Search for Life on Mars

Jorge L. Vago, F. Westall, F. Goesmann, F. Raulin, W. Brinckerhoff, H. Steininger, W. Goetz, C. Szopa,
D. Loizeau, E. Sefton-Nash, H. Svedhem, D. Rodionov, ExoMars science working team and project team

GeoPlanet Visit
9 January 2018, ESTEC (NL)

Early Terrestrial Planet Evolution

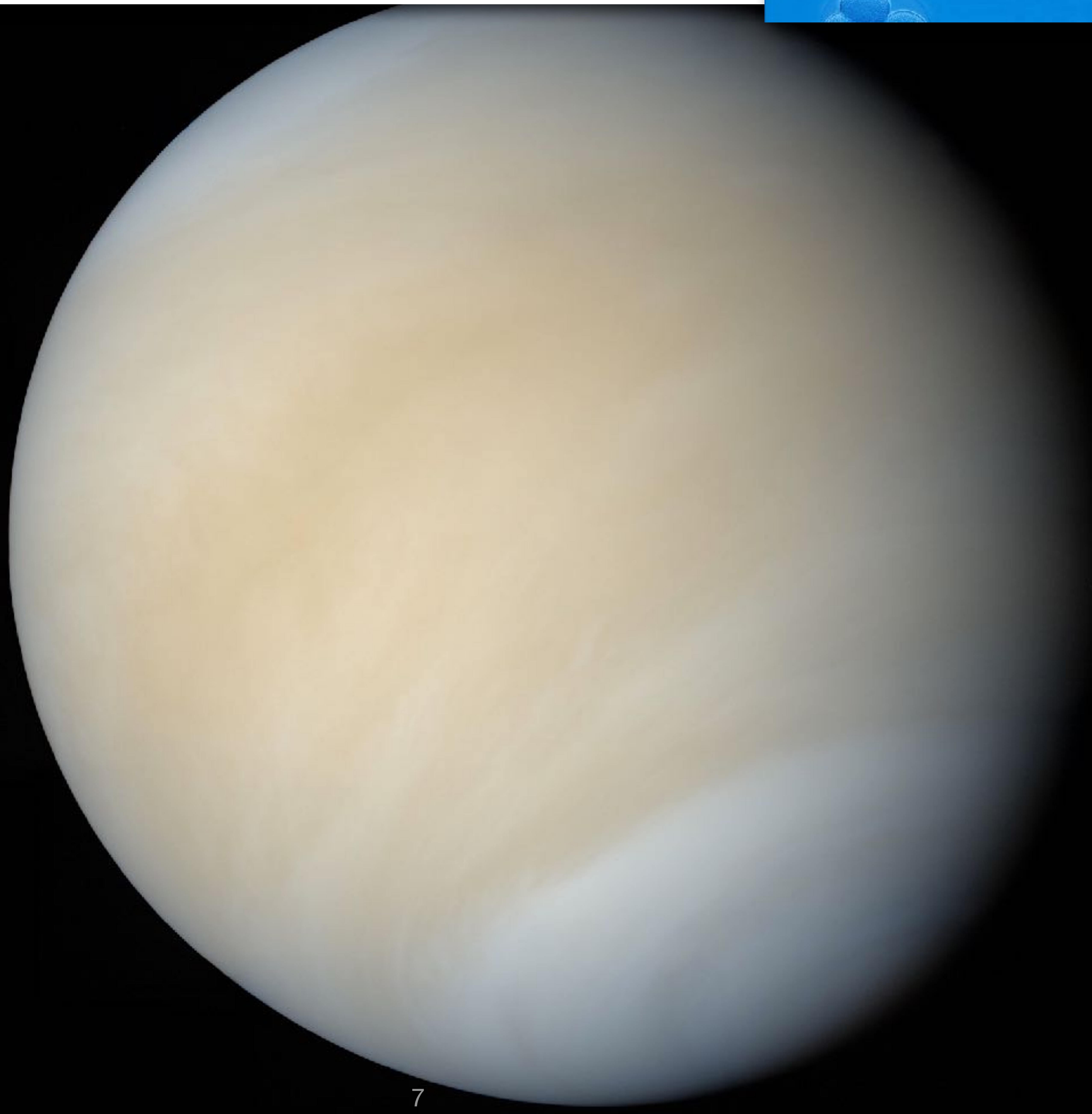
Early Terrestrial Planet Evolution

Early Terrestrial Planet Evolution

Early Terrestrial Planet Evolution

Early Terrestrial Planet Evolution

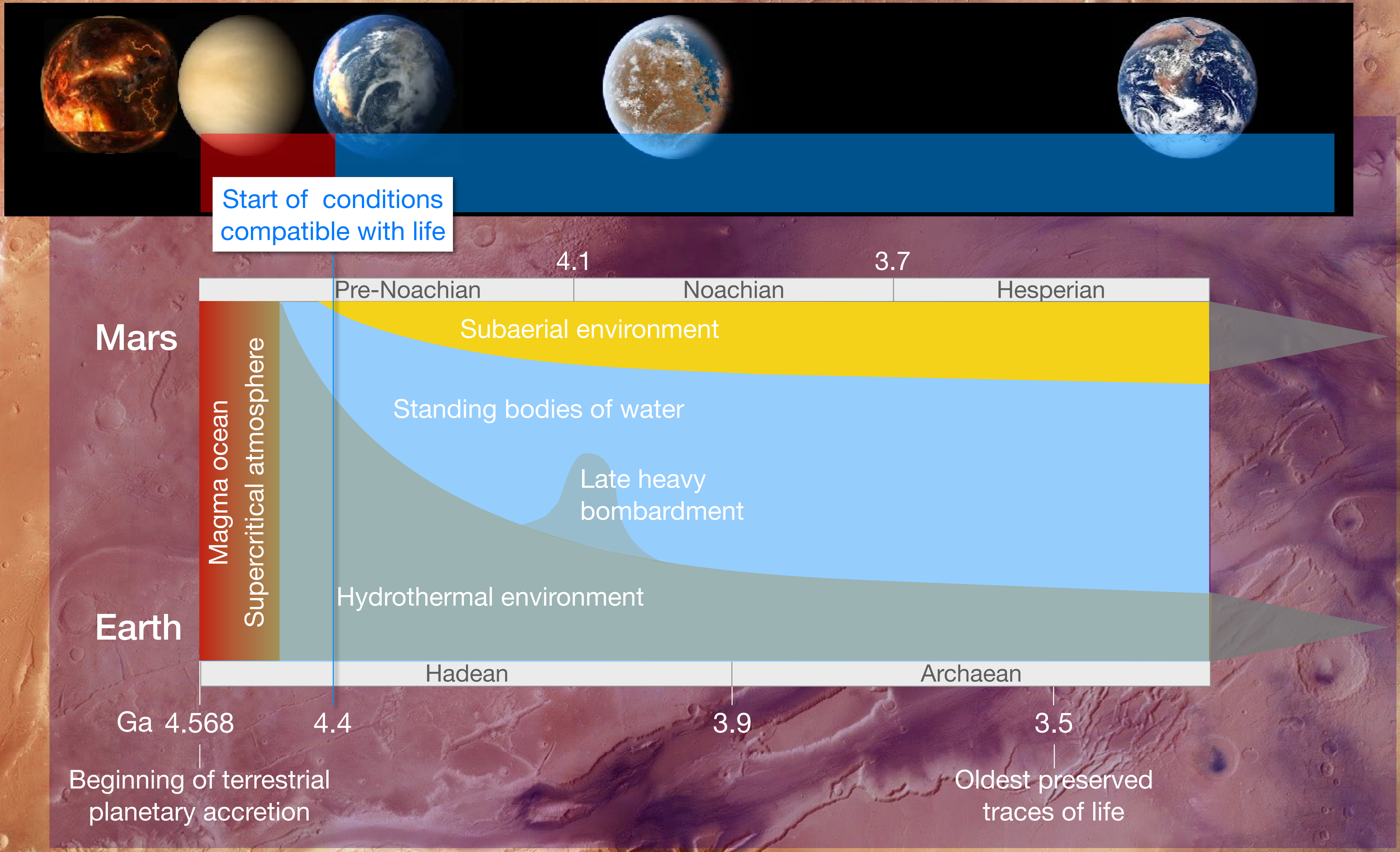
Early Terrestrial Planet Evolution



Early Terrestrial Planet Evolution

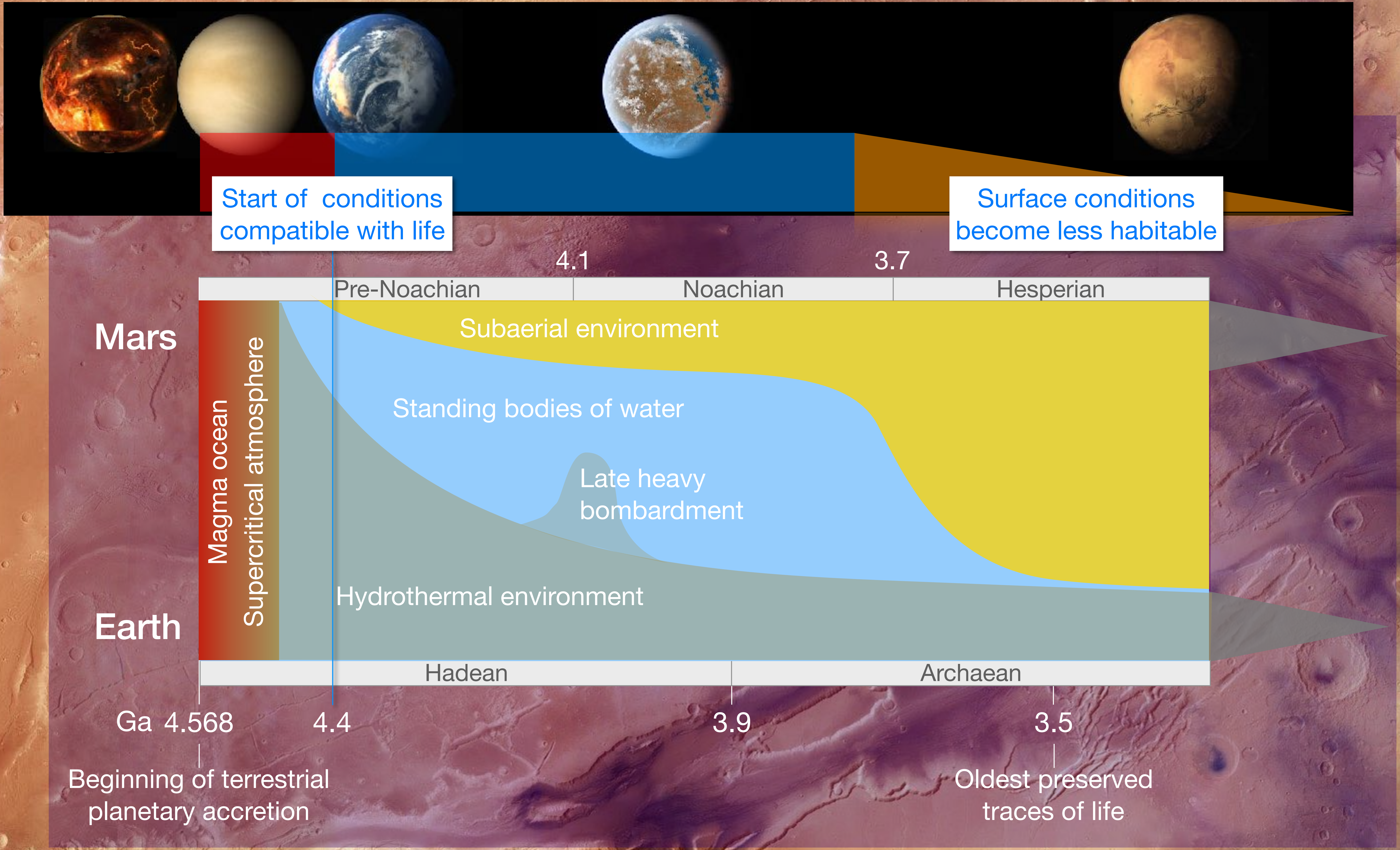
Early Terrestrial Planet Evolution

Early Earth



Credit: Kasei Valles, MEX/HRSC

Early Mars



Credit: Kasei Valles, MEX/HRSC

Early Crust

Early Earth and Mars hosted numerous reducing, nutrient-rich, hydrothermal submarine environments with conditions that would have allowed hosting life.

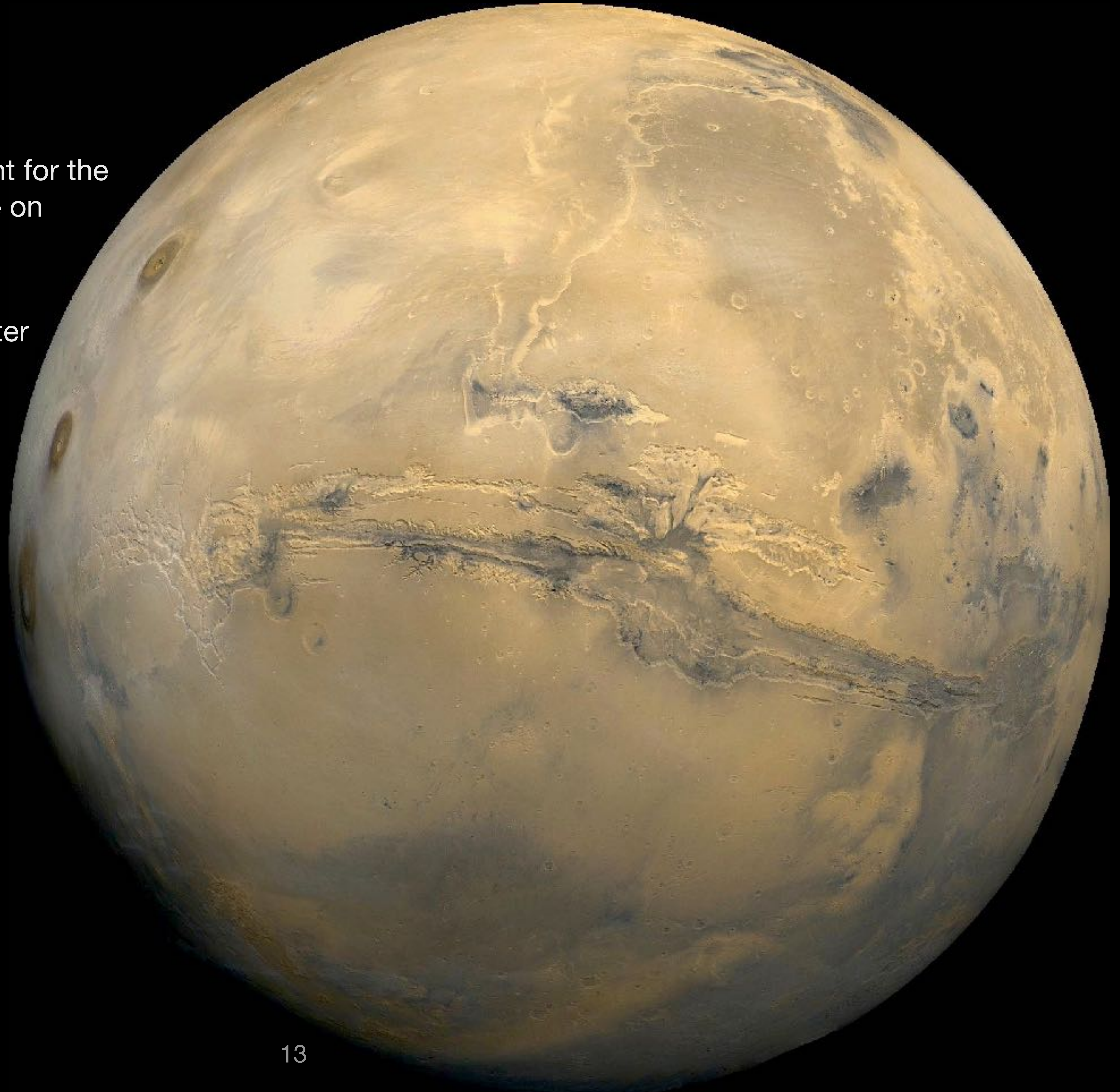
Desirable attributes:

- Low-energy water environments
- Settings known to preserve biosignatures
- Aqueous mineral variety

Credit: Champagne vent white smoker, NOAA

Why Life on Mars ?

- Many processes considered important for the origin of life on Earth were also active on young Mars;
- Early in the history of Mars, liquid water was present on its surface;
- The absence of plate tectonics on Mars means we can study rocks from the period when life appeared on our planet.



