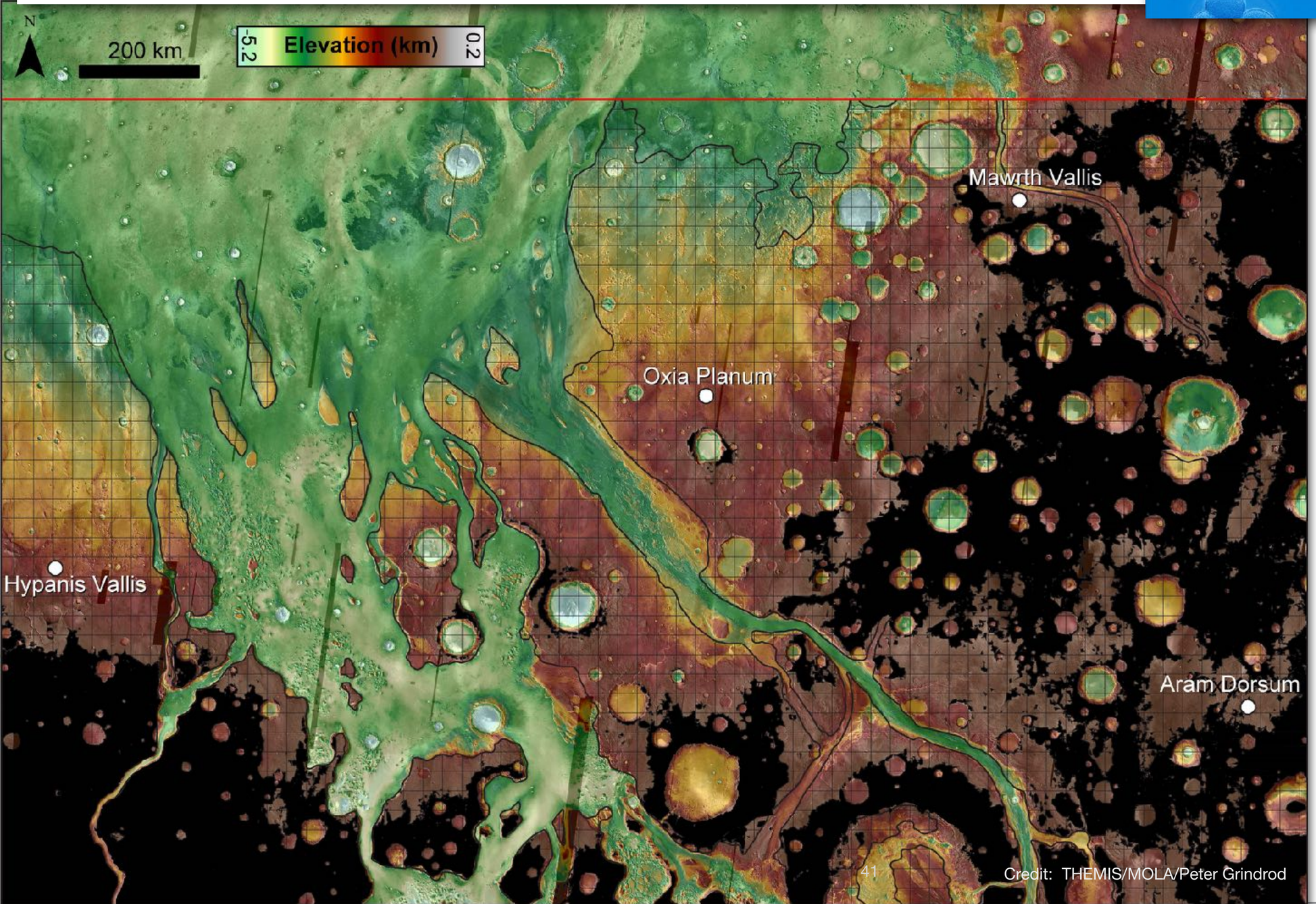
Landing Site Requirements

Final landing site workshop to take place on 8–9 Nov 2018, in Leicester (UK)



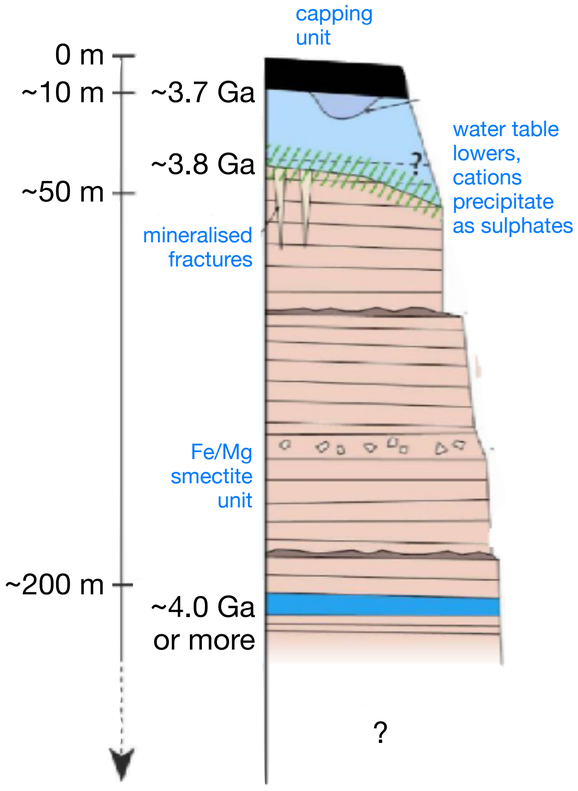
Credit: ESA/Medialab

Candidate Landing Sites



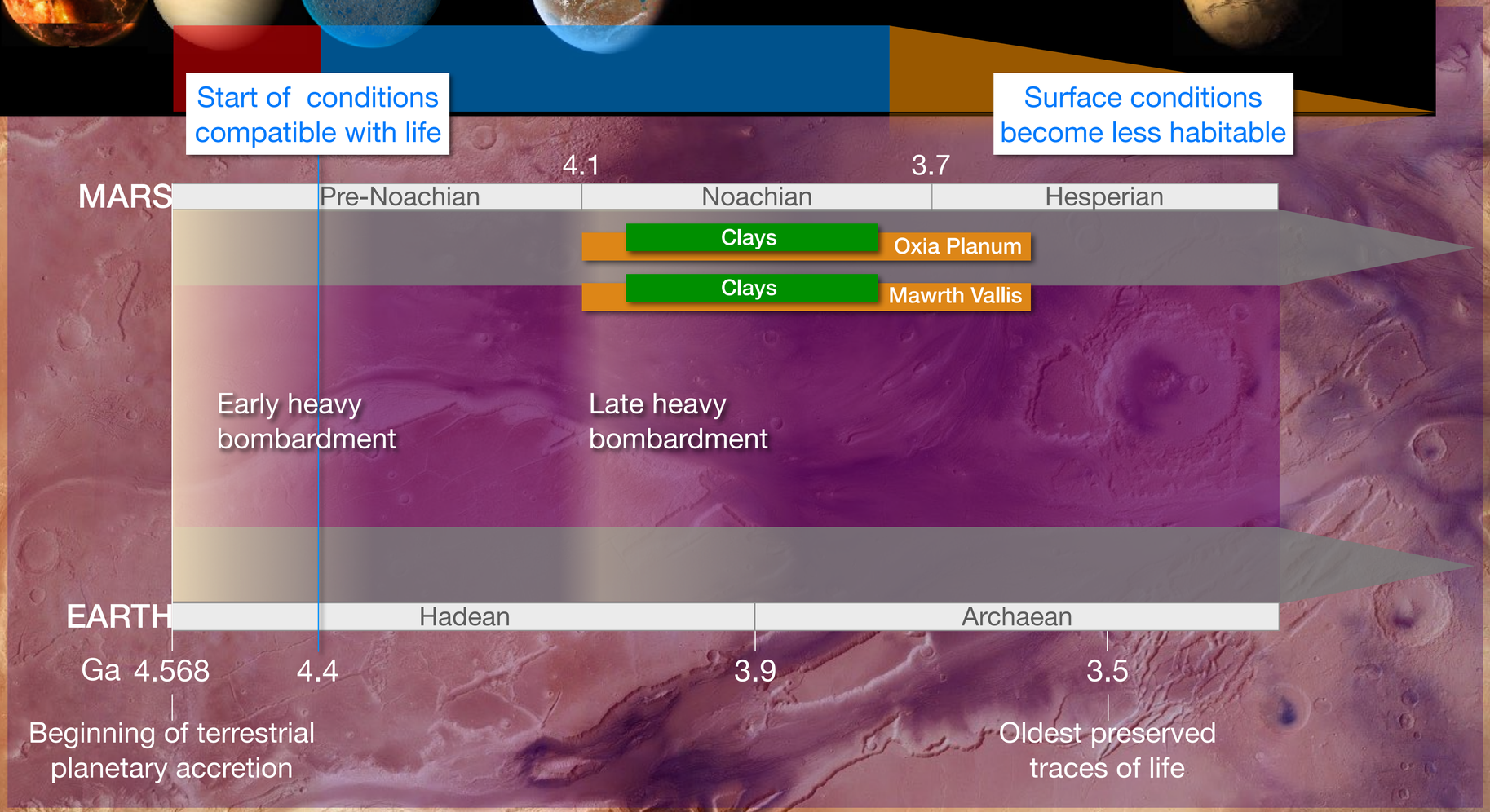
Credit: THEMIS/MOLA/Peter Grindrod

Candidate landing sites:
Oxia Planum
Mawrth Vallis



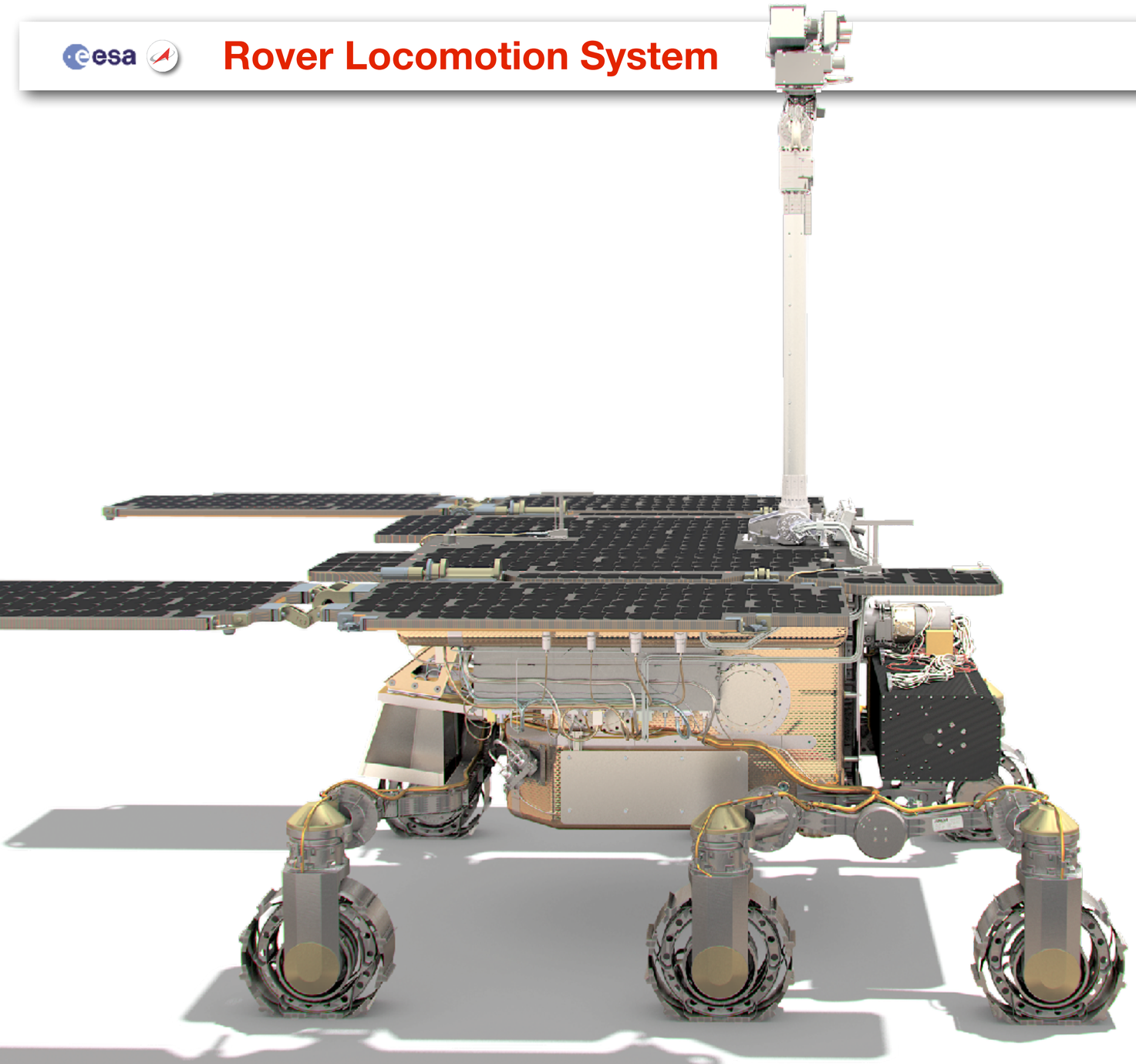
Oldest terrains to be targeted

Candidate Landing Sites



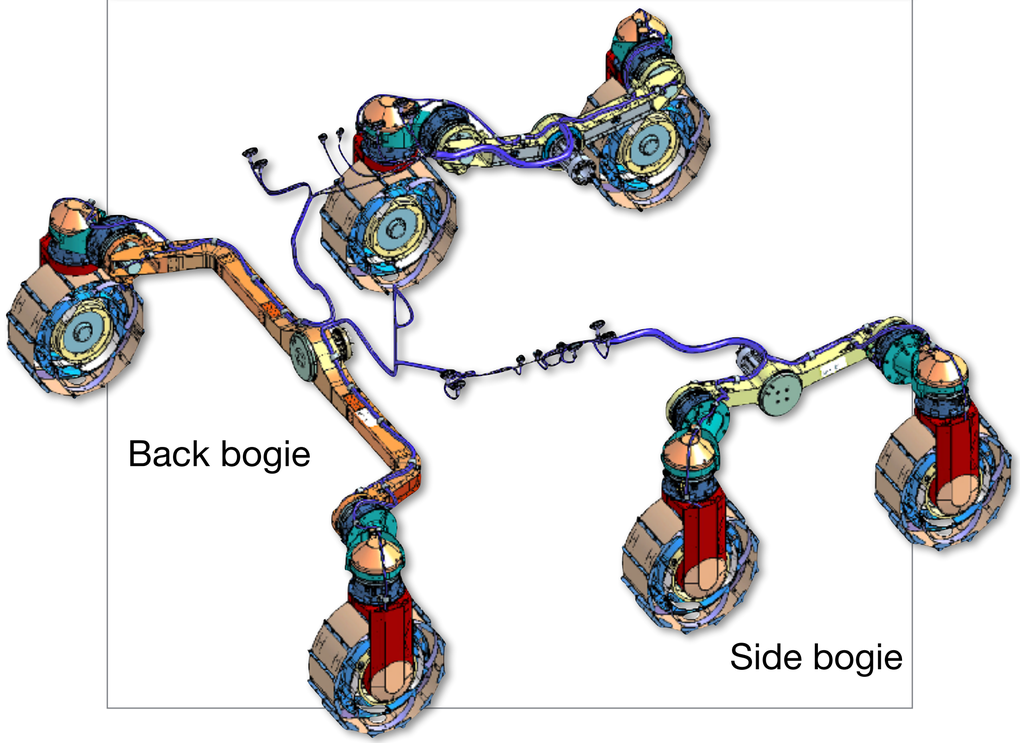
Kasei Valles, MEX / HRSC

Rover Locomotion System