Credit: NASA/MGS

HABITABILITY

Potential to Detect Life

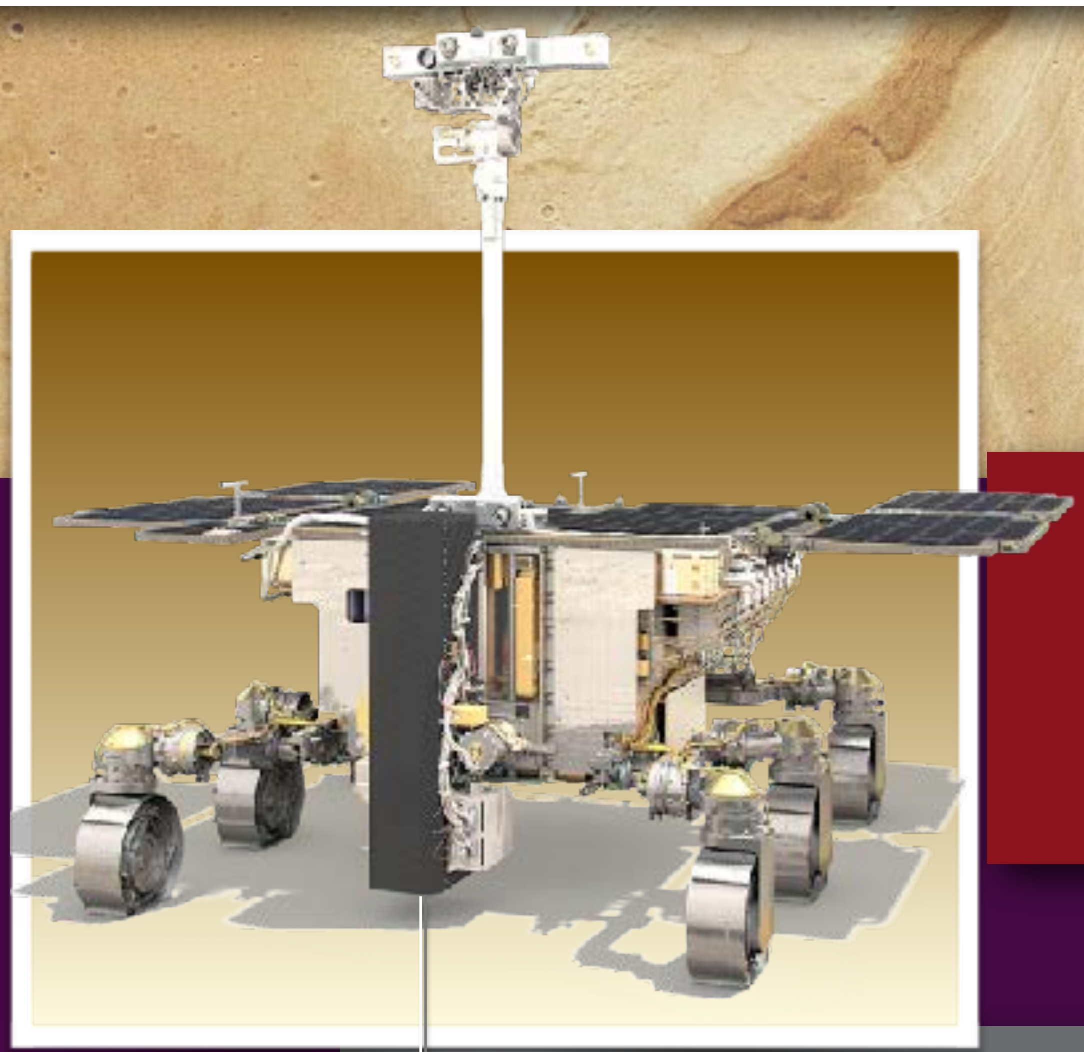
PRESERVATION

Credit: Cape Verde, Opportunity

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.

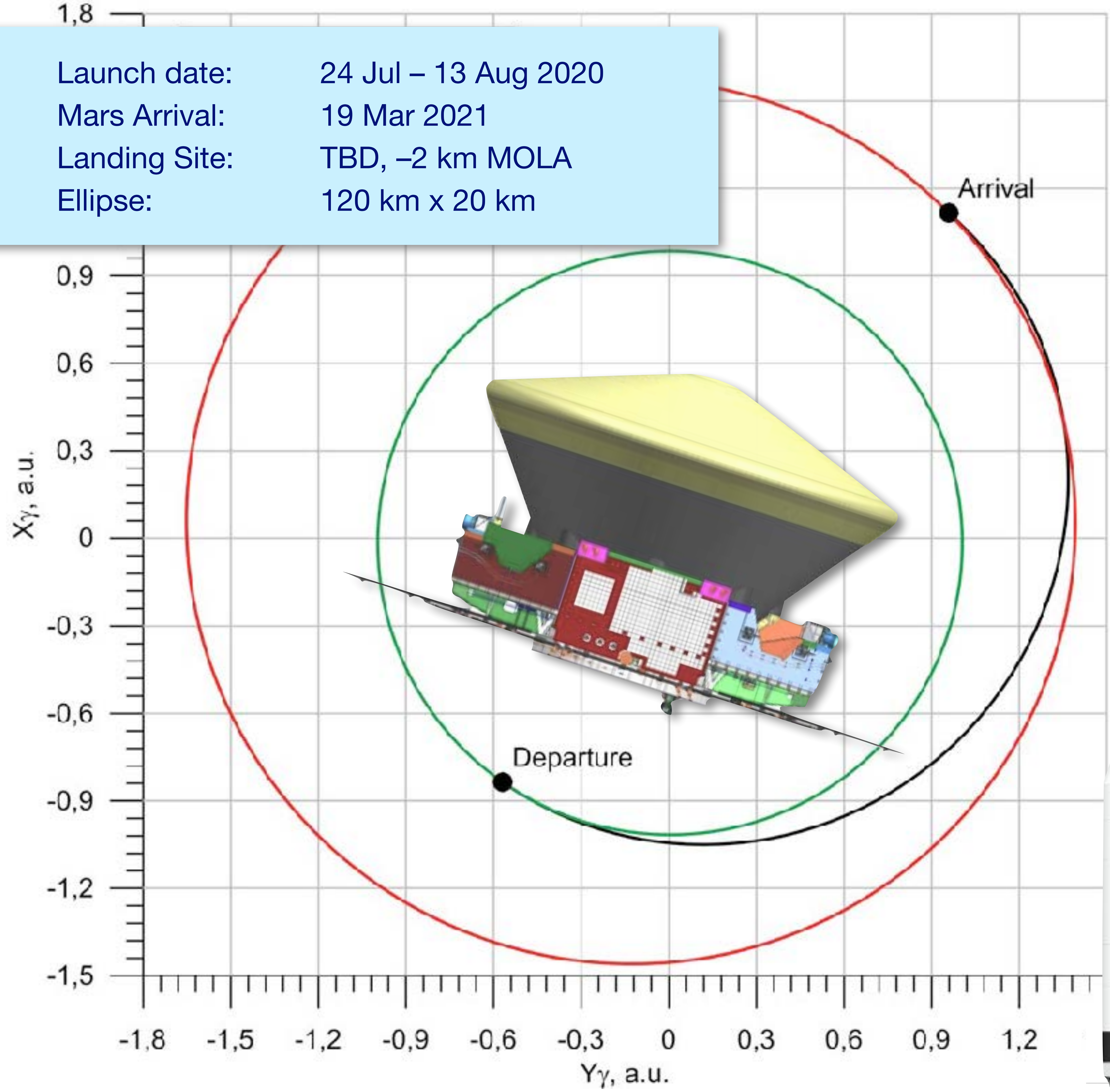
- To characterise the surface environment.

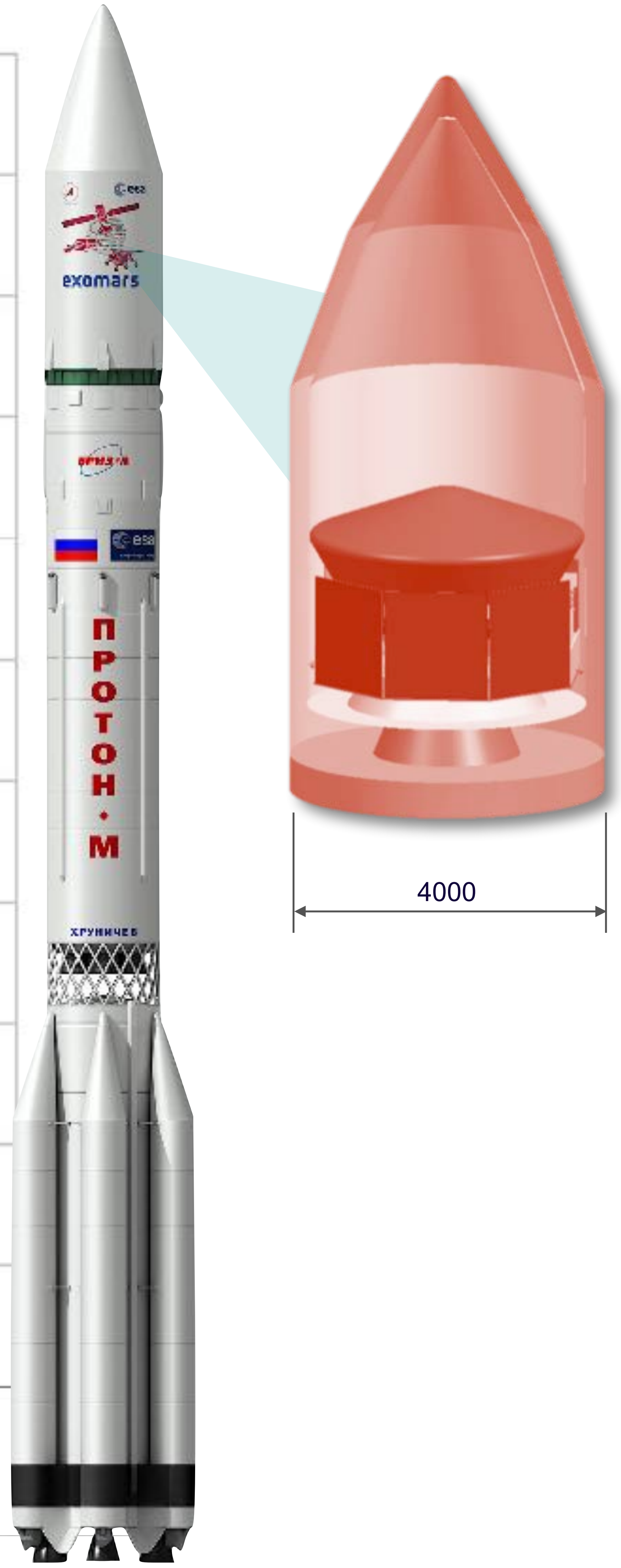
- Throttleable braking engines for planetary landing.
- Russian deep-space communications stations working in combination with ESA's ESTRACK.