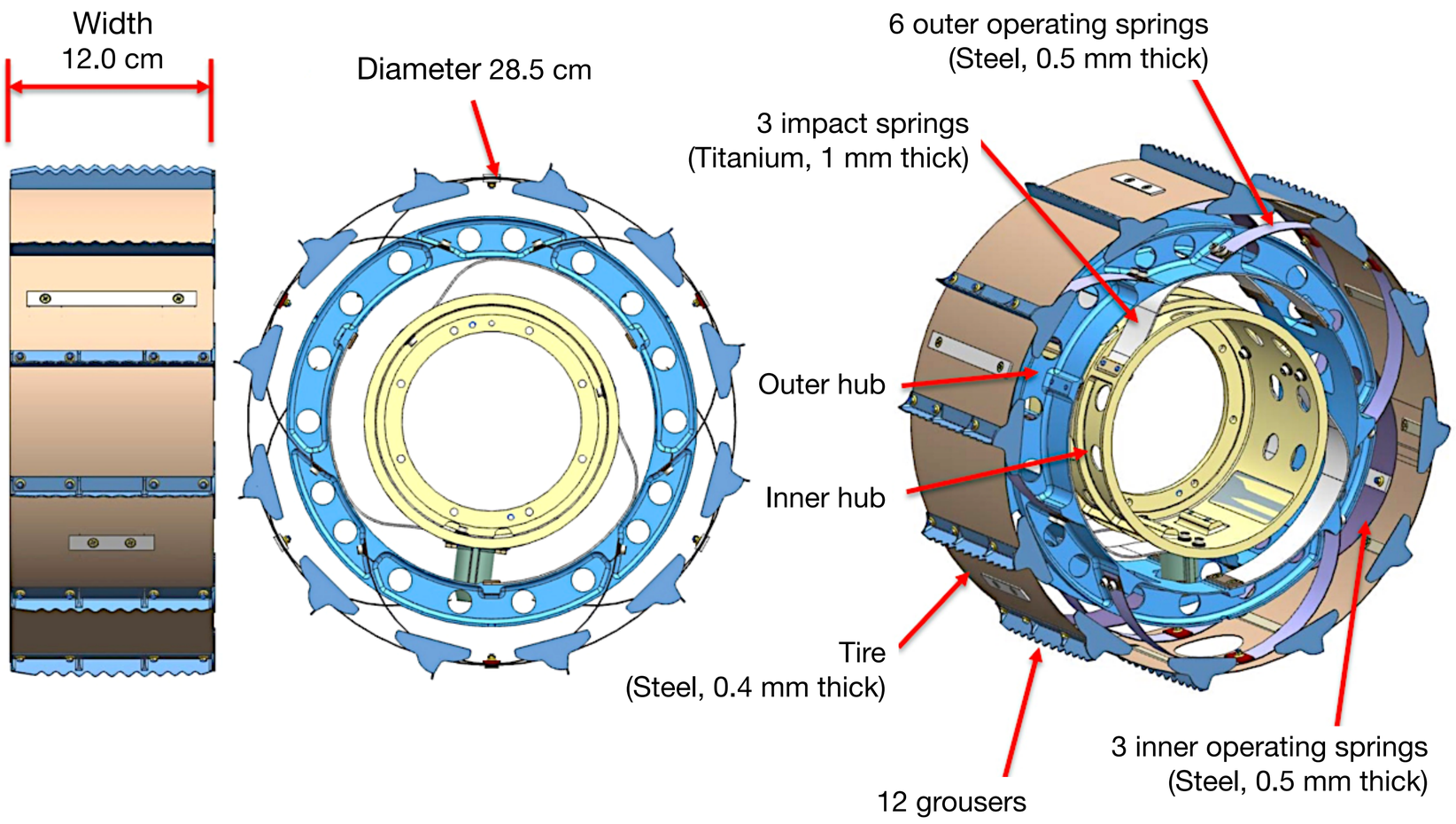


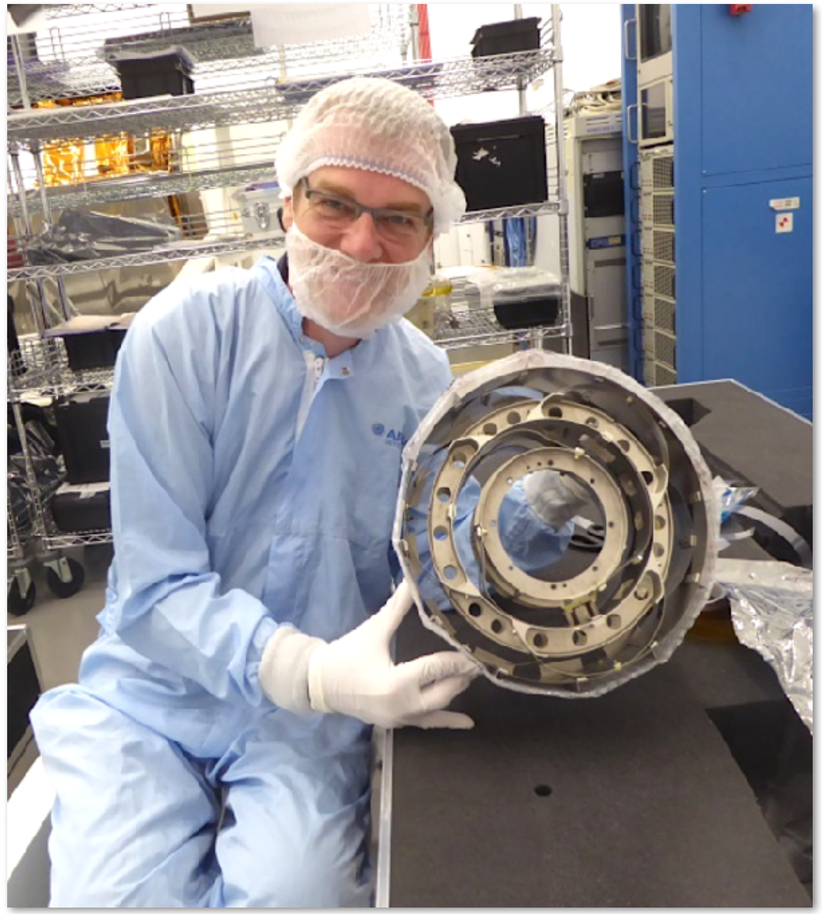
Locomotion formula: 6 x 6 x 6 + 6

6 supporting wheels
6 driven wheels
6 steered wheels
6 articulated knees



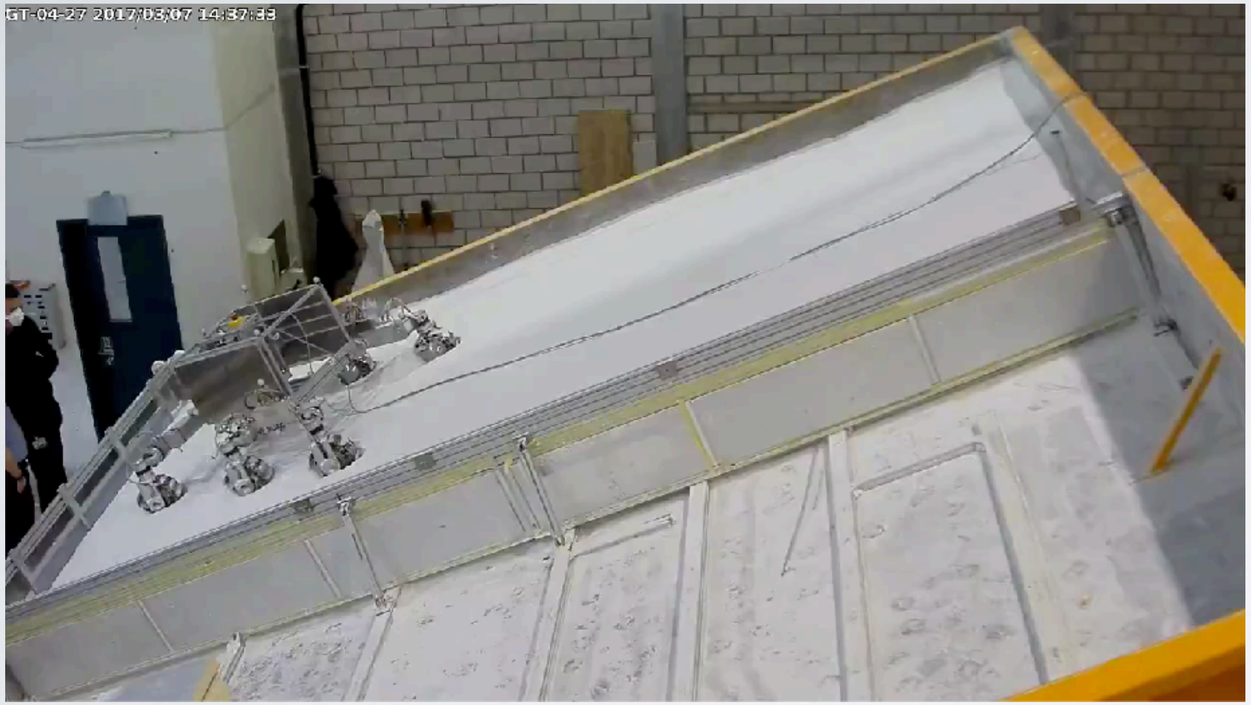
Flexible Wheels





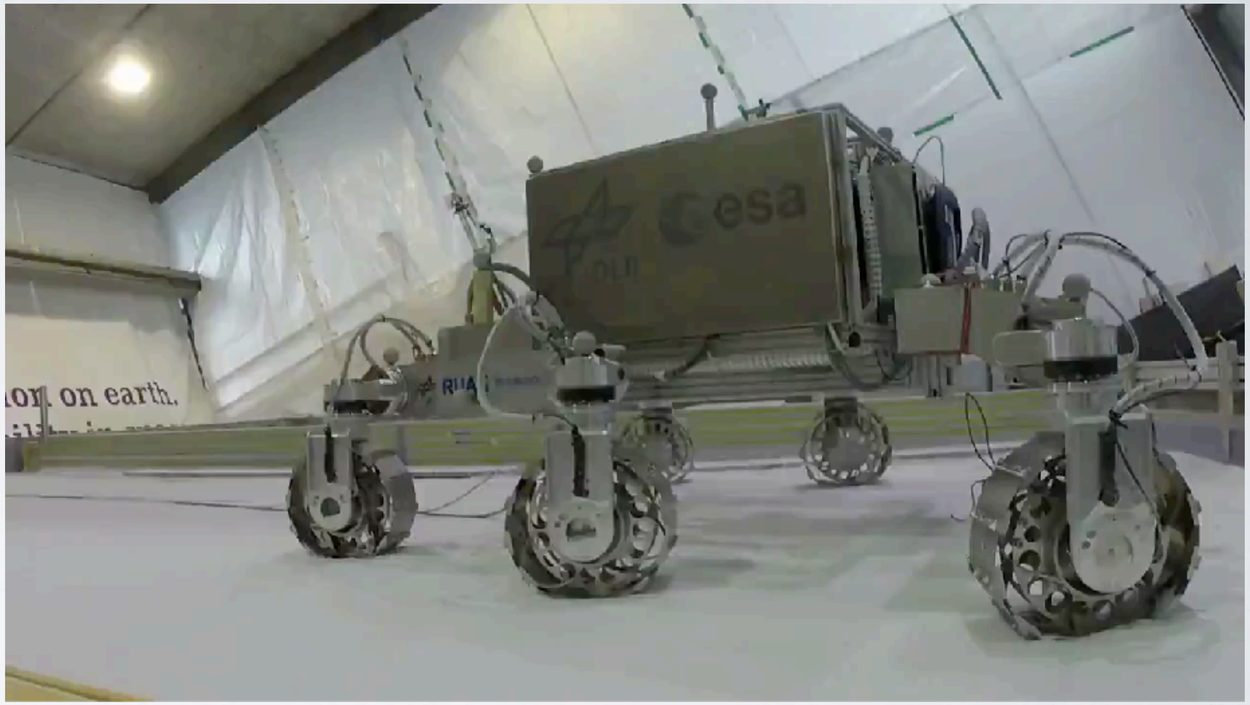
ES2 Soil - 21° Upslope - Back & Forth

Vivotec camera (GT-04-27)



video accelerated x25

GoPro camera (GT-04-27)



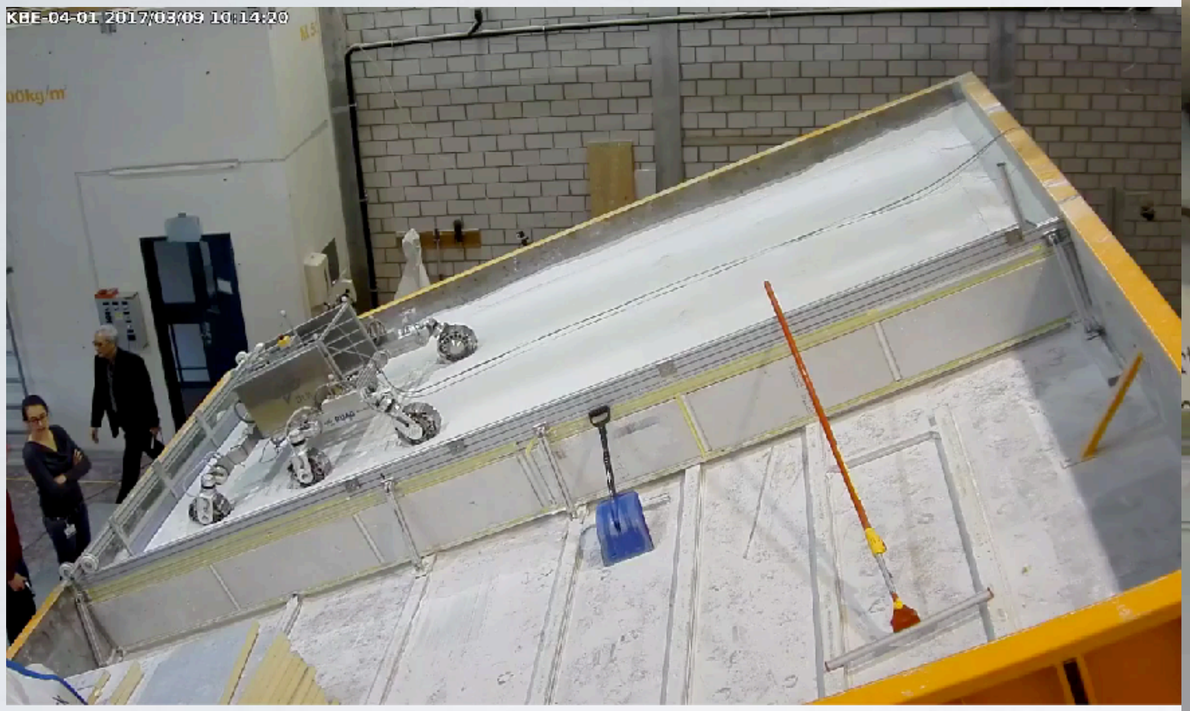
video accelerated x25

Credit: RUAG, Airbus Defence & Space, ESA

Result: progress of 1.3 m in 94 min, excessive sinkage & slip

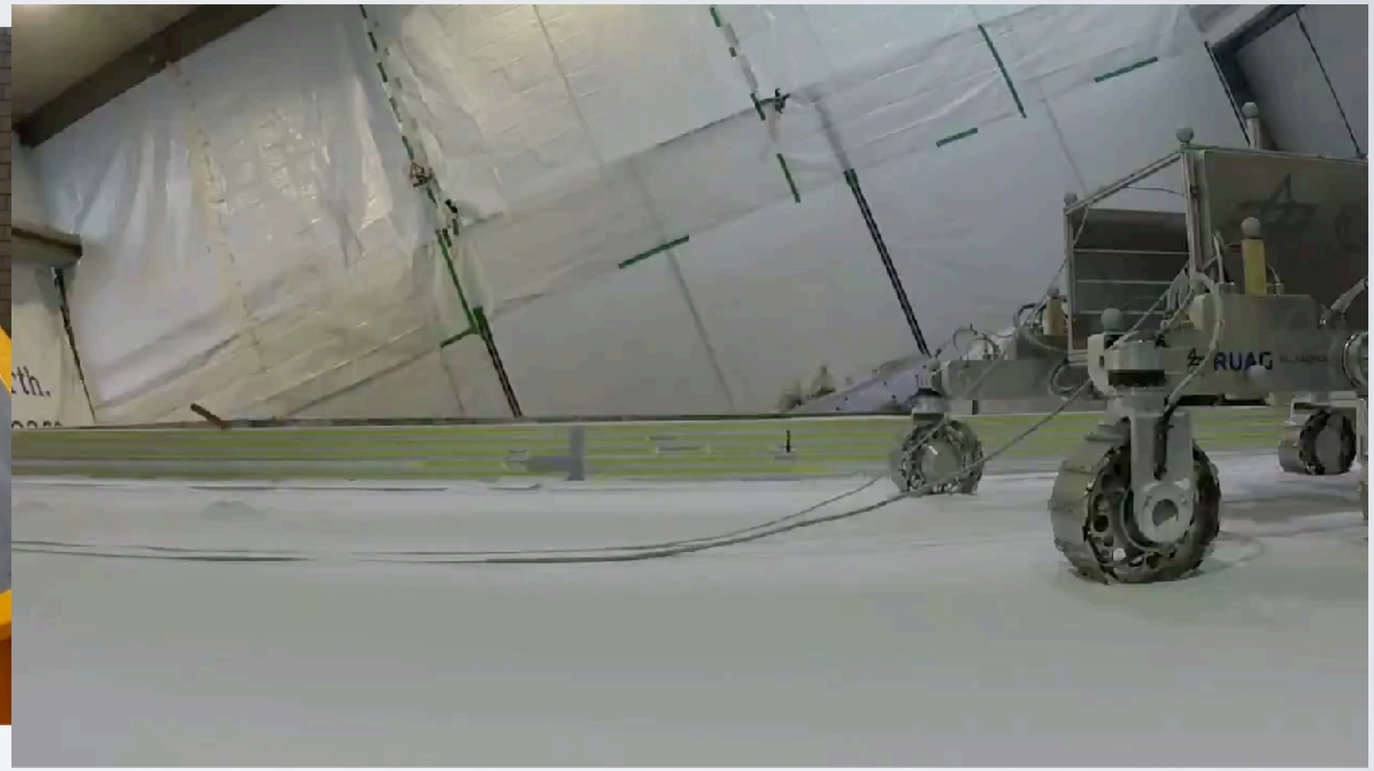
ES2 Soil - 21° Upslope - Wheel Walking

Vivotec camera (KBE-04-01)



video accelerated x15

GoPro camera (KBE-04-01)