Credit: Mamers Valles, MEX/HRSC

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

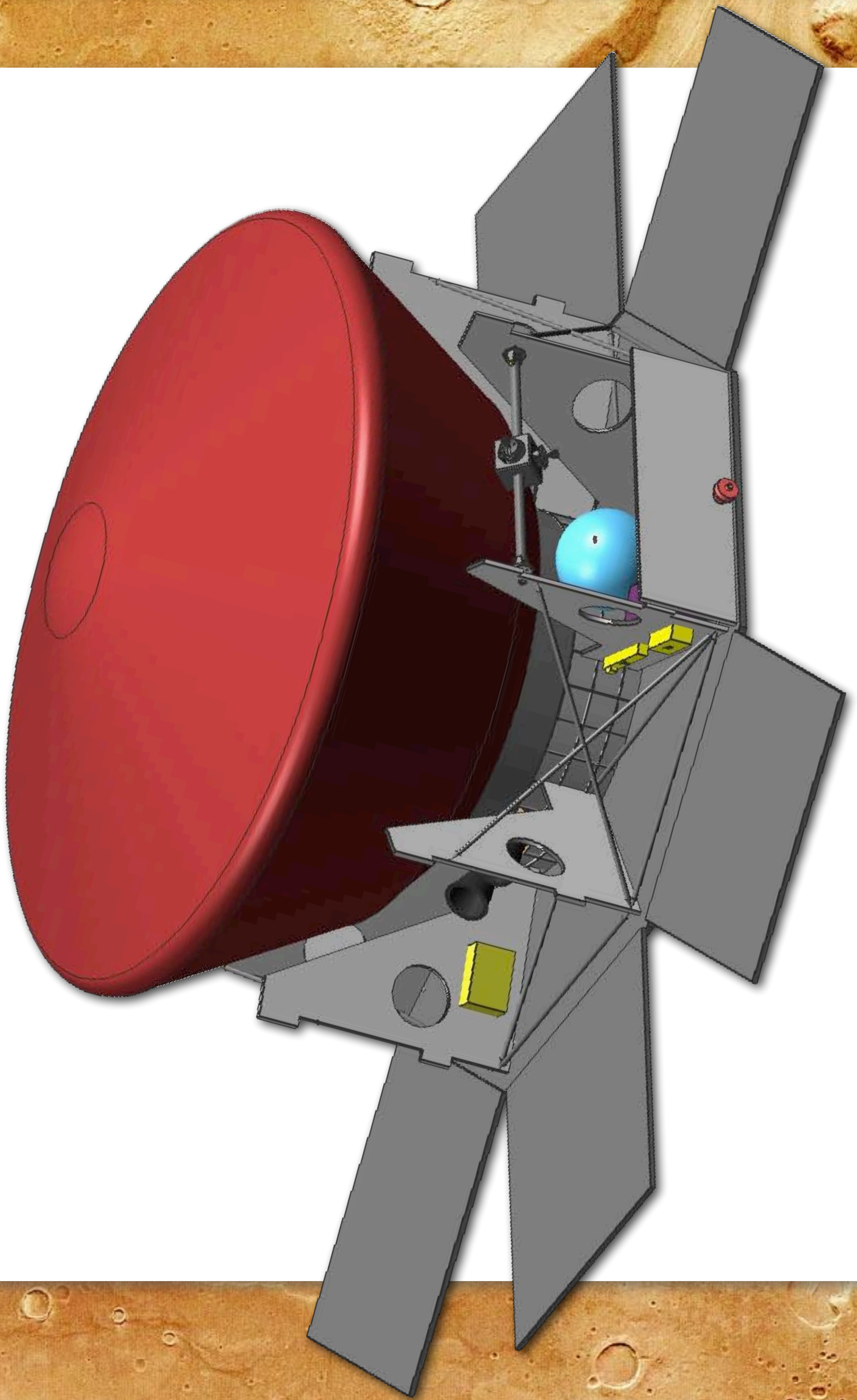


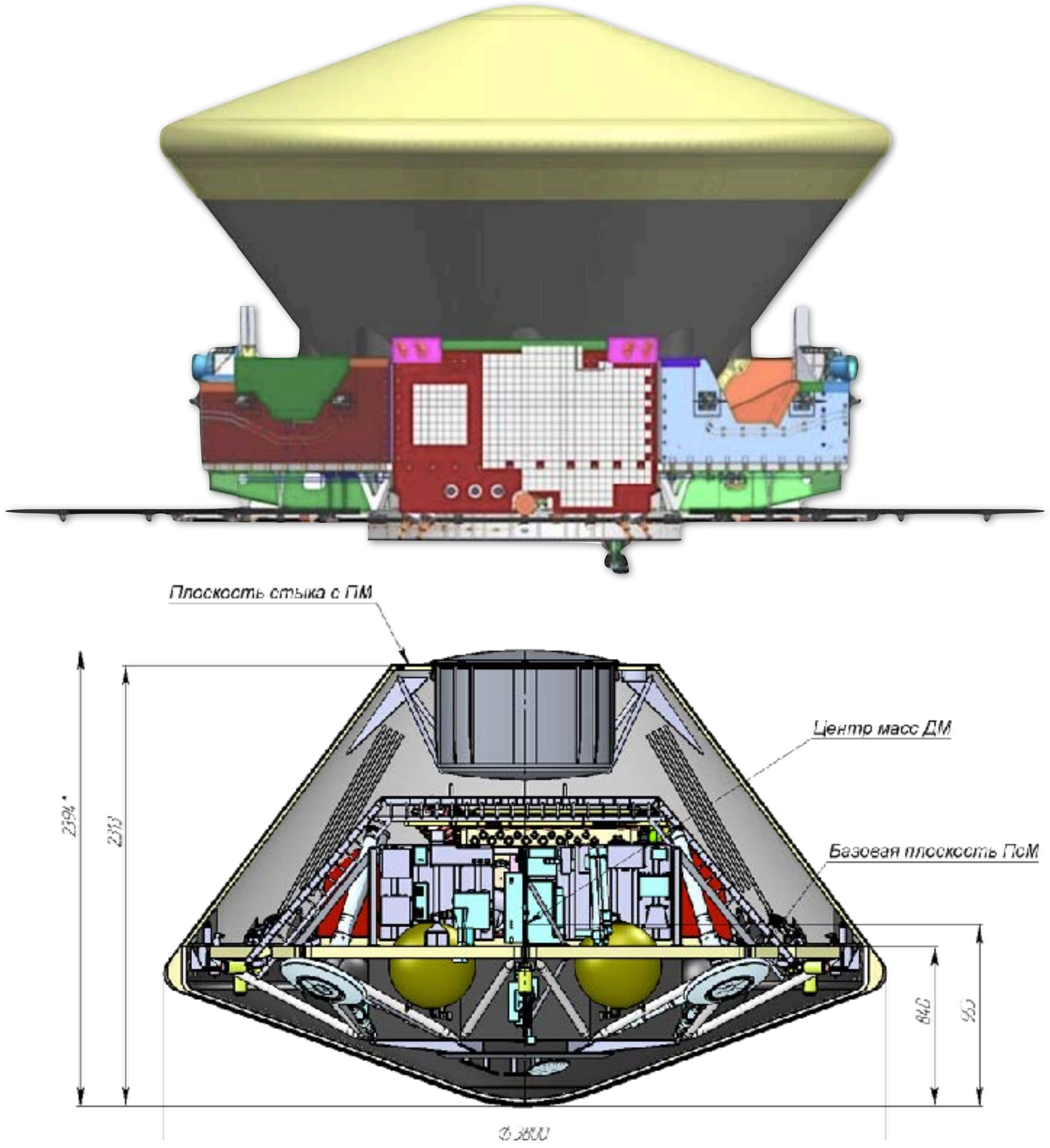


Credit: Mamers Valles, MEX/HRSC

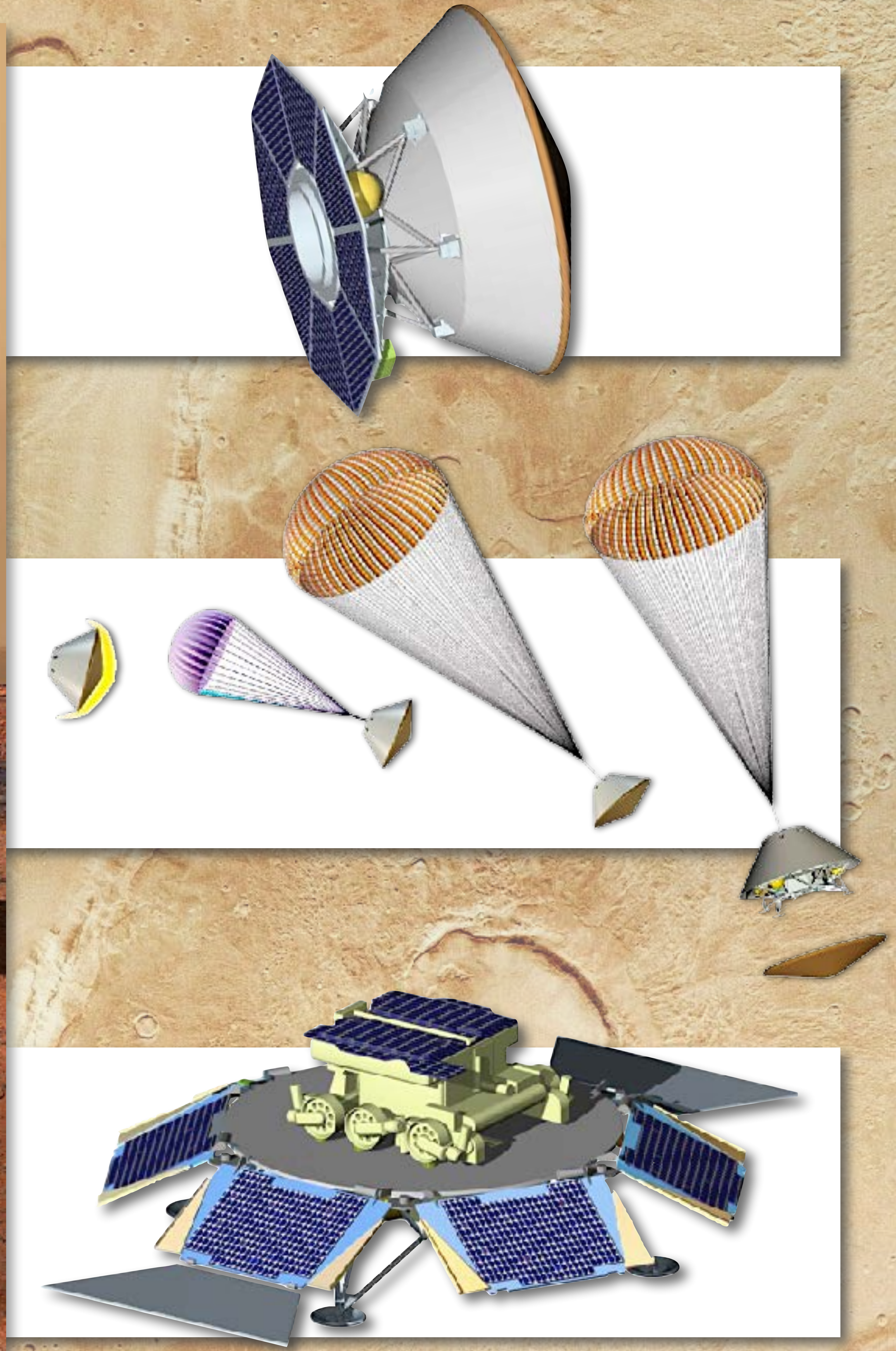
Carrier and Descent Module

E X O M A R S



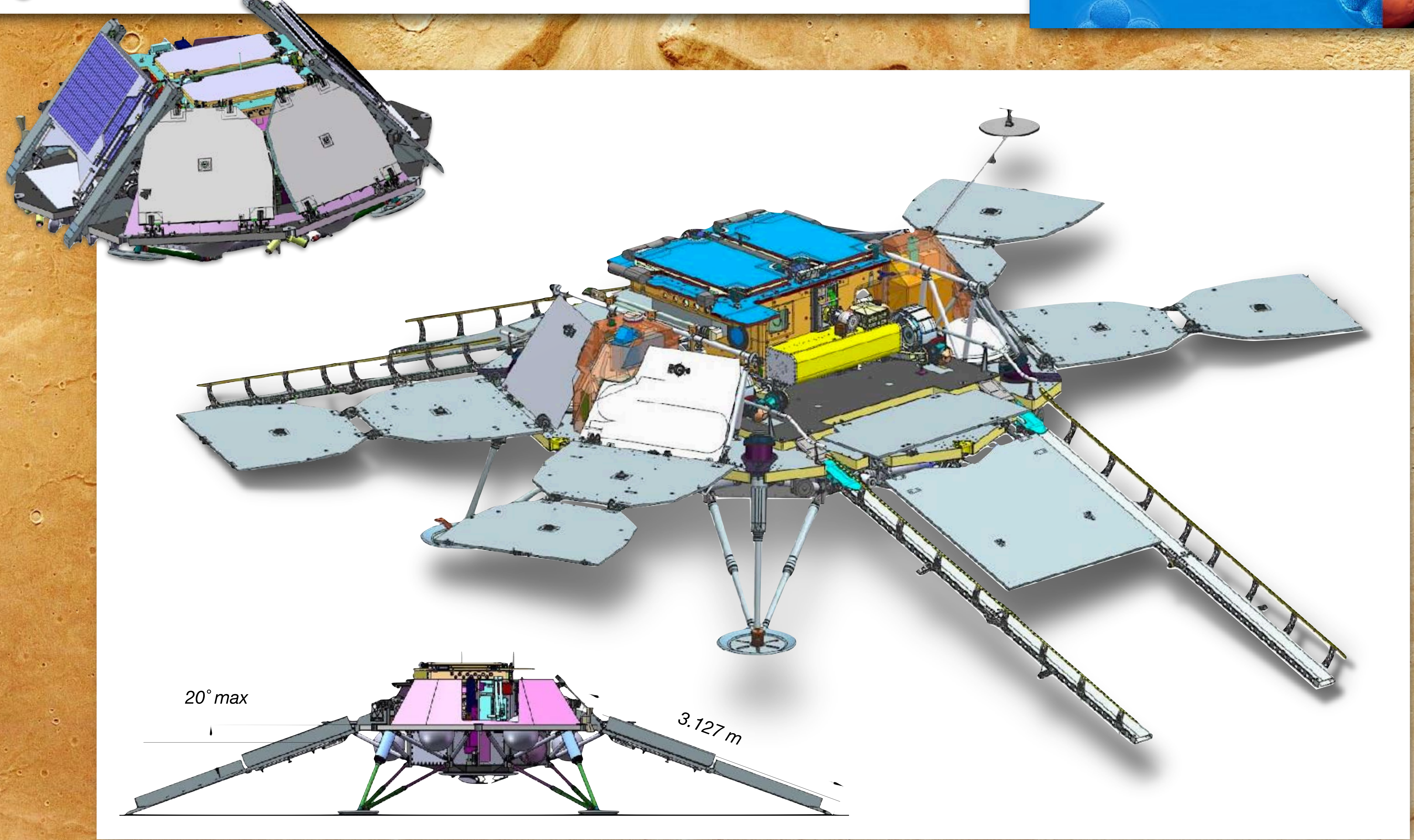


Entry, Descent, and Landing



Credit: Mamers Valles, MEX/HRSC

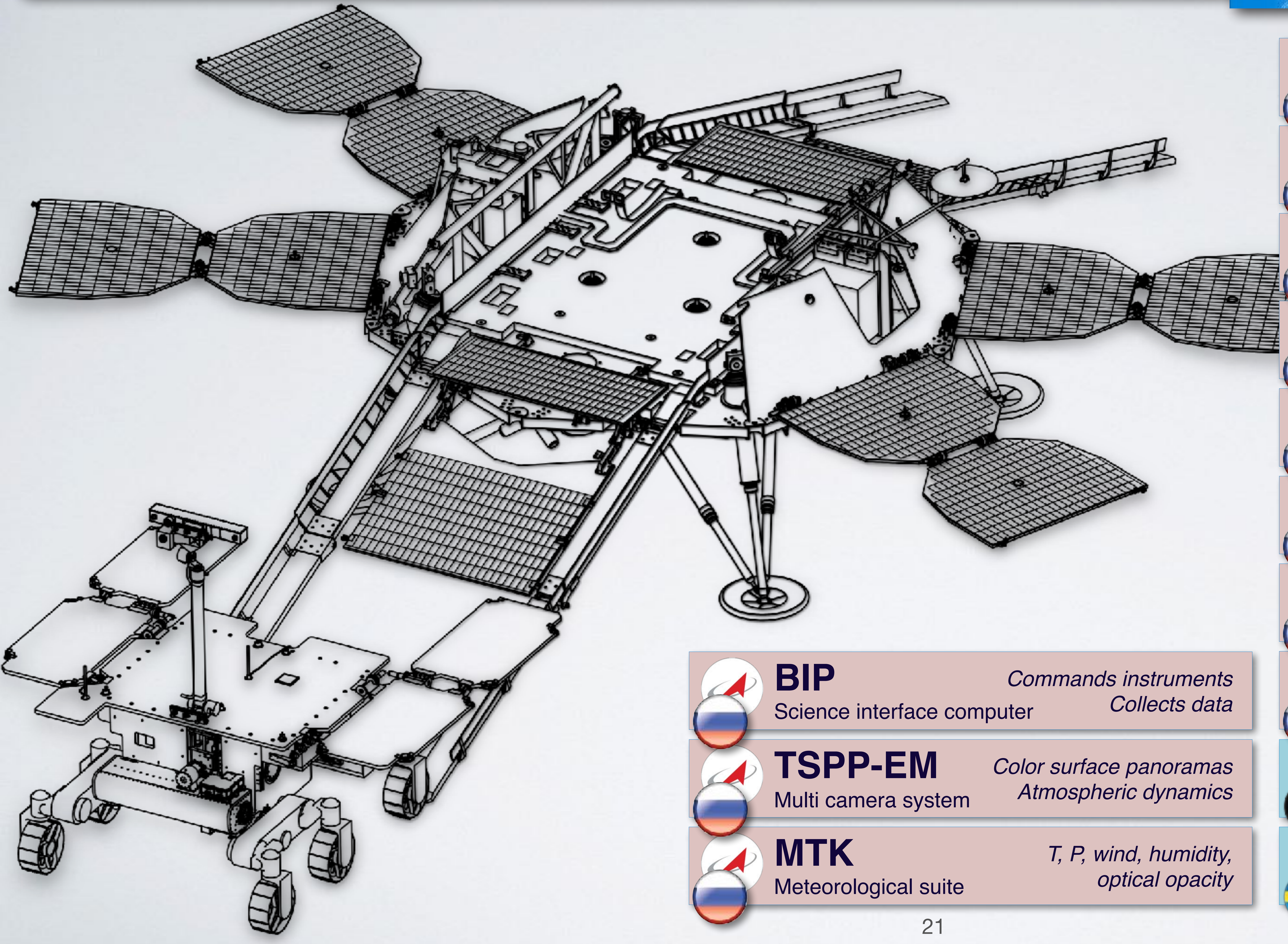
Descent Module



Credit: Mamers Valles, MEX/HRSC

Surface Platform

E X O M A R S



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

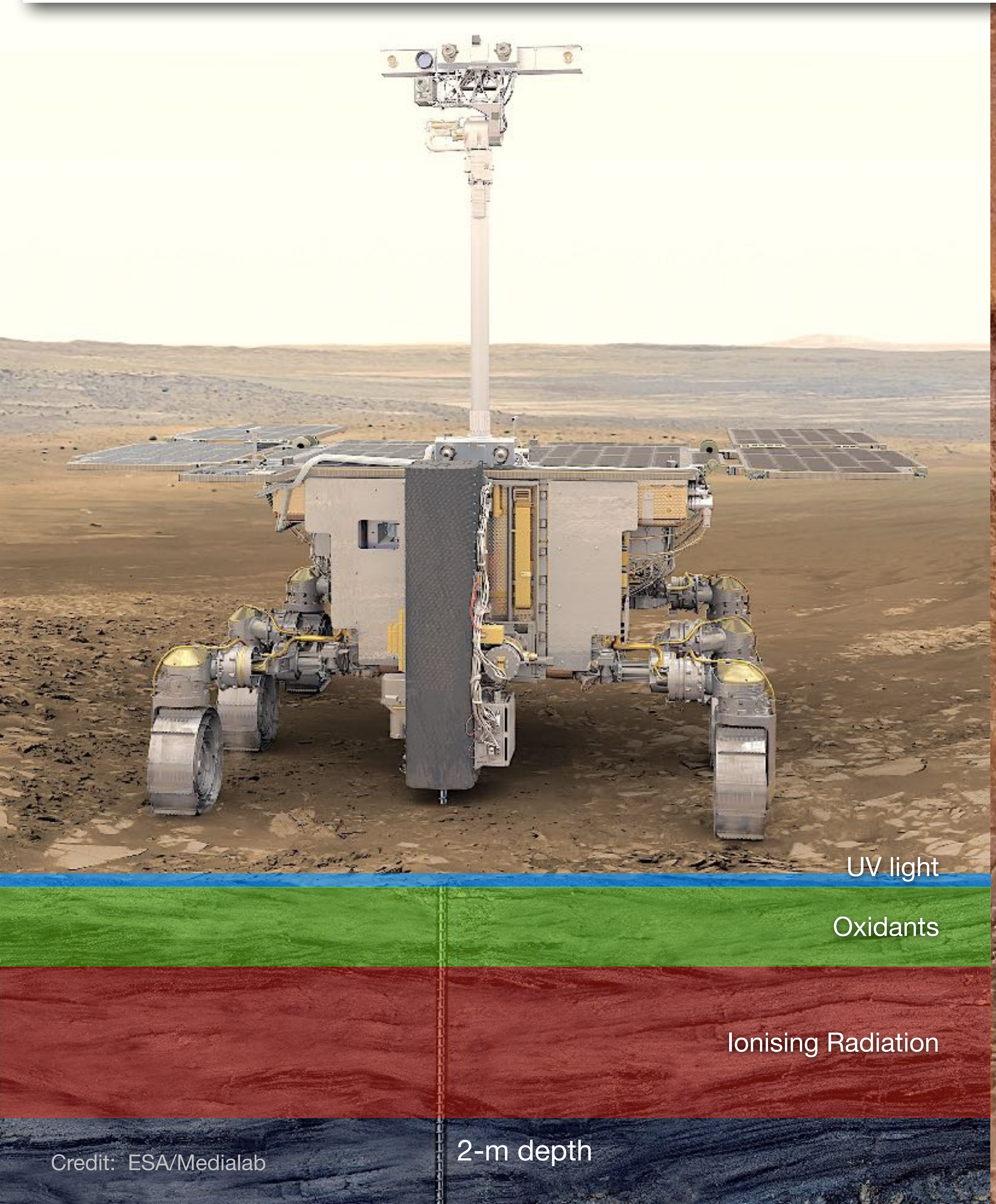
SEM — Seismometer
Internal Mars structure investigations