video accelerated x15

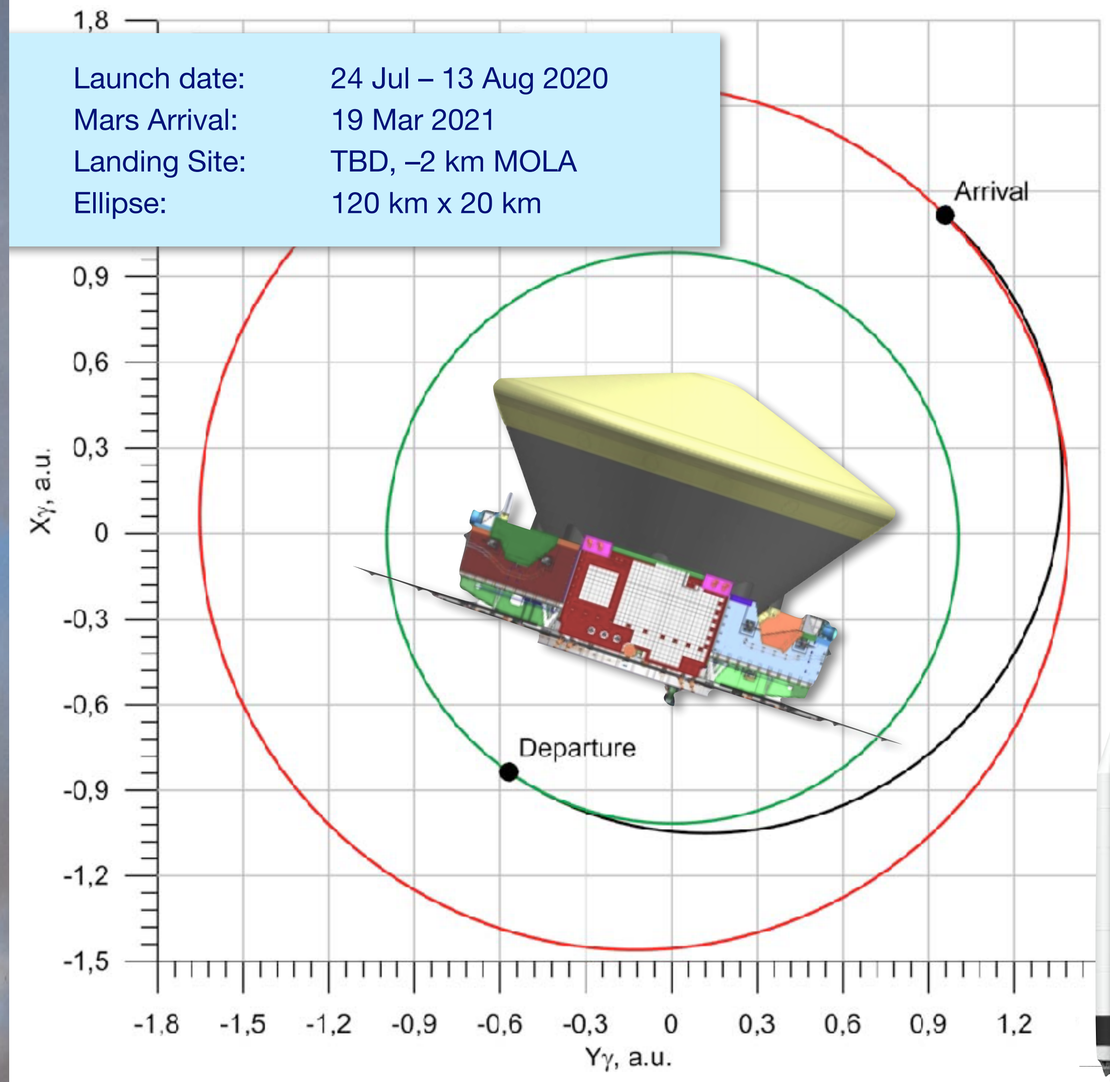
Credit: RUAG, Airbus Defence & Space, ESA

The tested WW gait respects all hardware kinematic constraints.

Result: progress of 3 m in 34 mins, low sinkage

Launch

Launch date:	24 Jul – 13 Aug 2020
Mars Arrival:	19 Mar 2021
Landing Site:	TBD, –2 km MOLA
Ellipse:	120 km x 20 km



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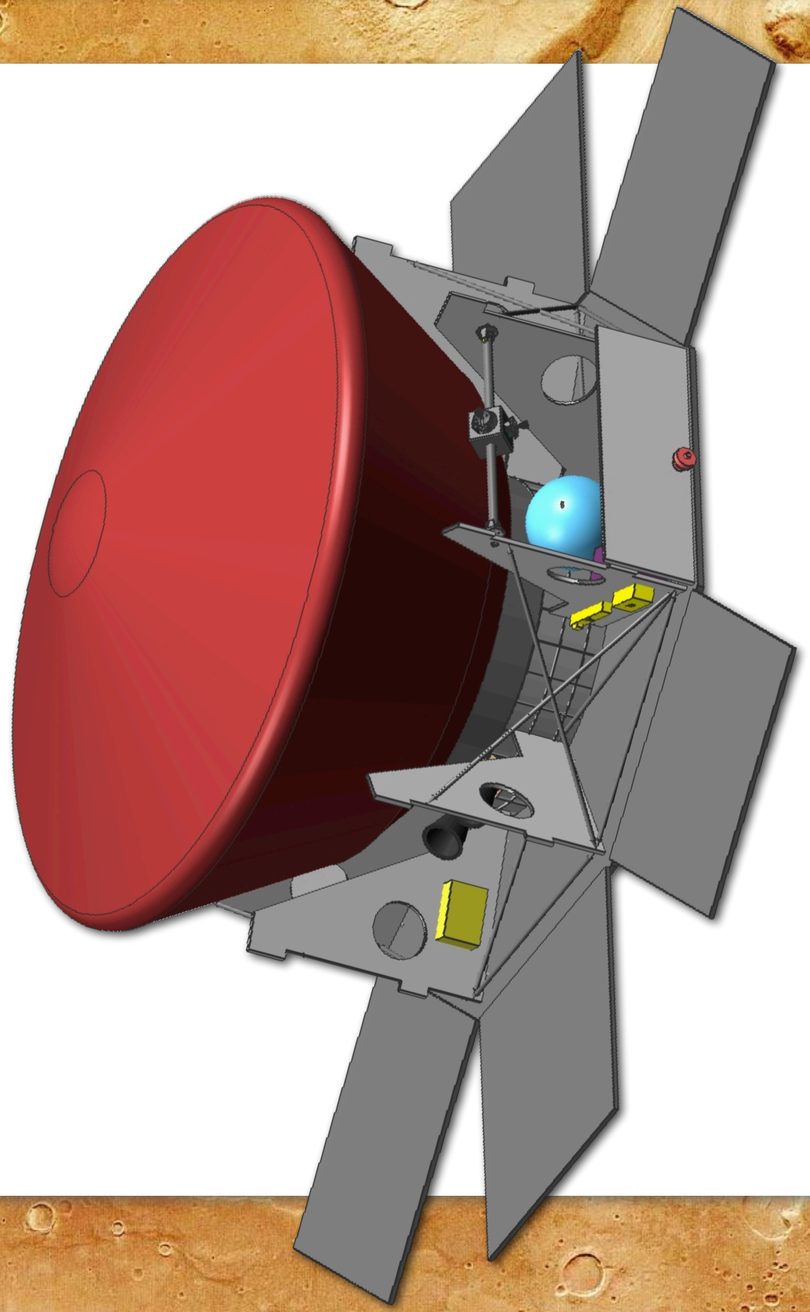
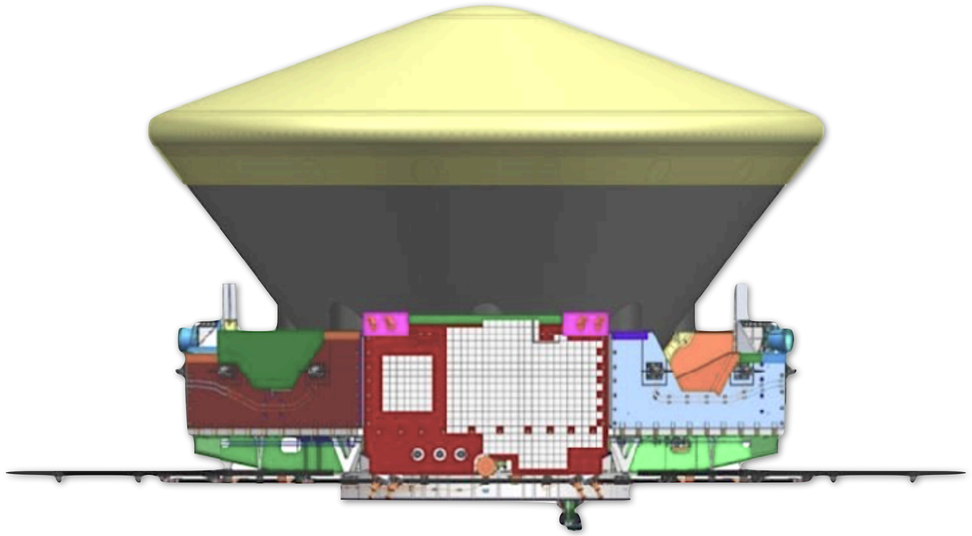
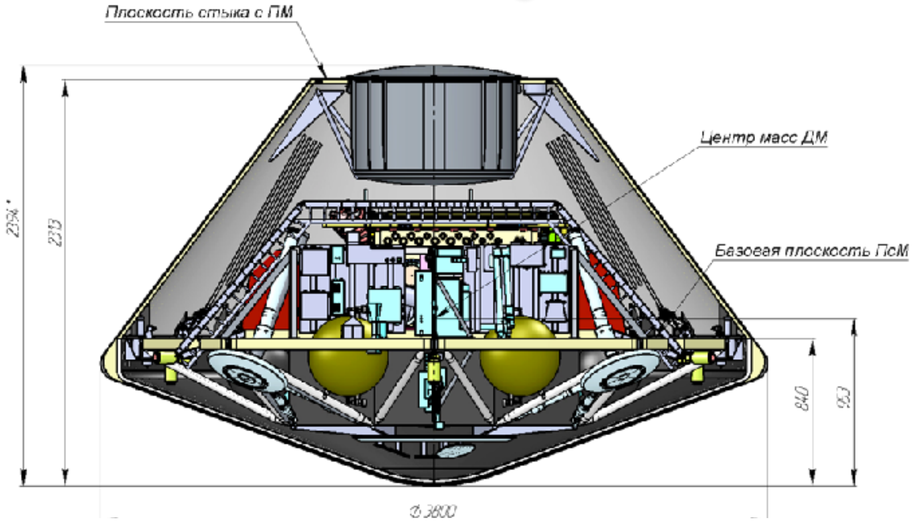
Carrier and Descent Module







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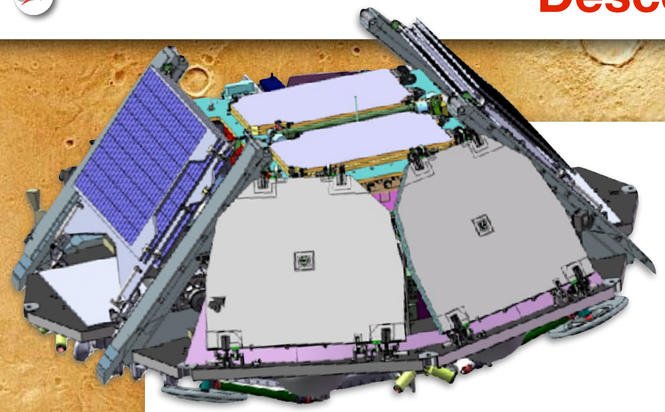
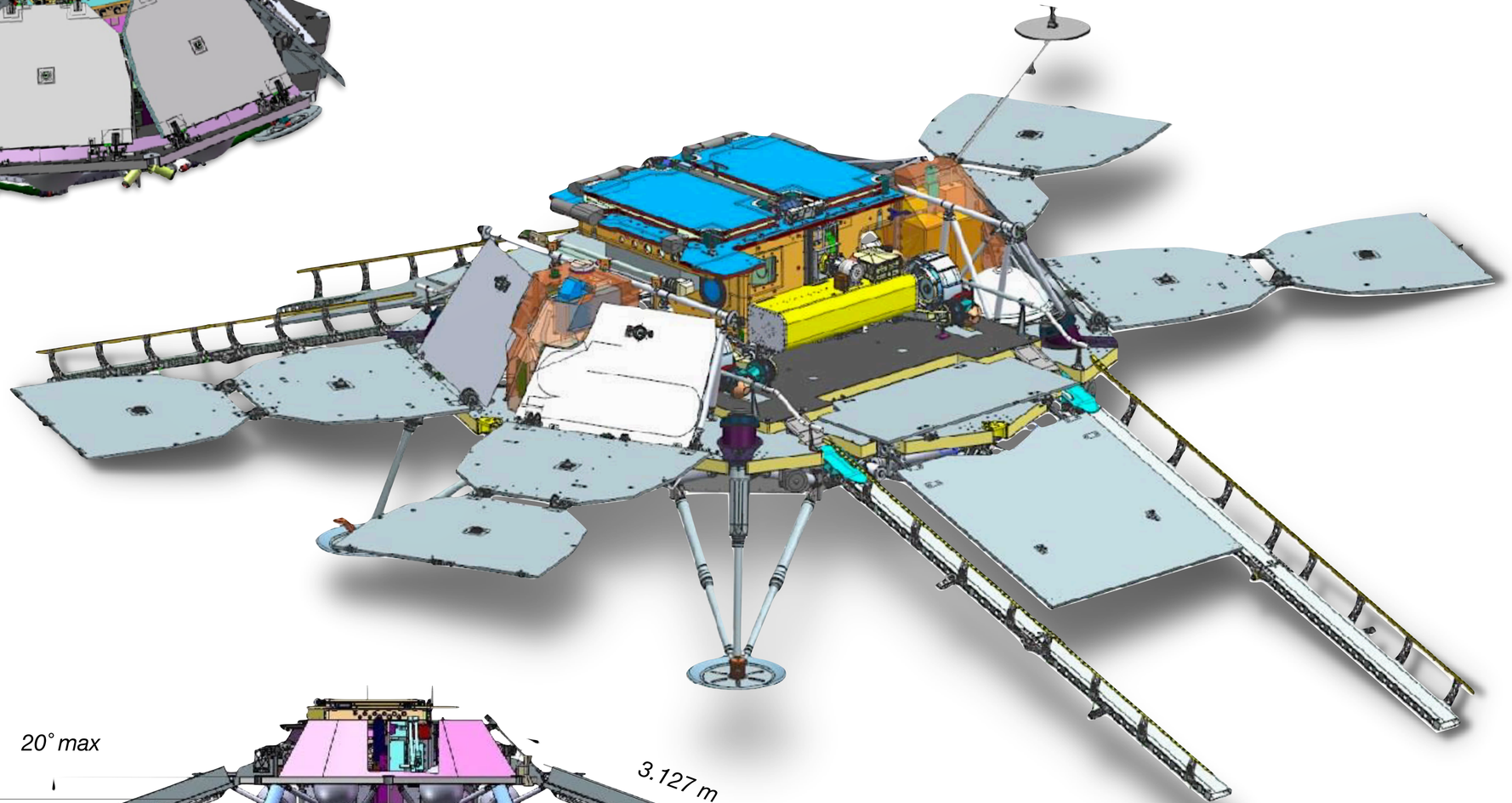
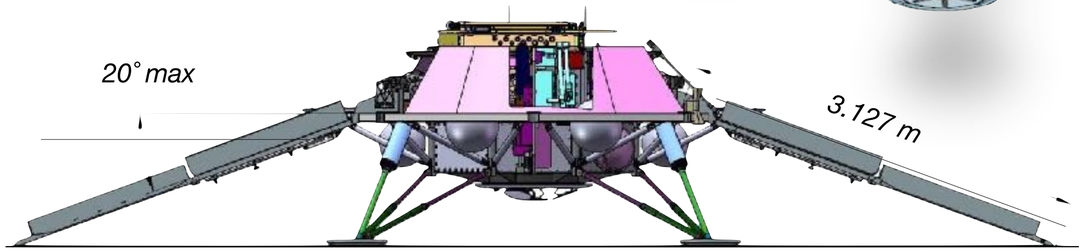
Descent Module