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

LaRa — Coherent transponder
Radio science for internal structure investigations

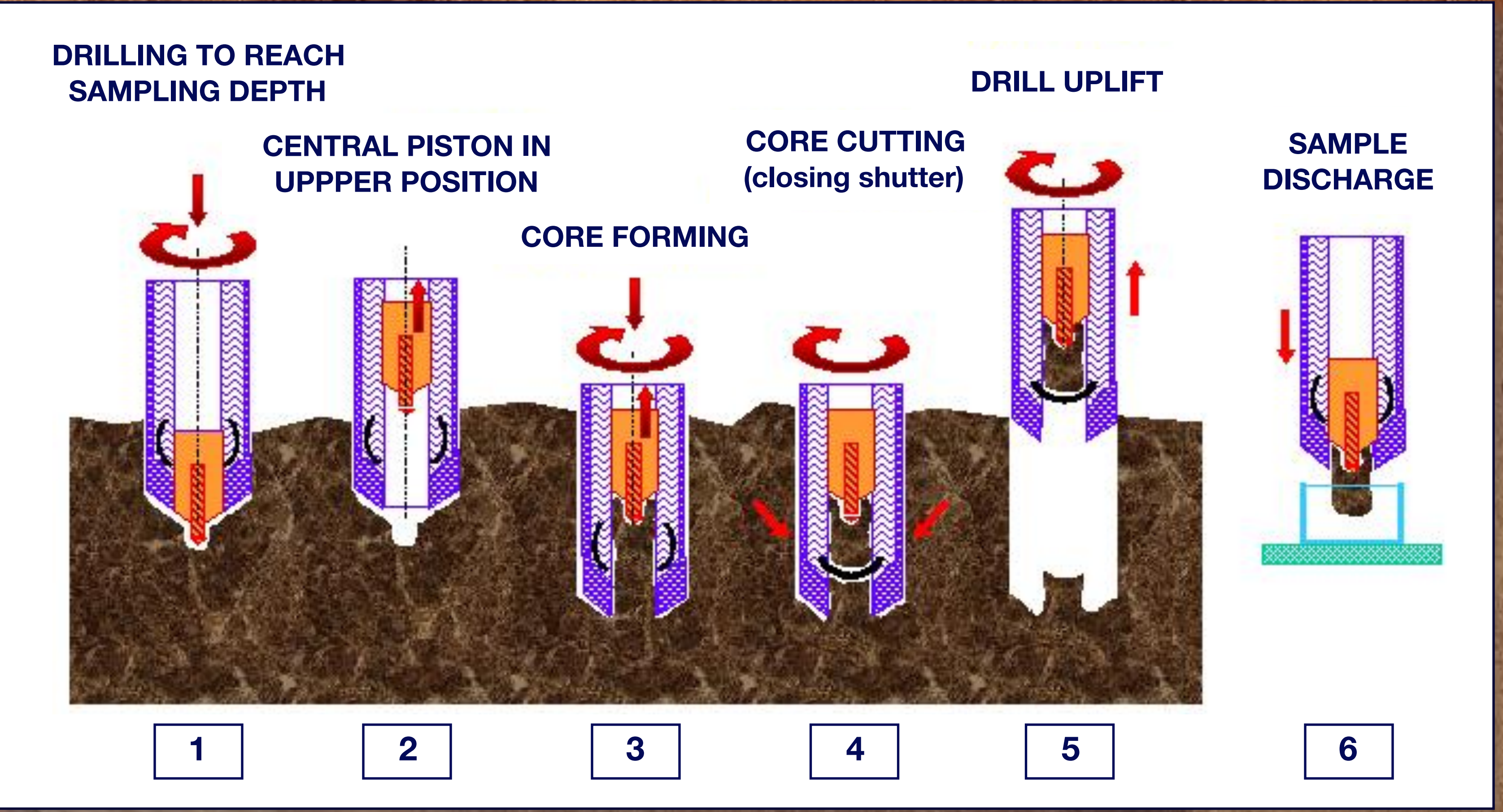
HABIT — Habitability studies
T, UV dose, humidity, salt deliquescence

Mobility + Subsurface Access



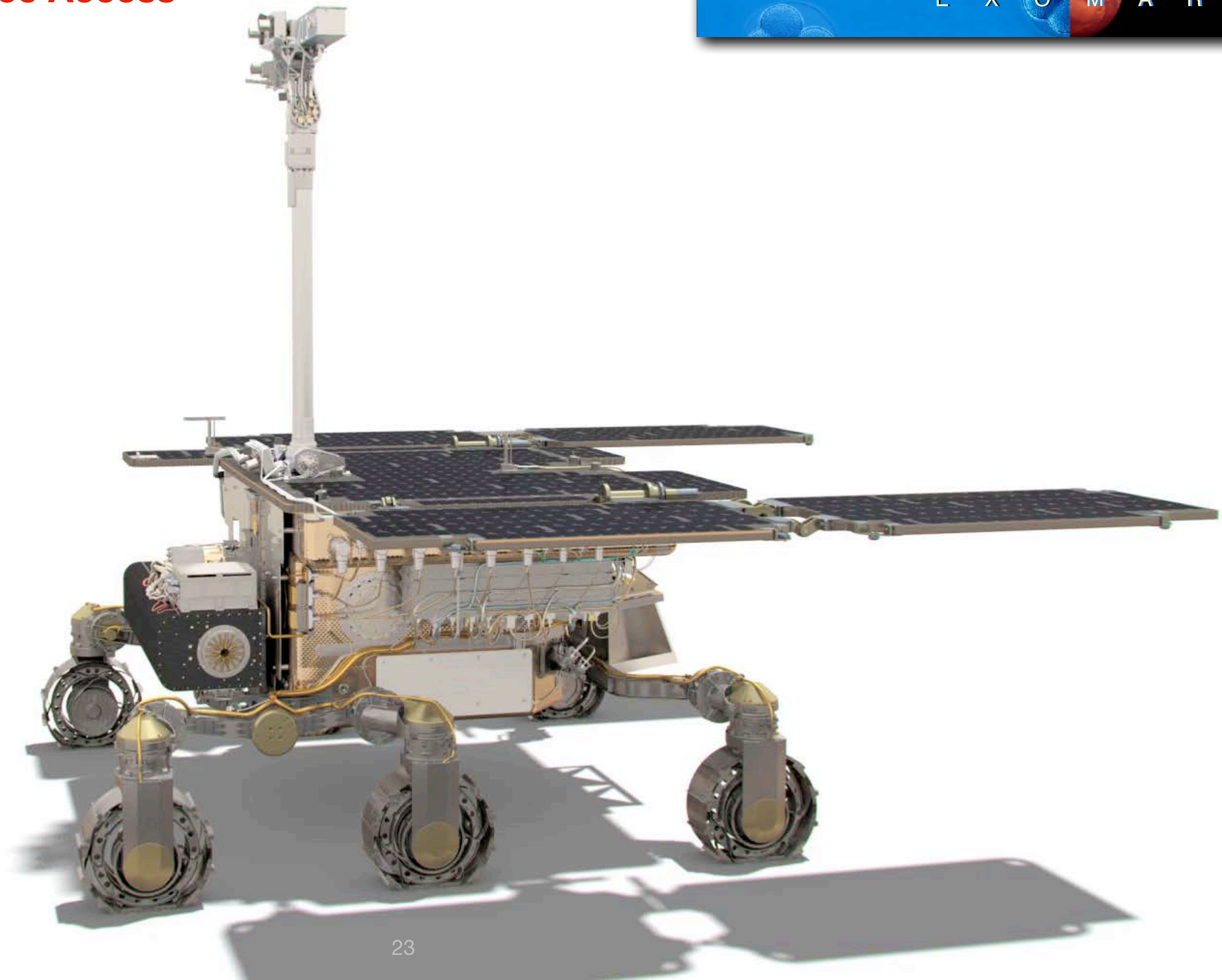
Credit: ESA/Medialab

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

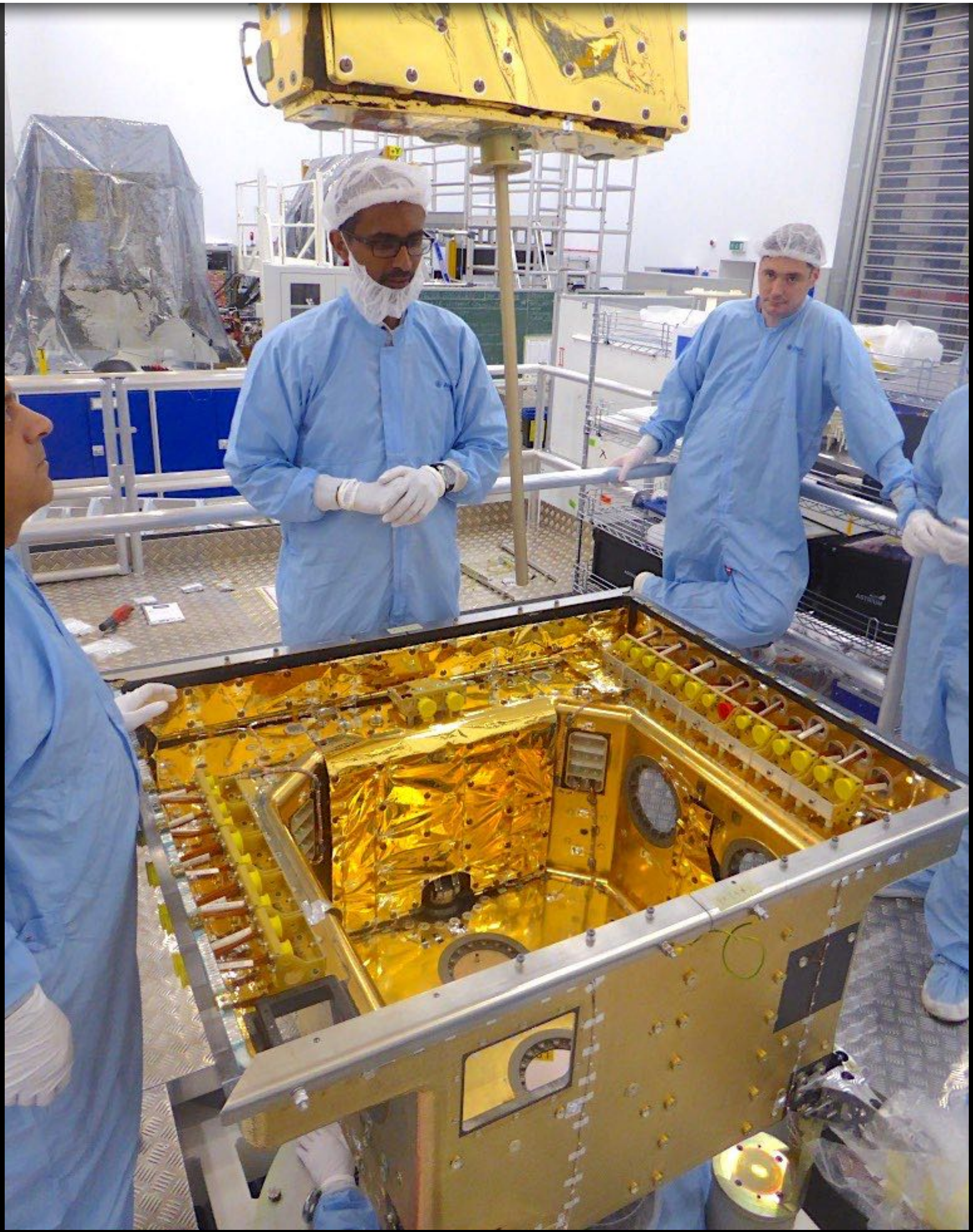


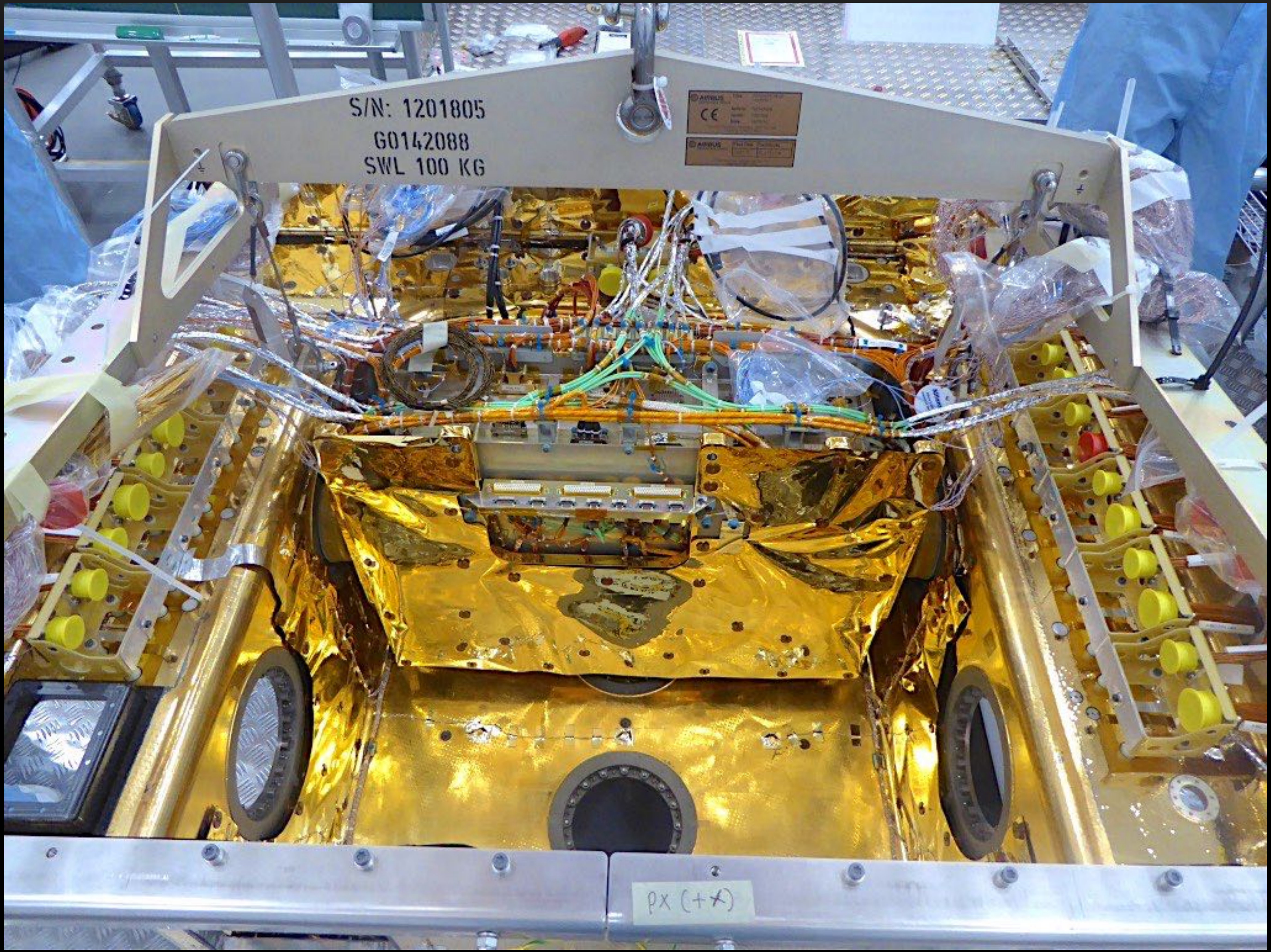
Credit: Argyre, MEX/HRSC

Mobility + Subsurface Access

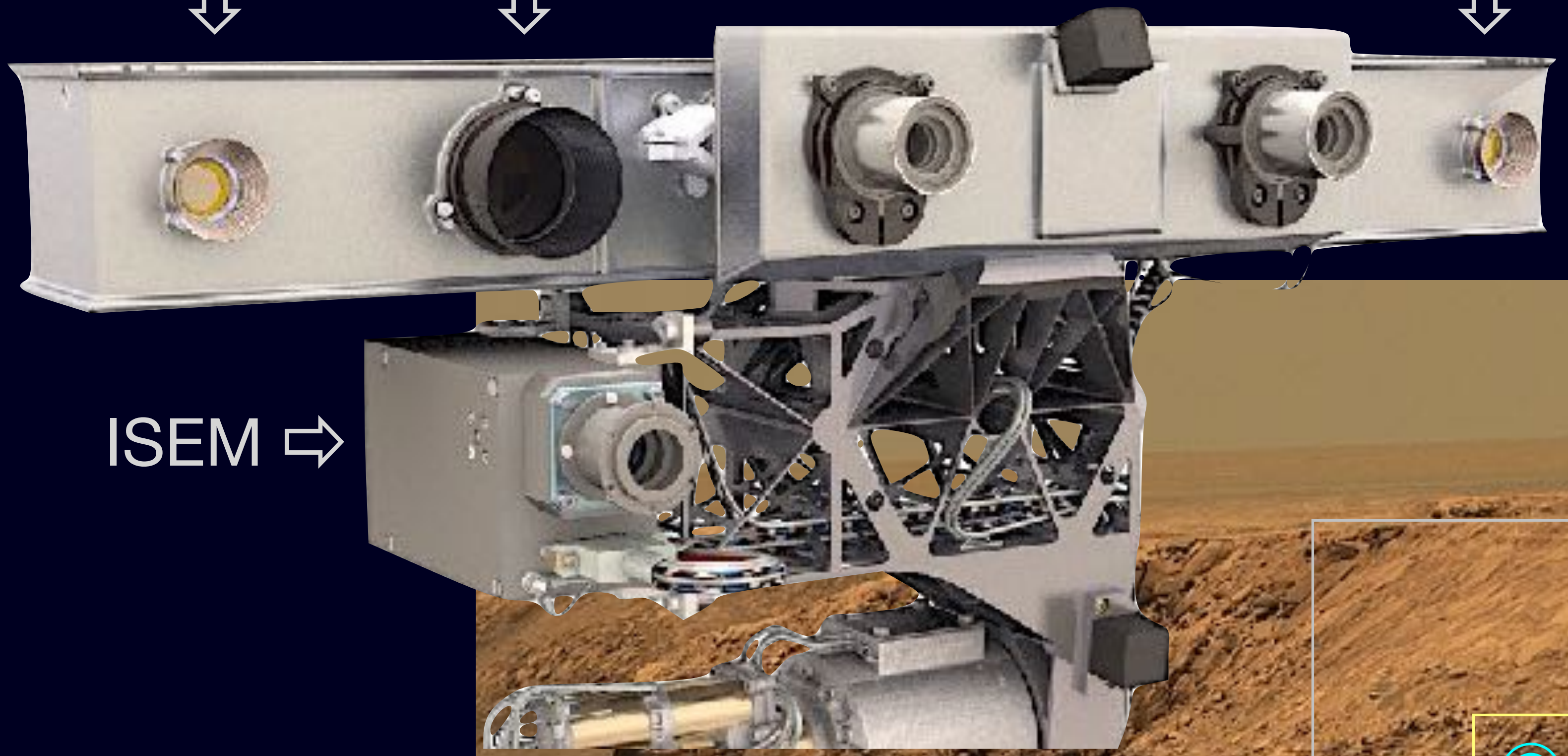


Integration of Service Module



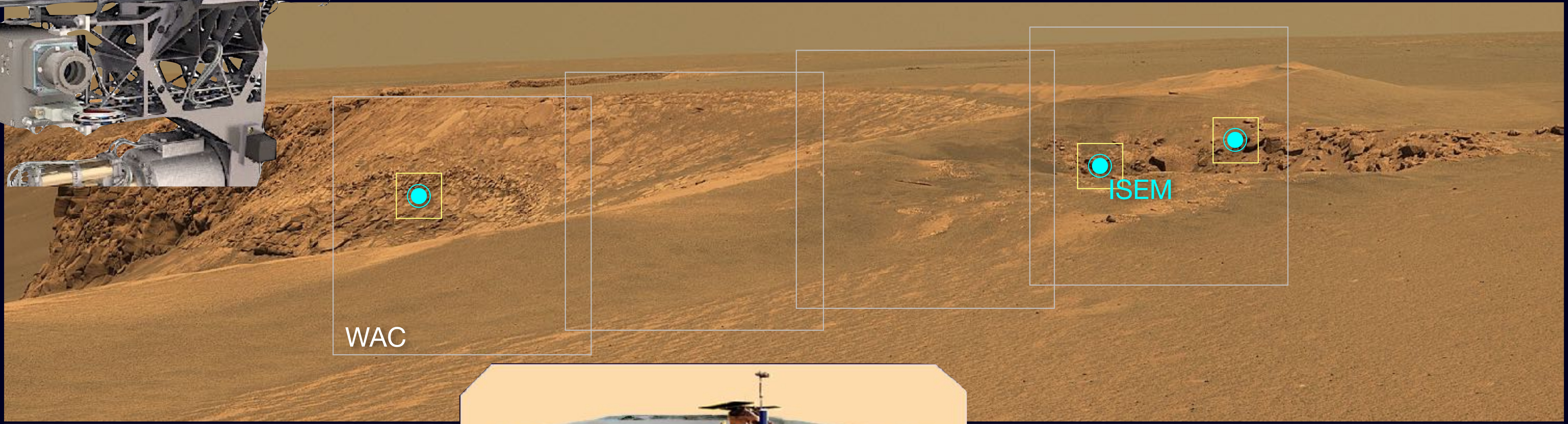


Site Characterisation



AT PANORAMIC SCALE: To establish the geological context

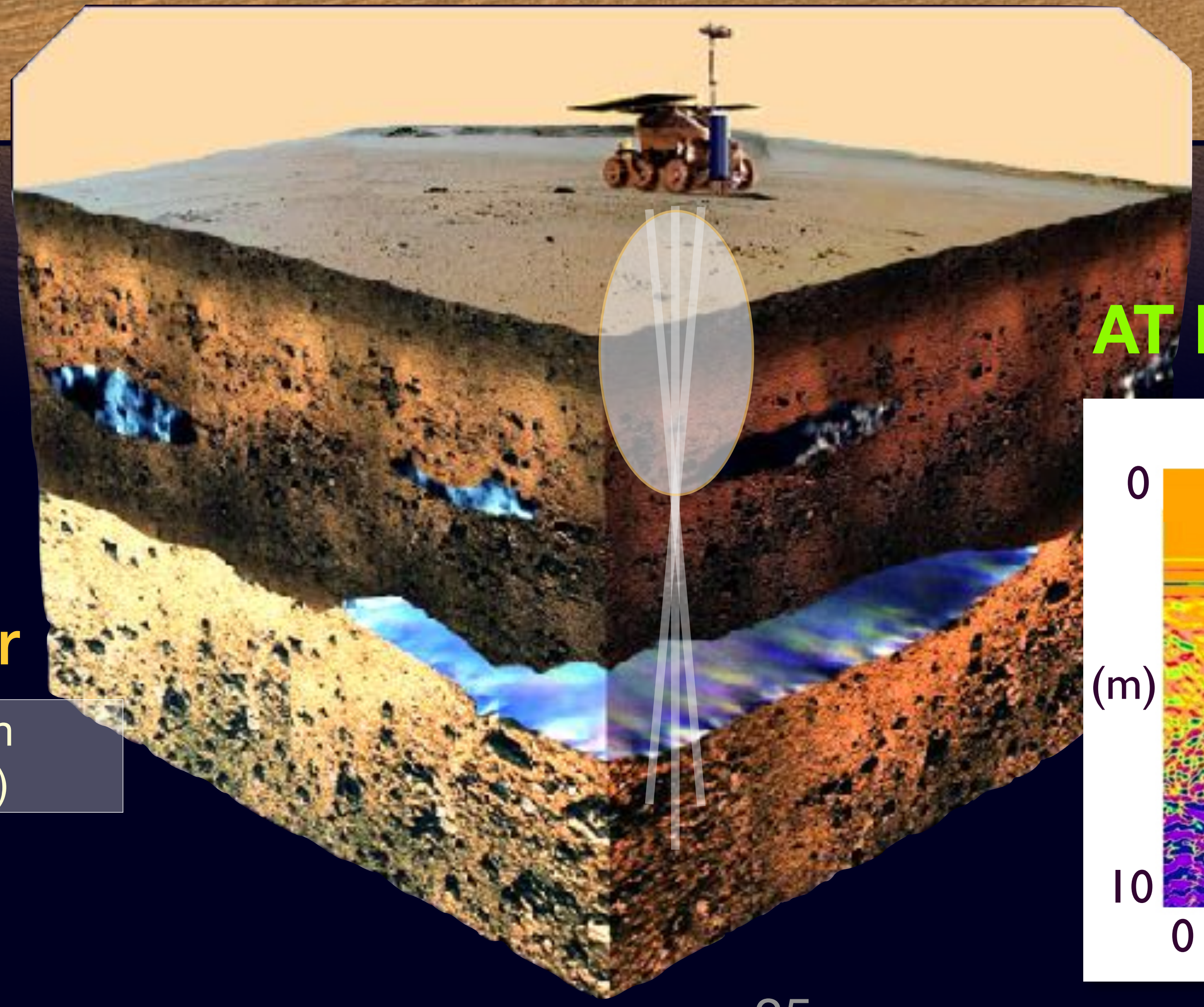
Two Wide Angle Cameras (WAC): Colour, stereo, 35° FOV;
One High-Resolution Camera (HRC): Colour, 5° FOV
One IR spectrometer (ISEM): 1° FOV.



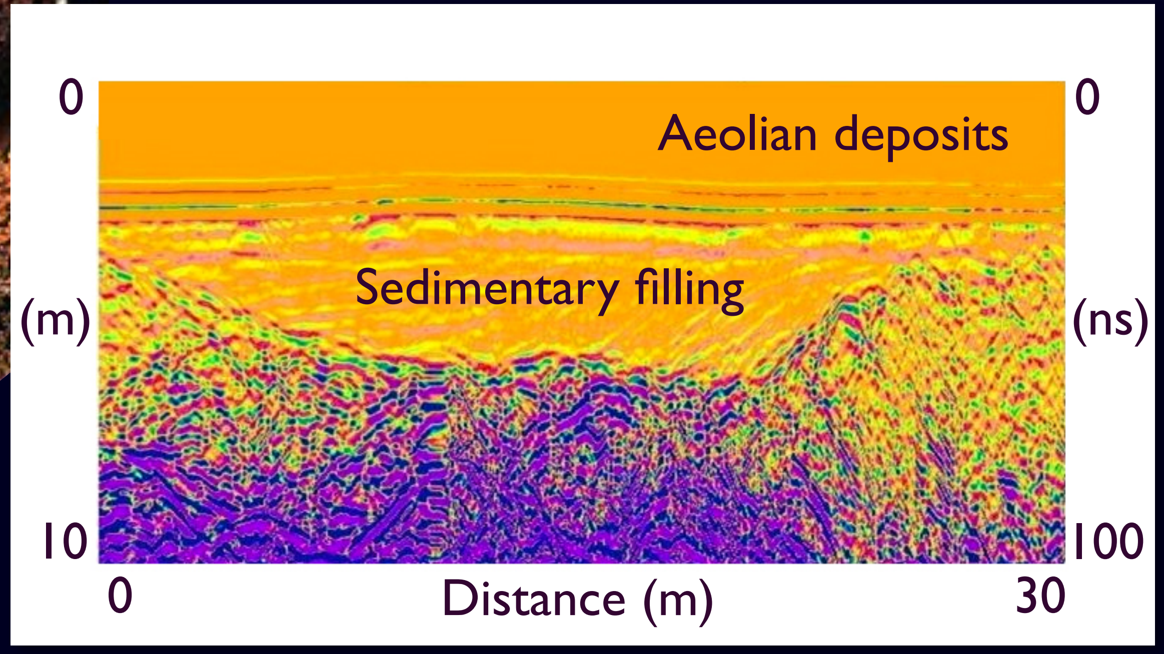
Neutron Detector

Ground Penetrating Radar

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



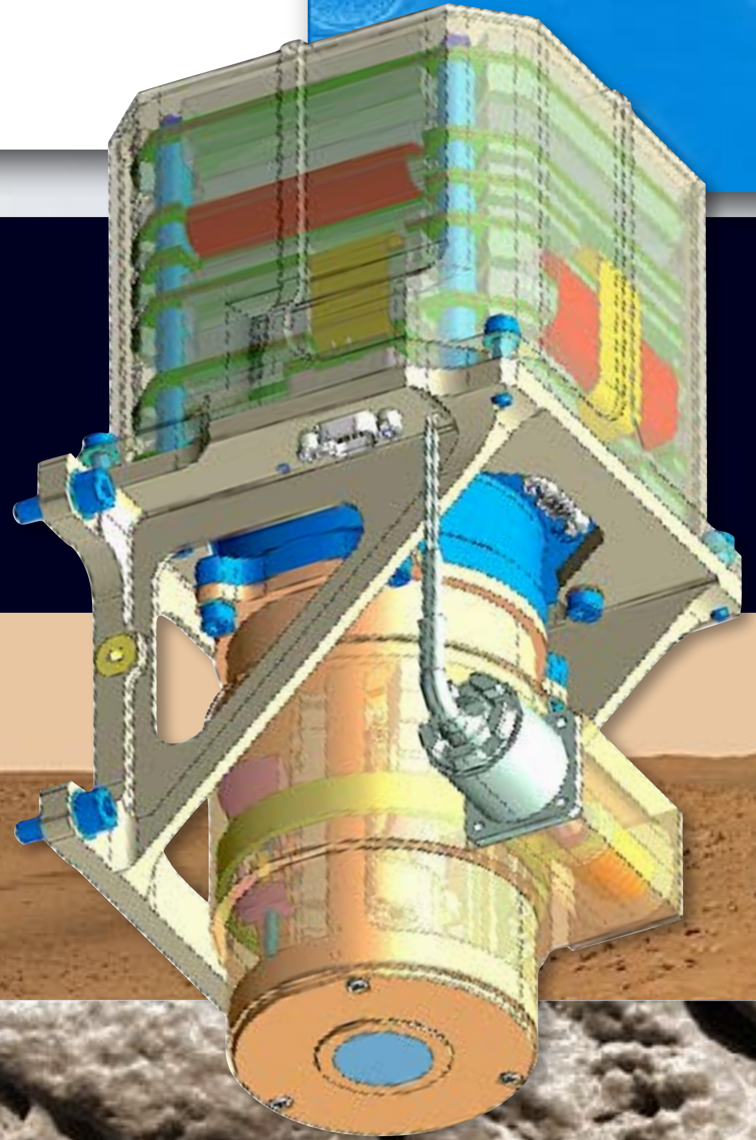
AT DEPTH: To study the stratigraphy for drilling