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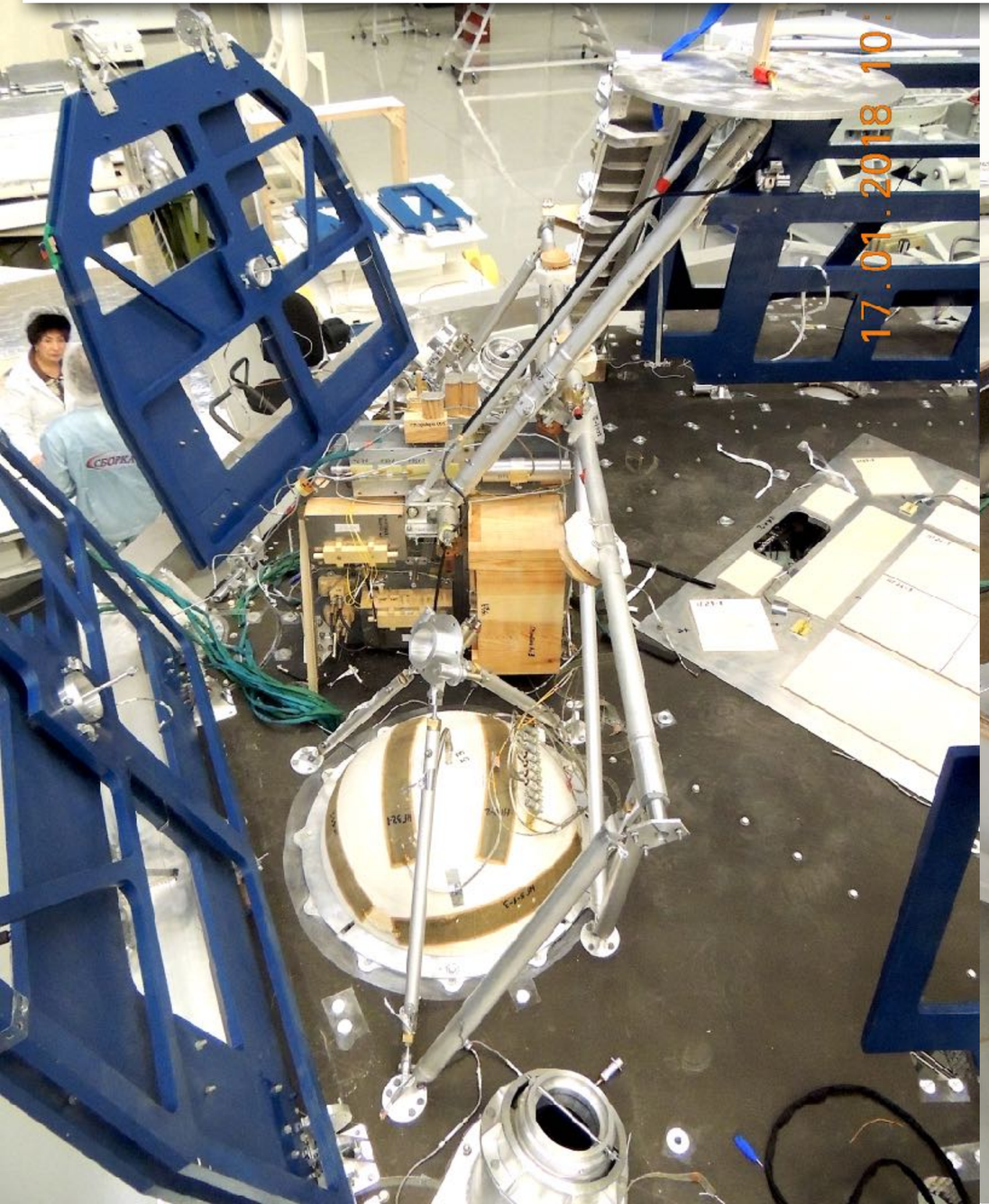
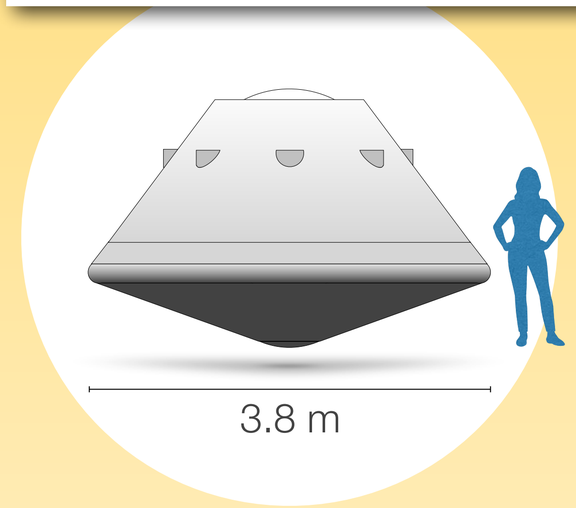
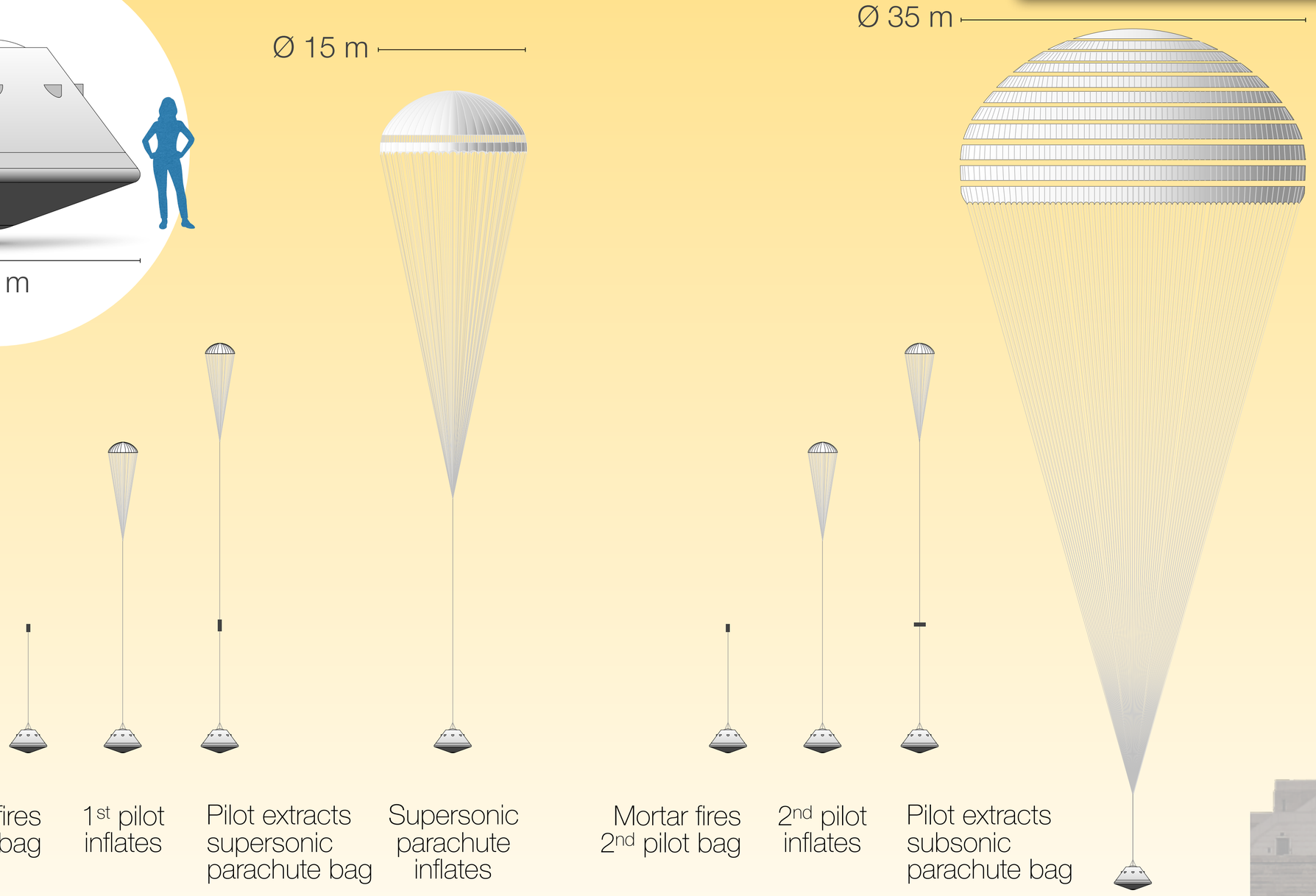
Descent Module