Heggy et al. 2007

Outcrop Characterisation

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

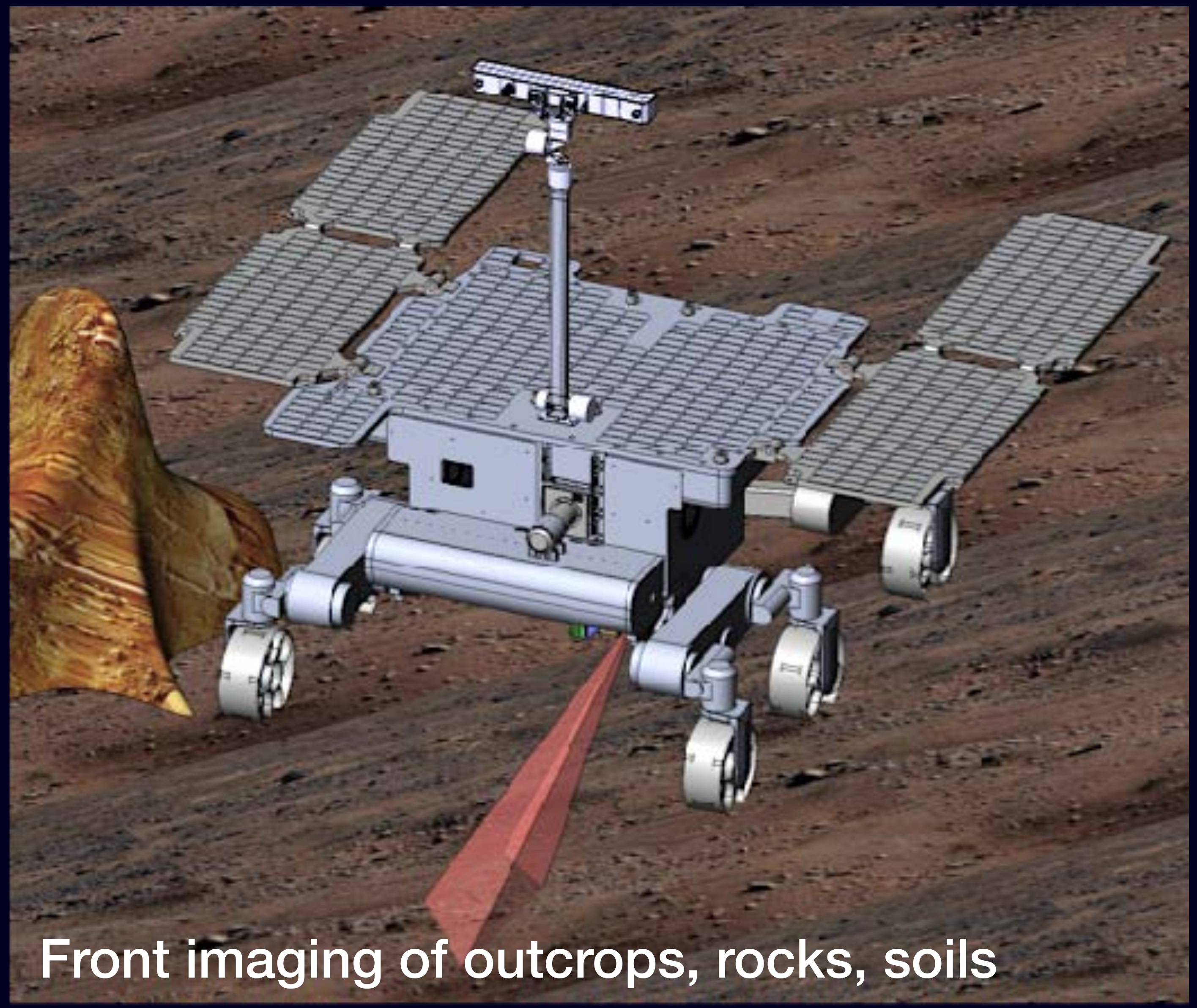


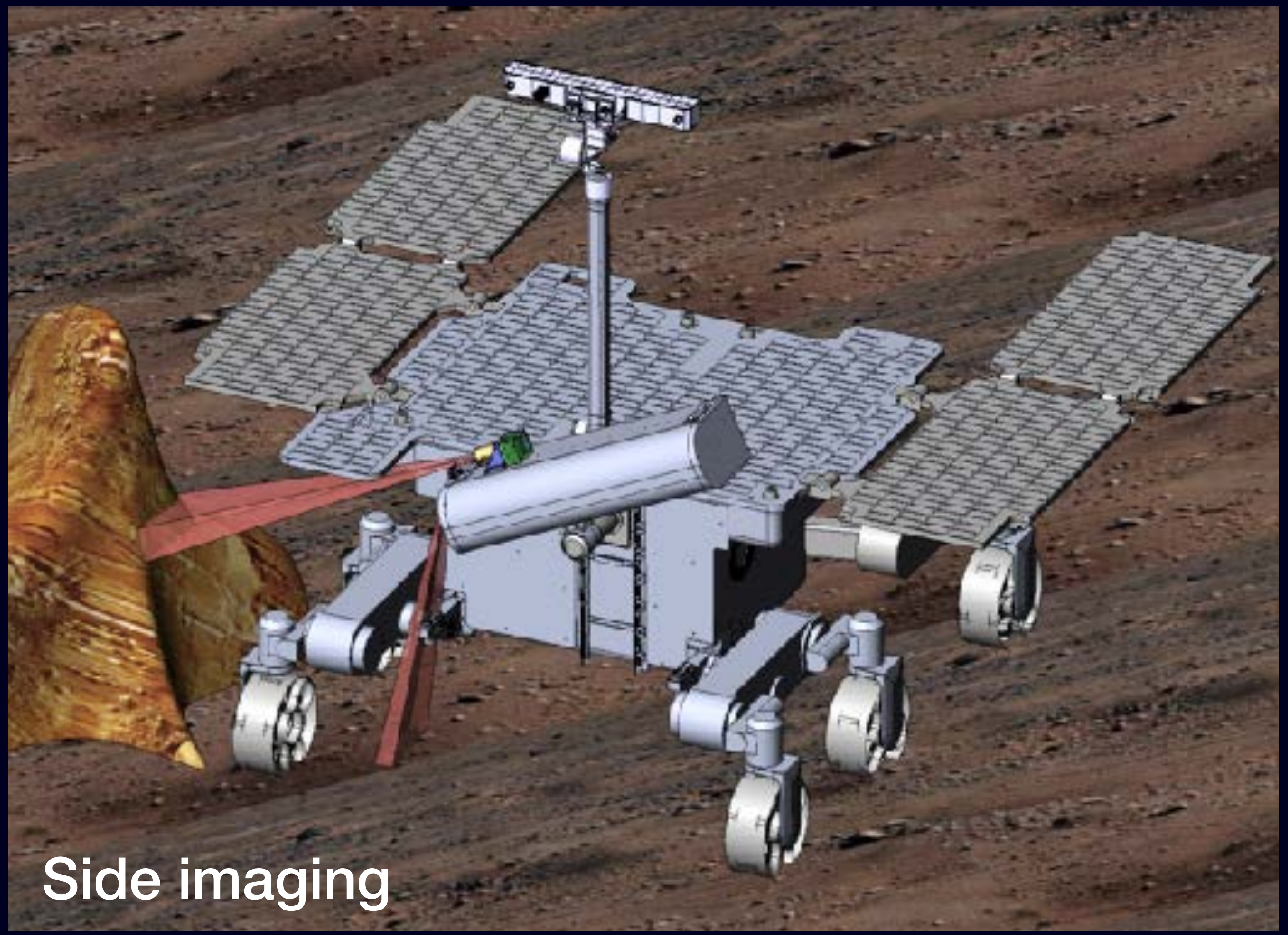
Next step: **ANALYSIS**

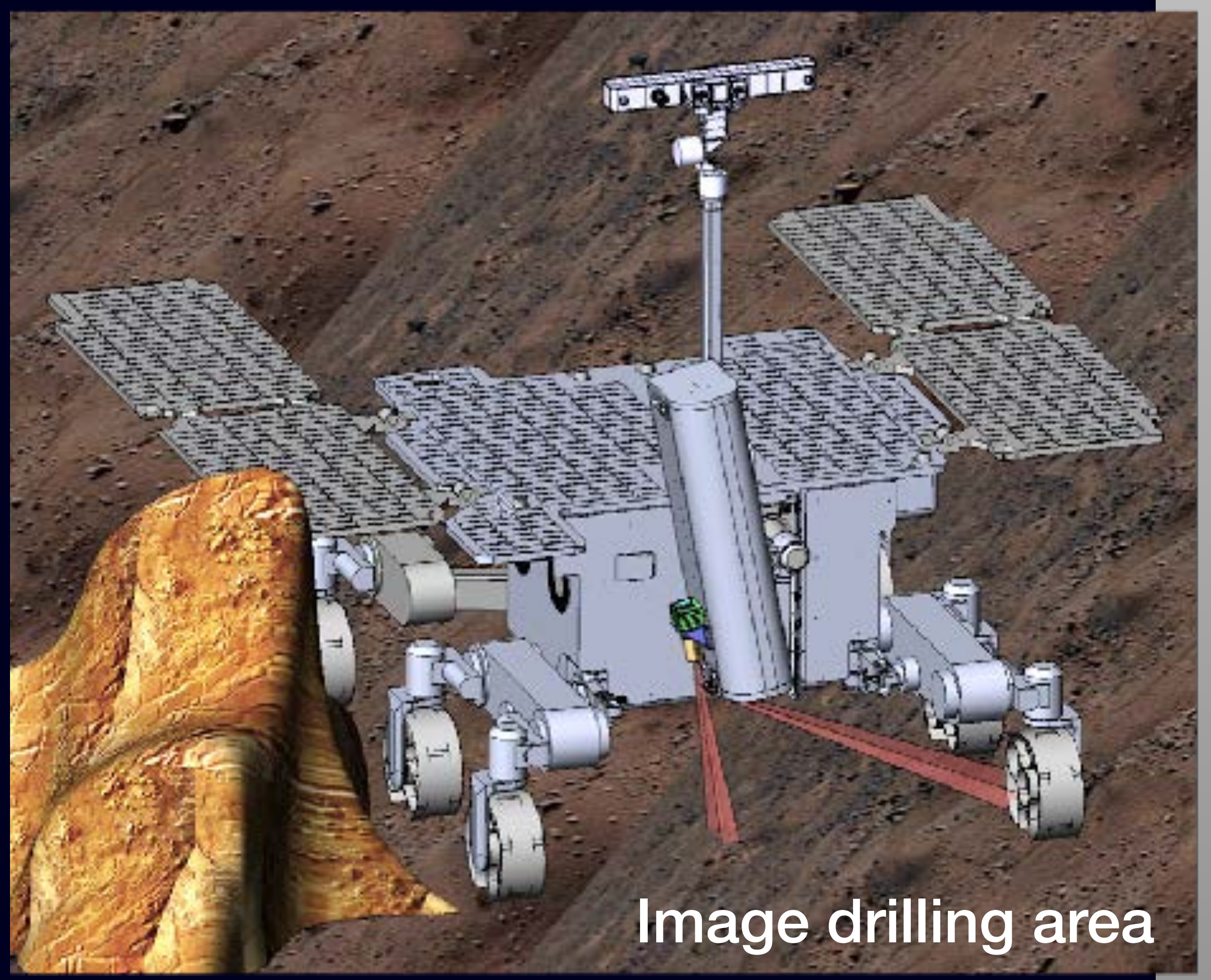
Use the drill to collect a sample

- From an outcrop
- From the subsurface

Close-Up Imager



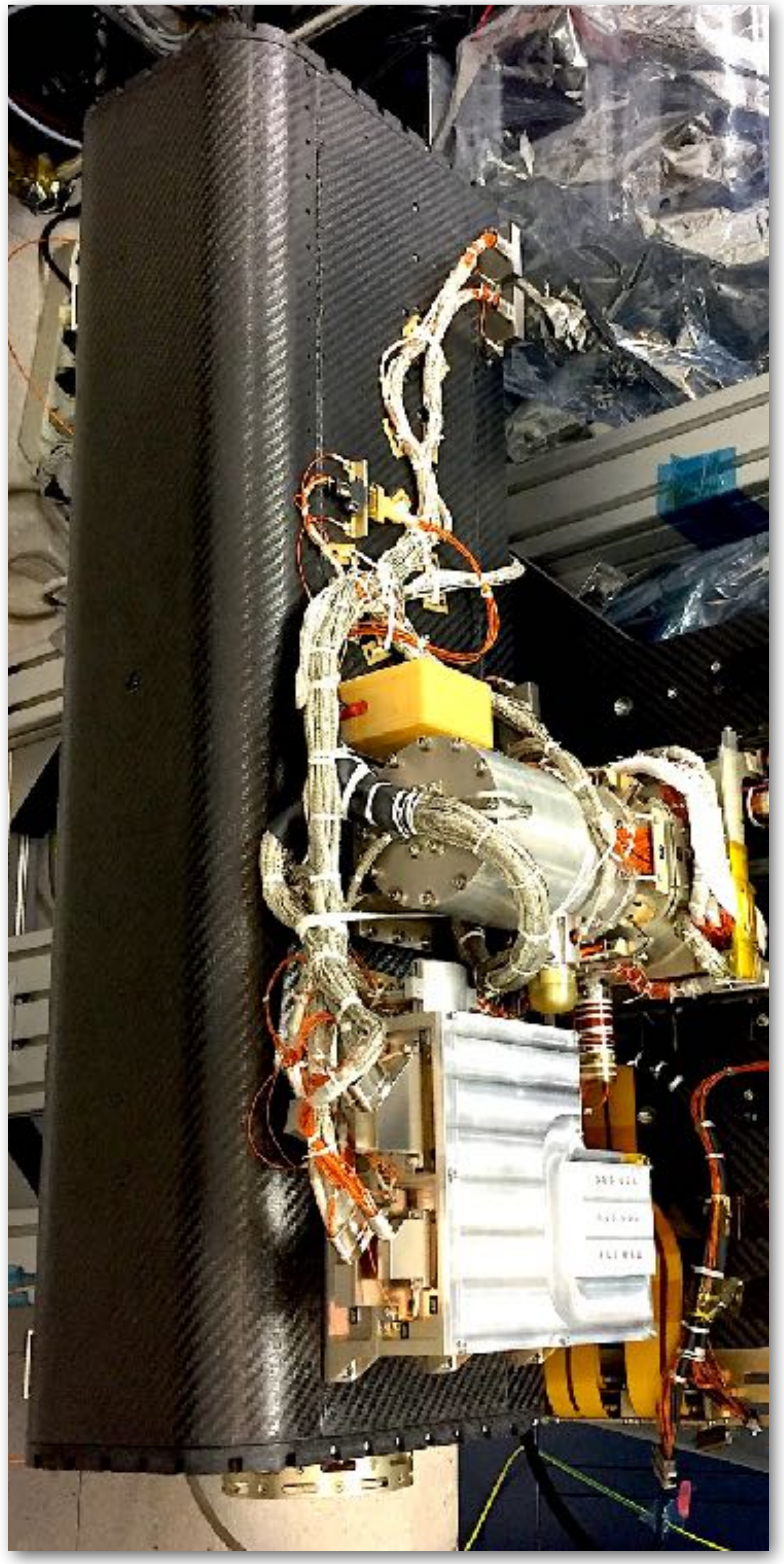


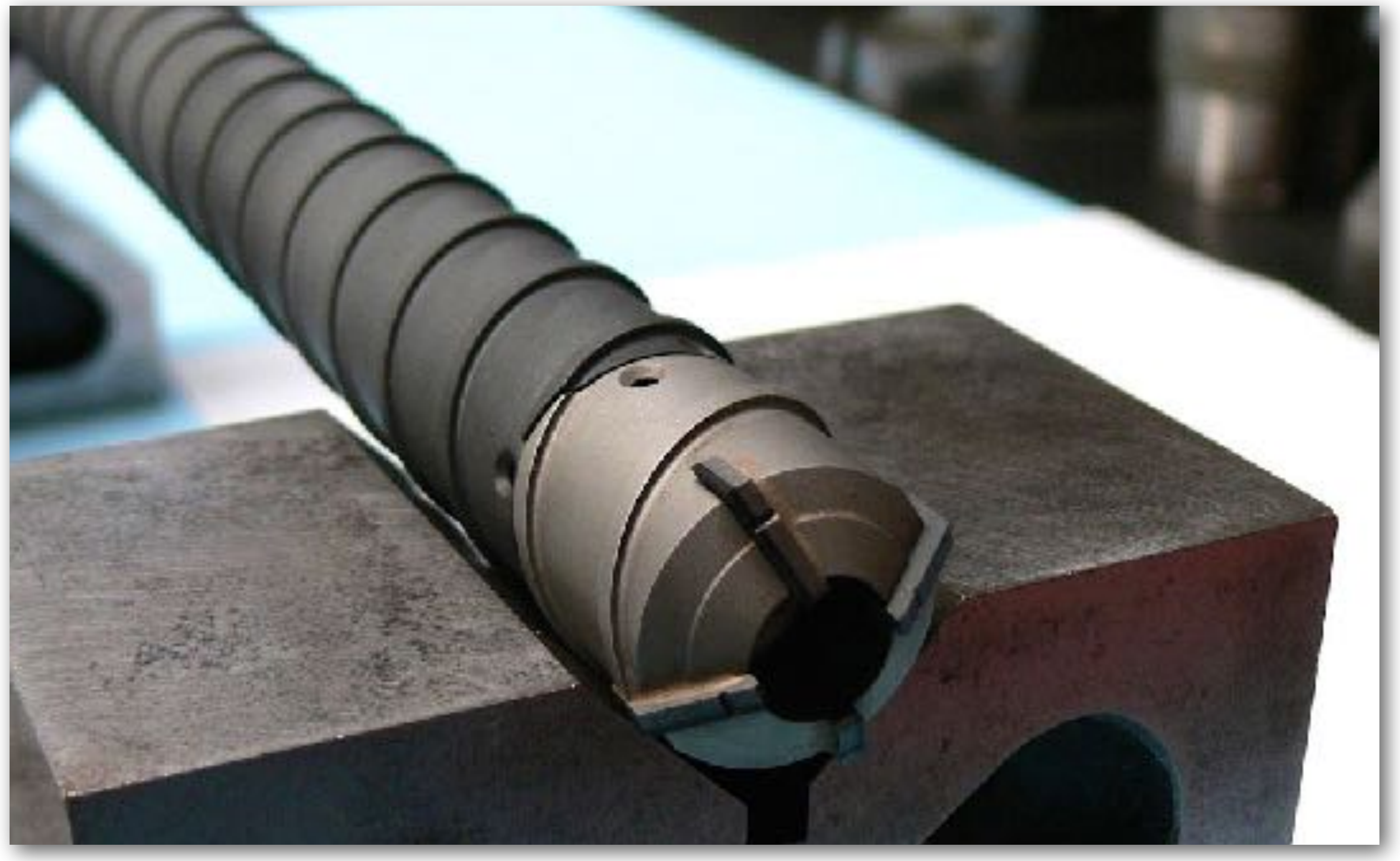


Credit: Space Exploration Institute

Subsurface Drill

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





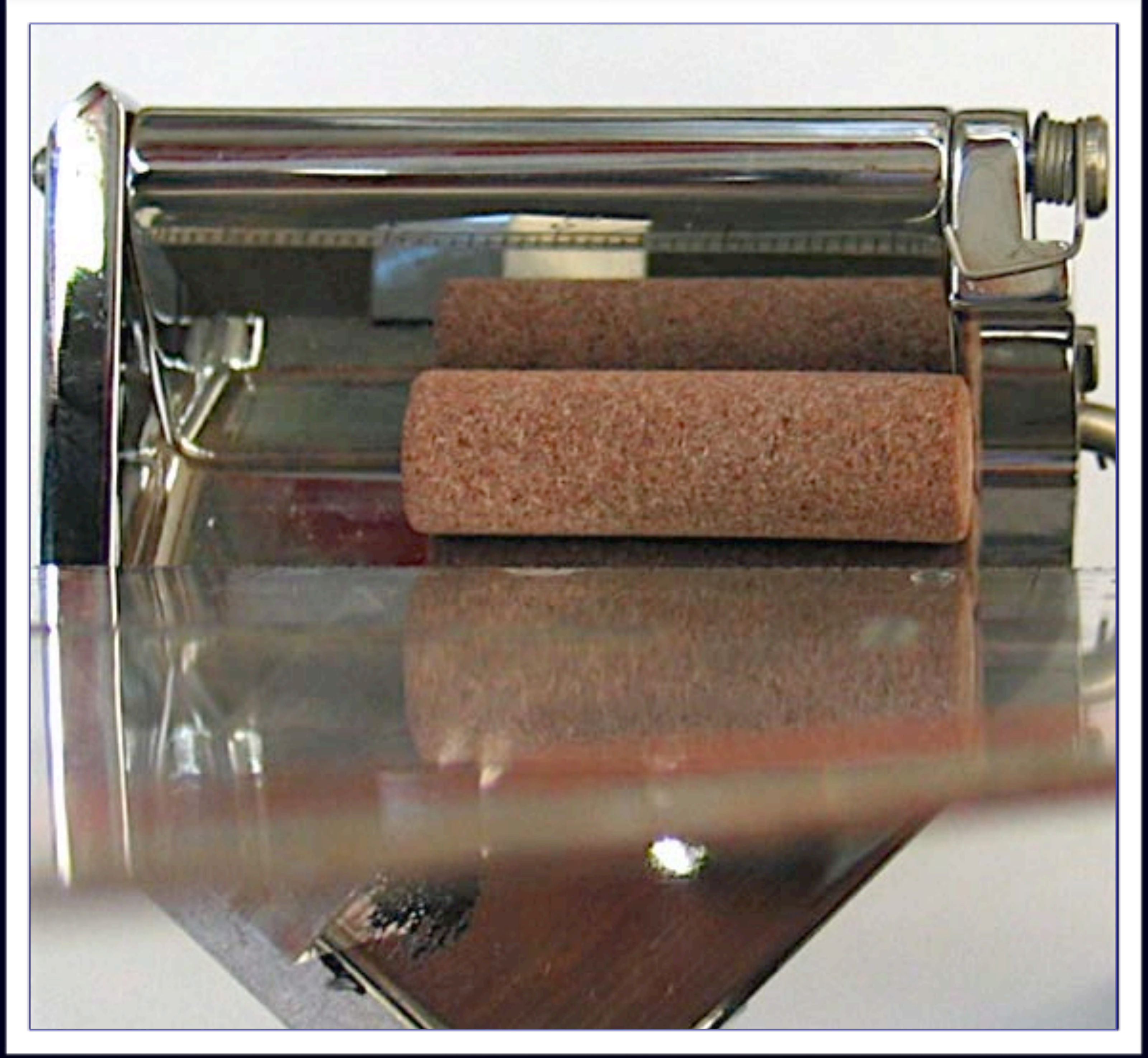
Subsurface drill includes a miniaturised IR spectrometer for borehole investigations.

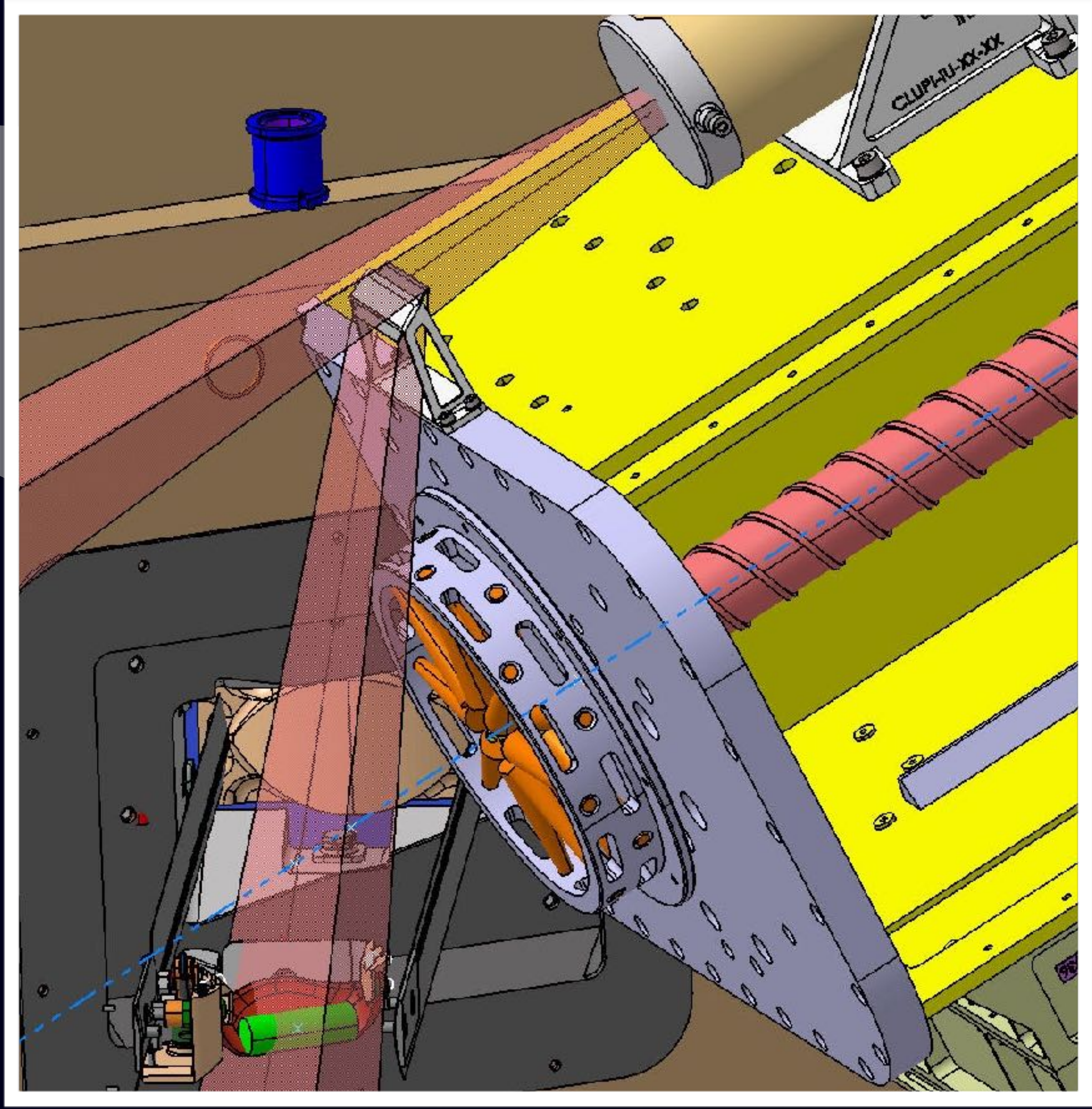
Subsurface Drill

Sample Delivery

E X O M A R S

DRILL discharges sample into Core Sample Transport Mechanism (CSTM).
PanCam HRC and CLUPI image the sample.
Sample is delivered to Analytical Laboratory Drawer (ALD) —15 min.