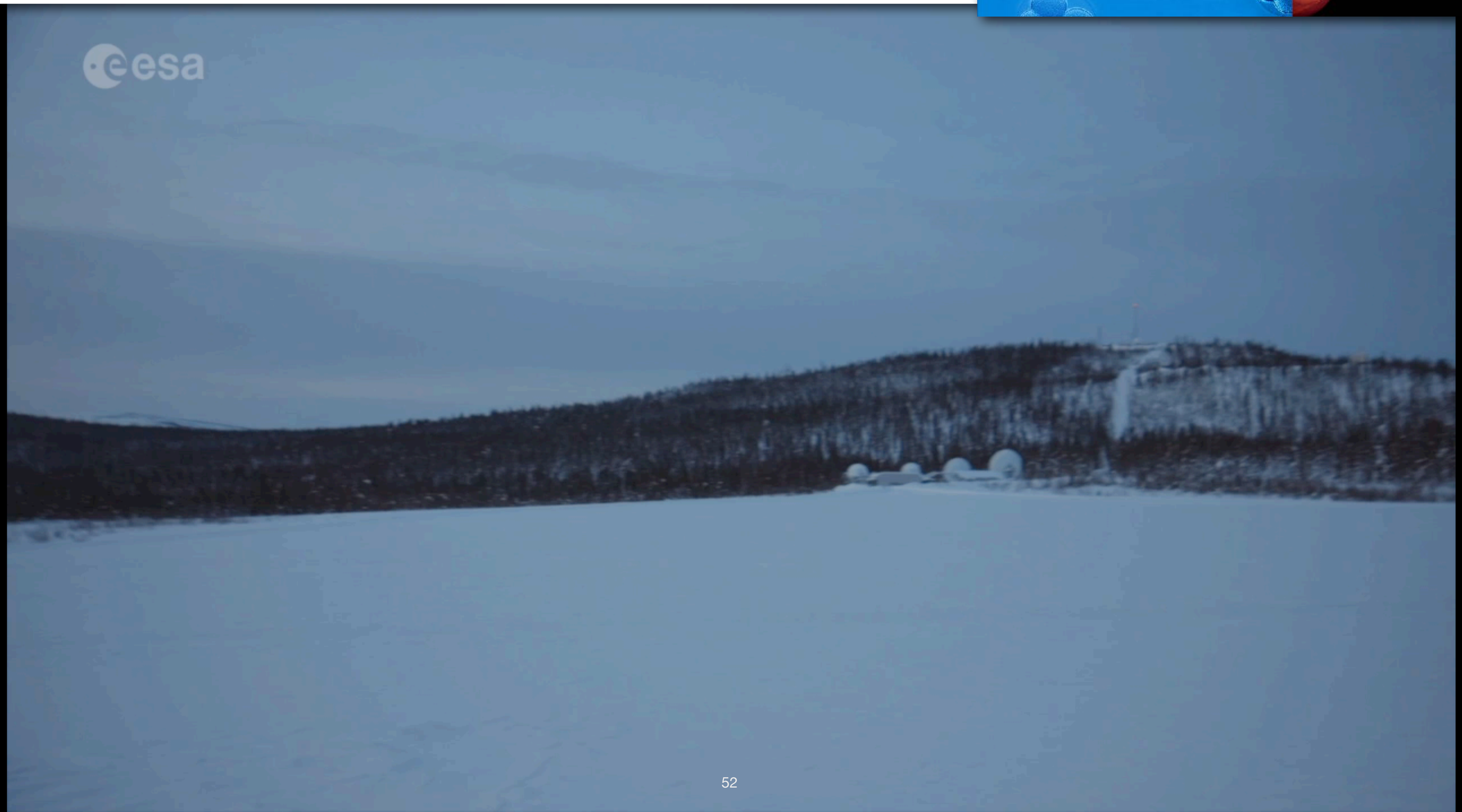
Credit: LAV

Parachute Deployment Sequence

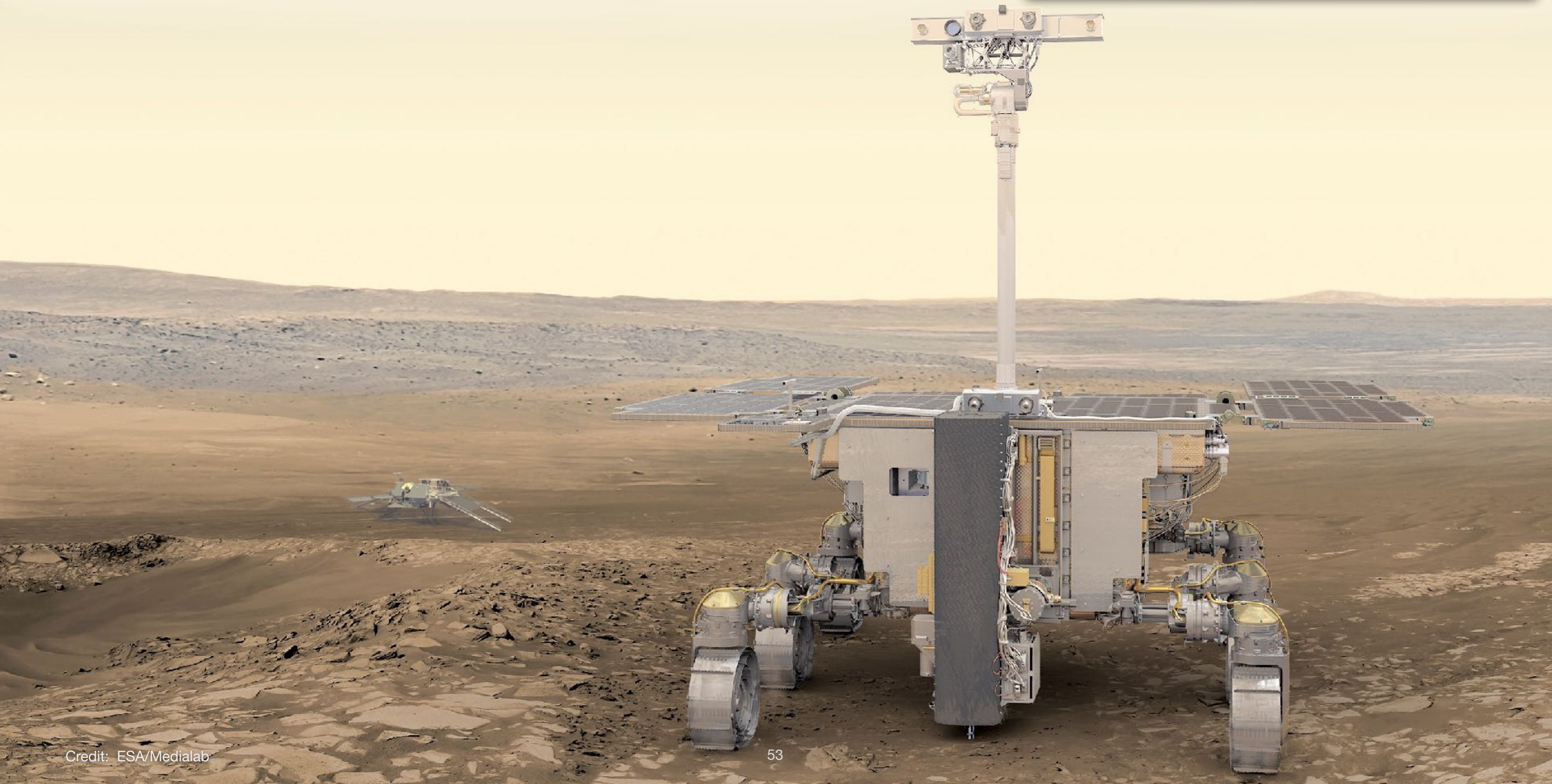




Subsonic Parachute Test

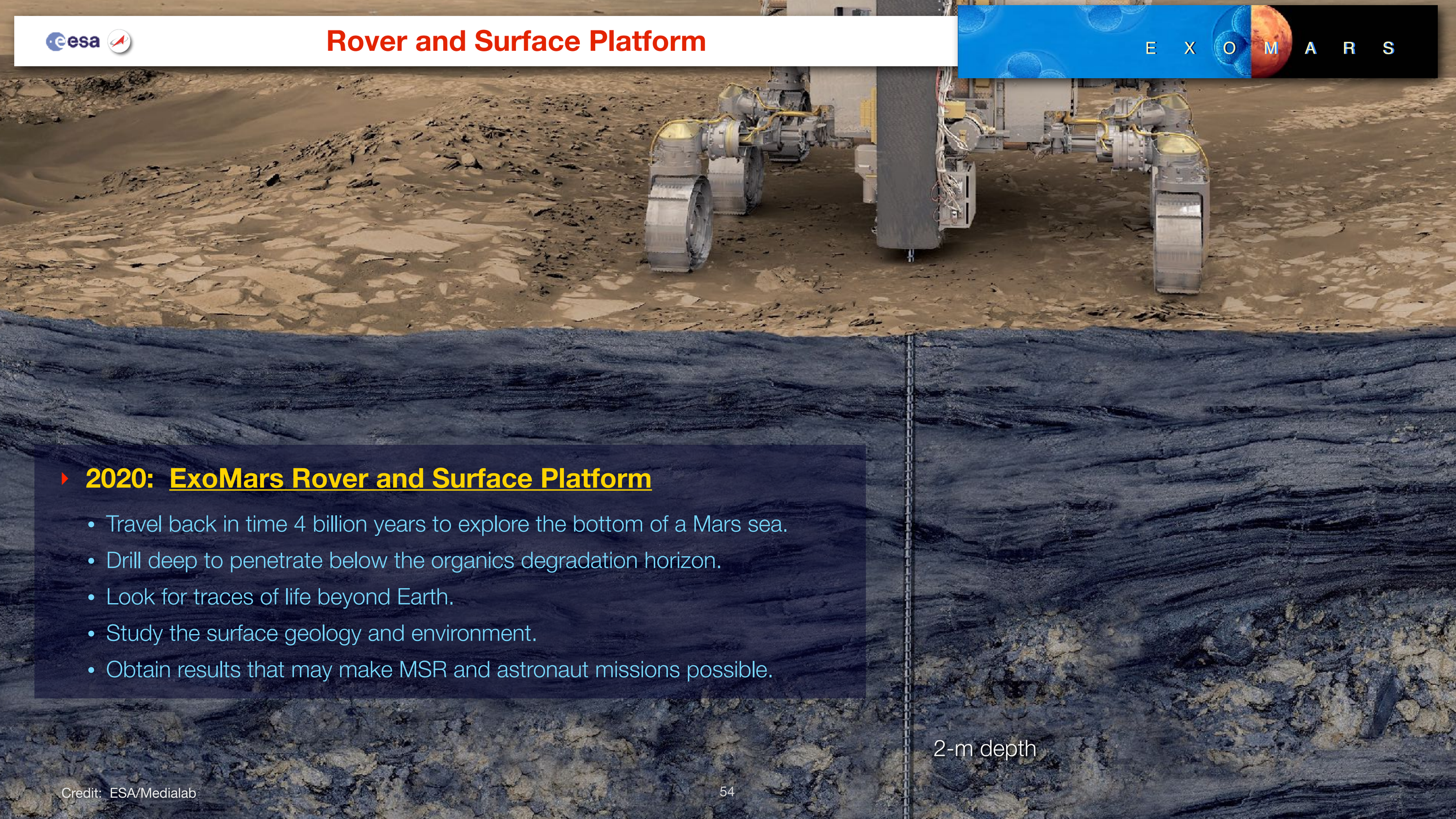


Rover and Surface Platform



Credit: ESA/Medialab

Rover and Surface Platform



- **2020: ExoMars Rover and Surface Platform**
  - Travel back in time 4 billion years to explore the bottom of a Mars sea.
  - Drill deep to penetrate below the organics degradation horizon.
  - Look for traces of life beyond Earth.
  - Study the surface geology and environment.
  - Obtain results that may make MSR and astronaut missions possible.

Credit: ESA/Medialab