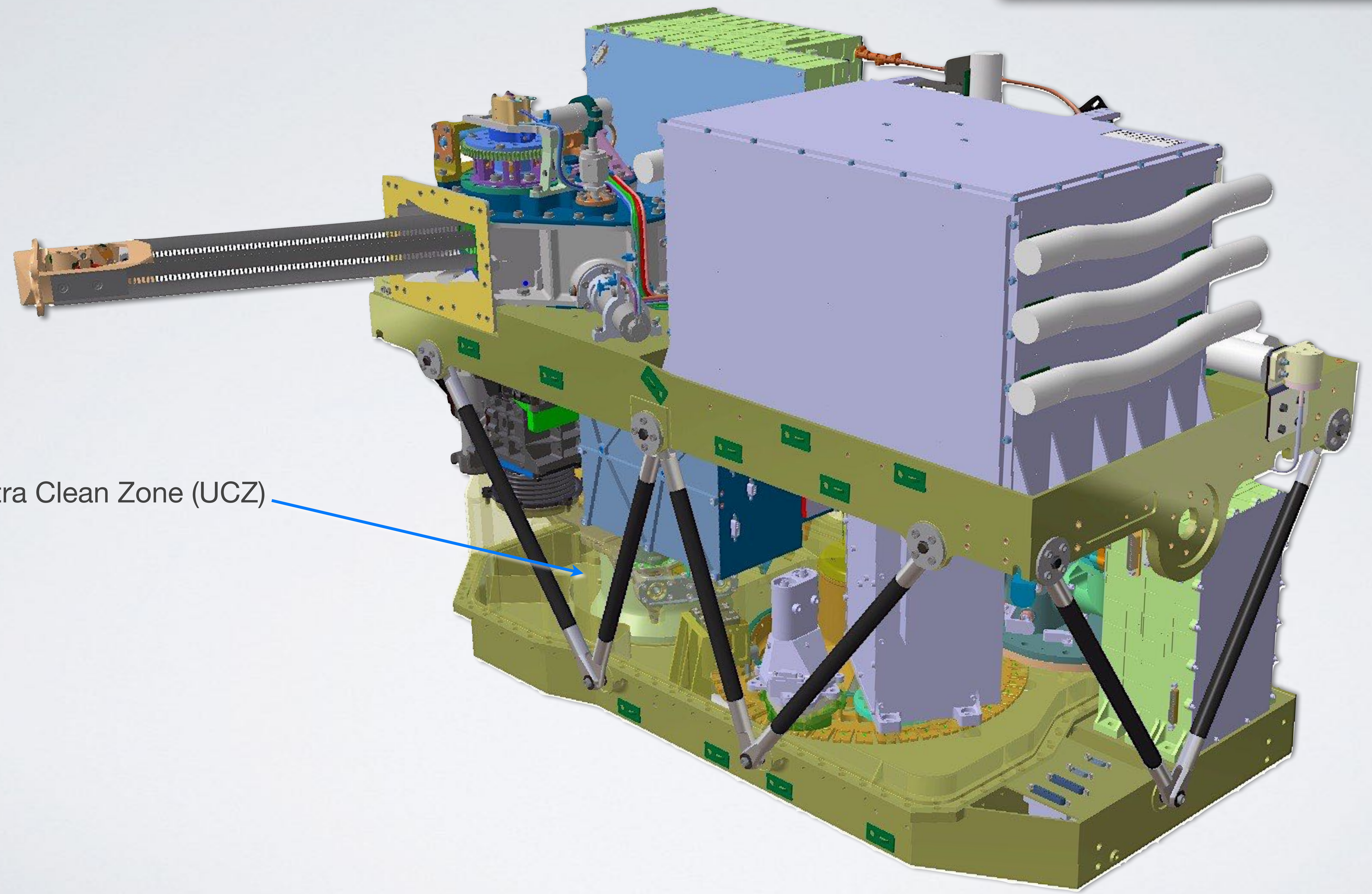


Analytical Laboratory Drawer

E X O M A R S

Credit: TAS-I

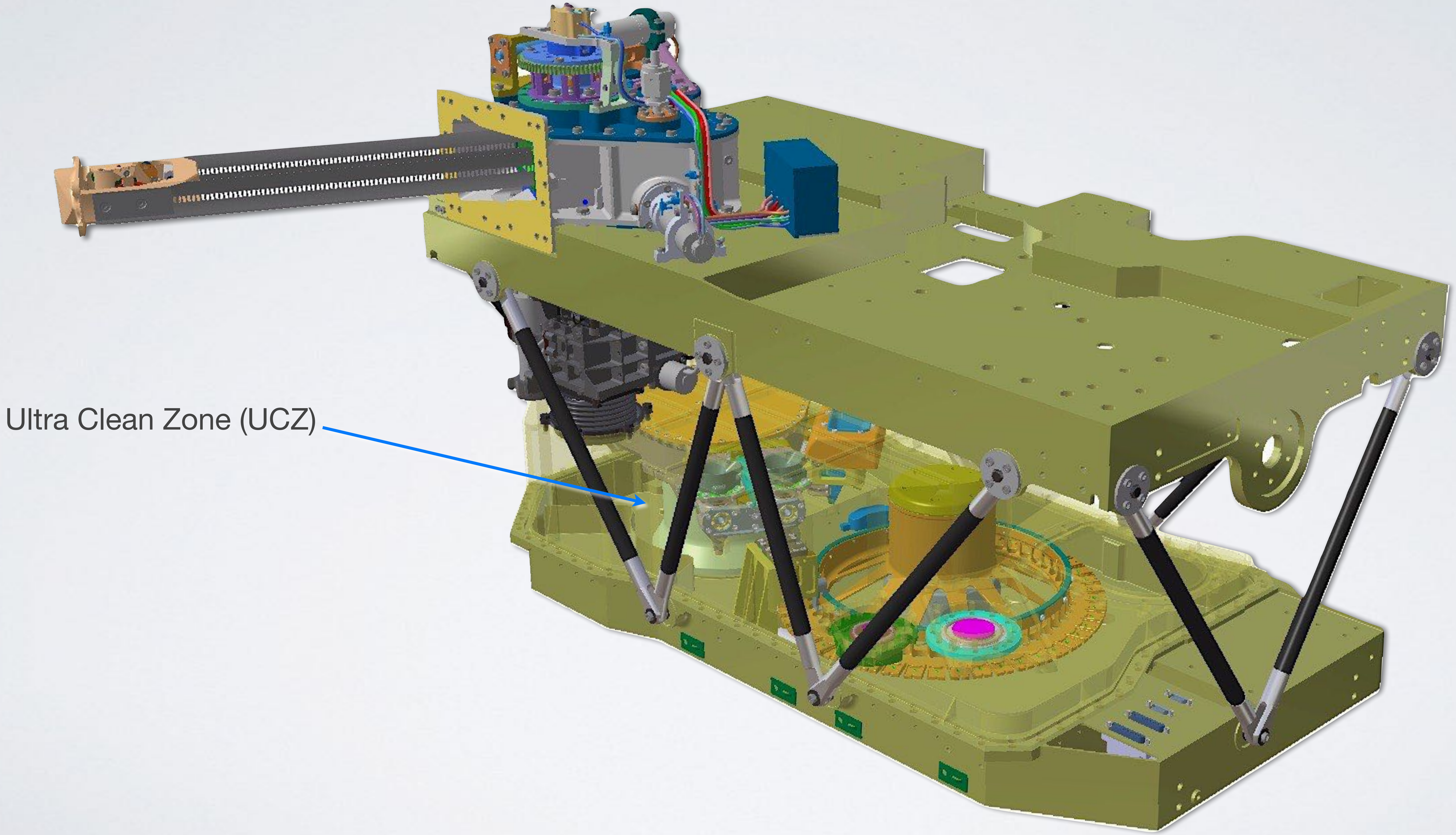
Analytical Laboratory Drawer



Credit: TAS-I

Analytical Laboratory Drawer

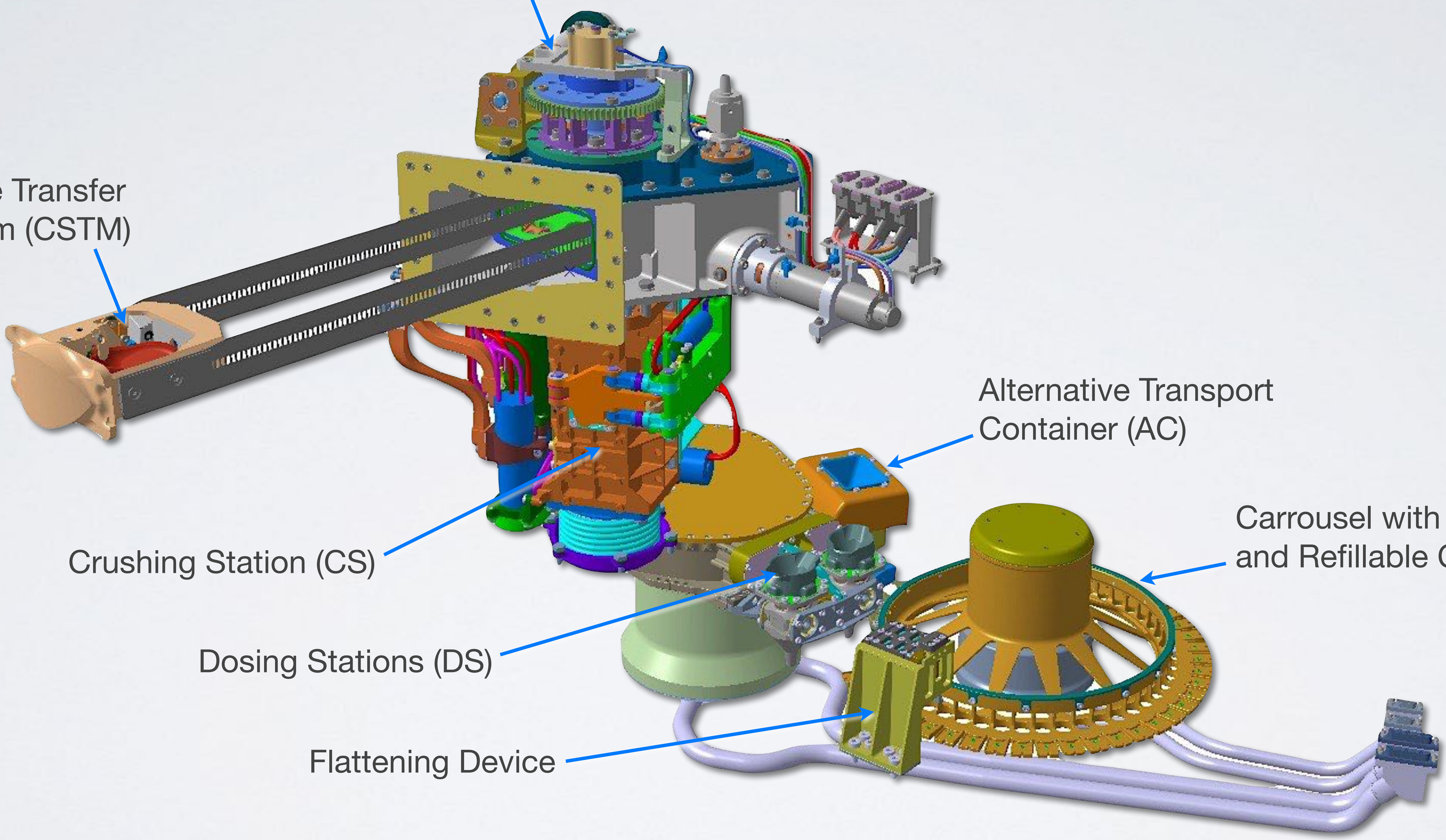
EXOMARS



Credit: TAS-I

Analytical Laboratory Drawer

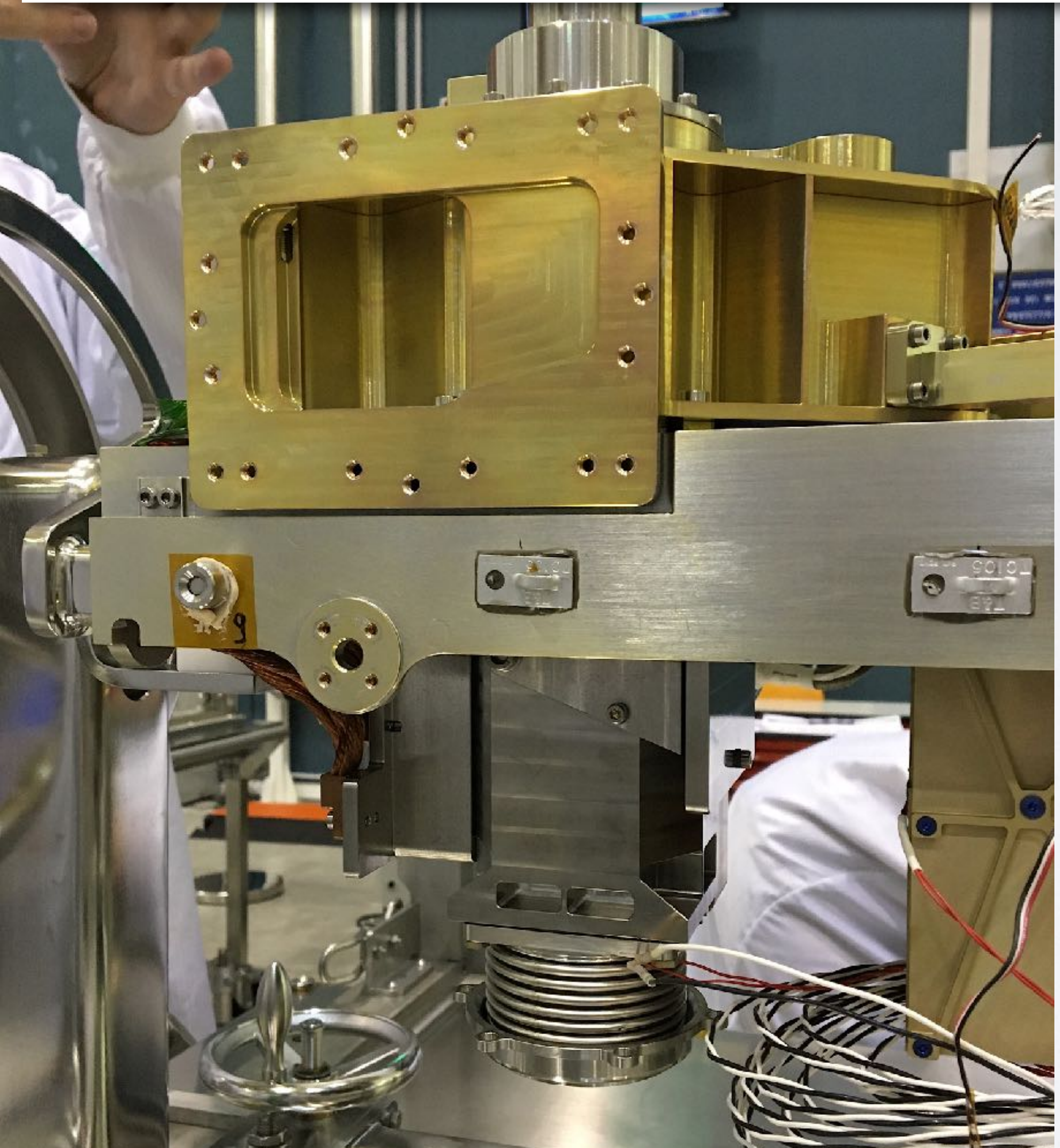
E X O M A R S

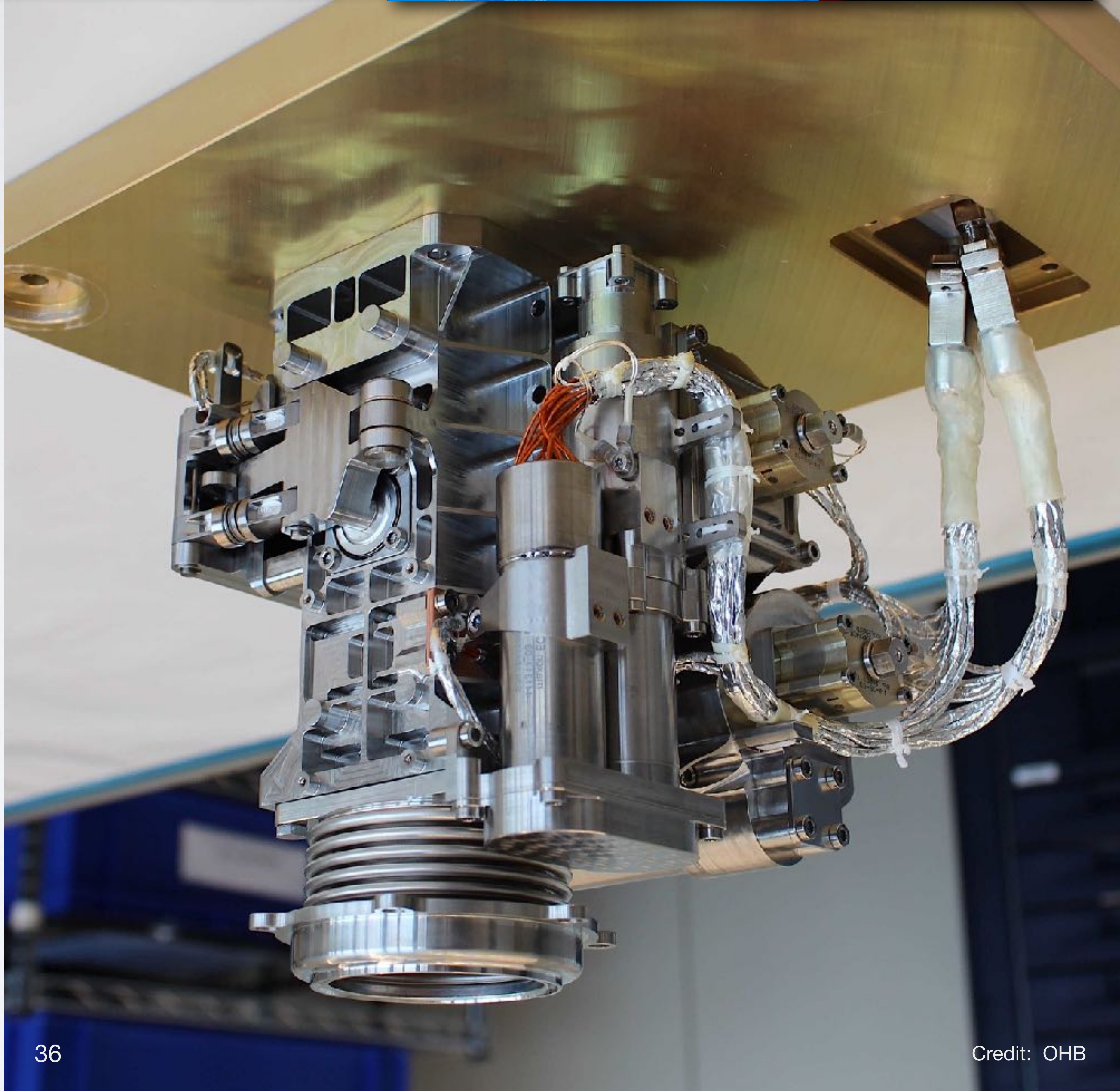


Credit: TAS-I

Analytical Laboratory Drawer

Rock Crushing Station





Credit: OHB

Powder Sample Dosing

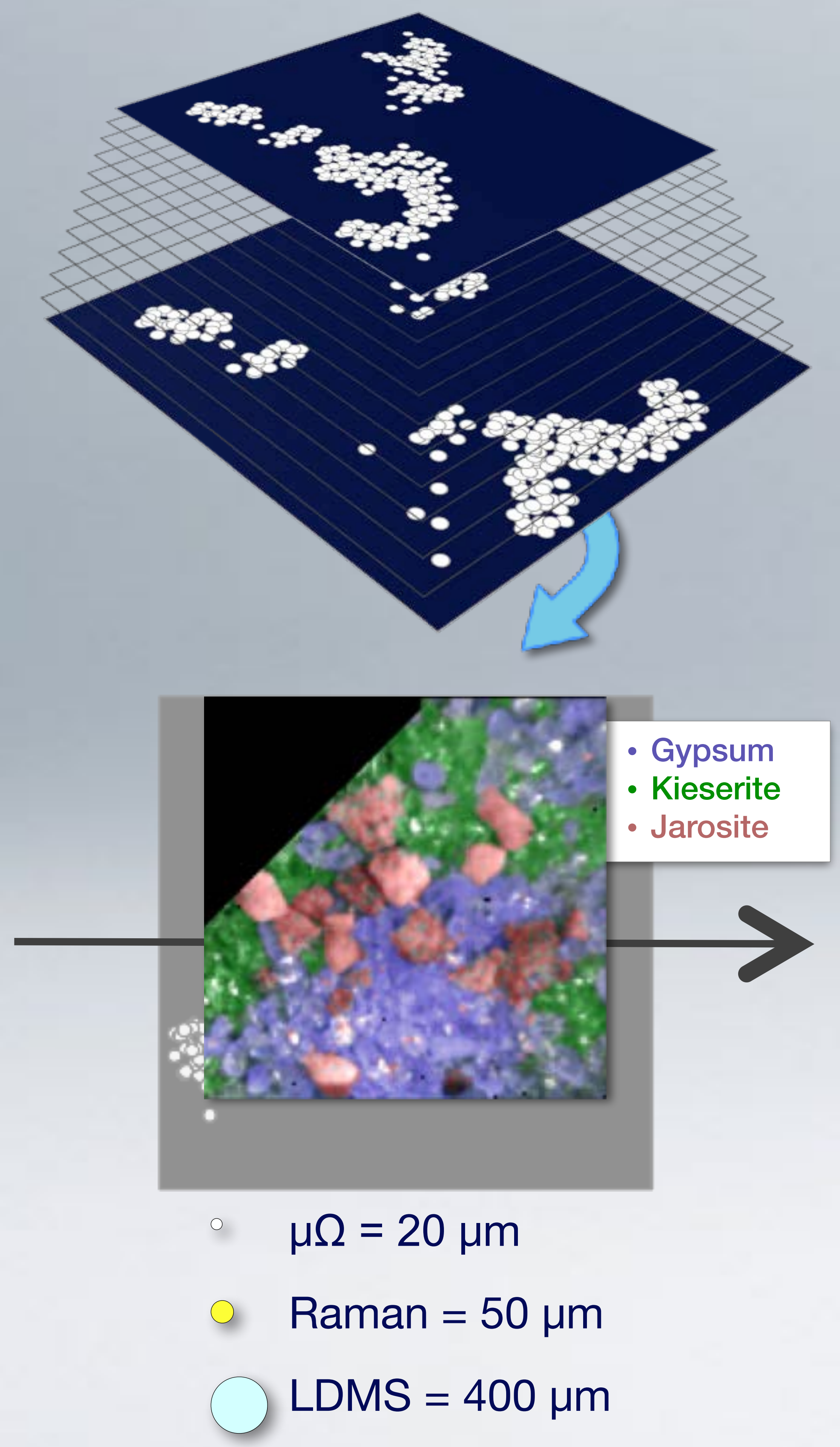
E X O M A R S

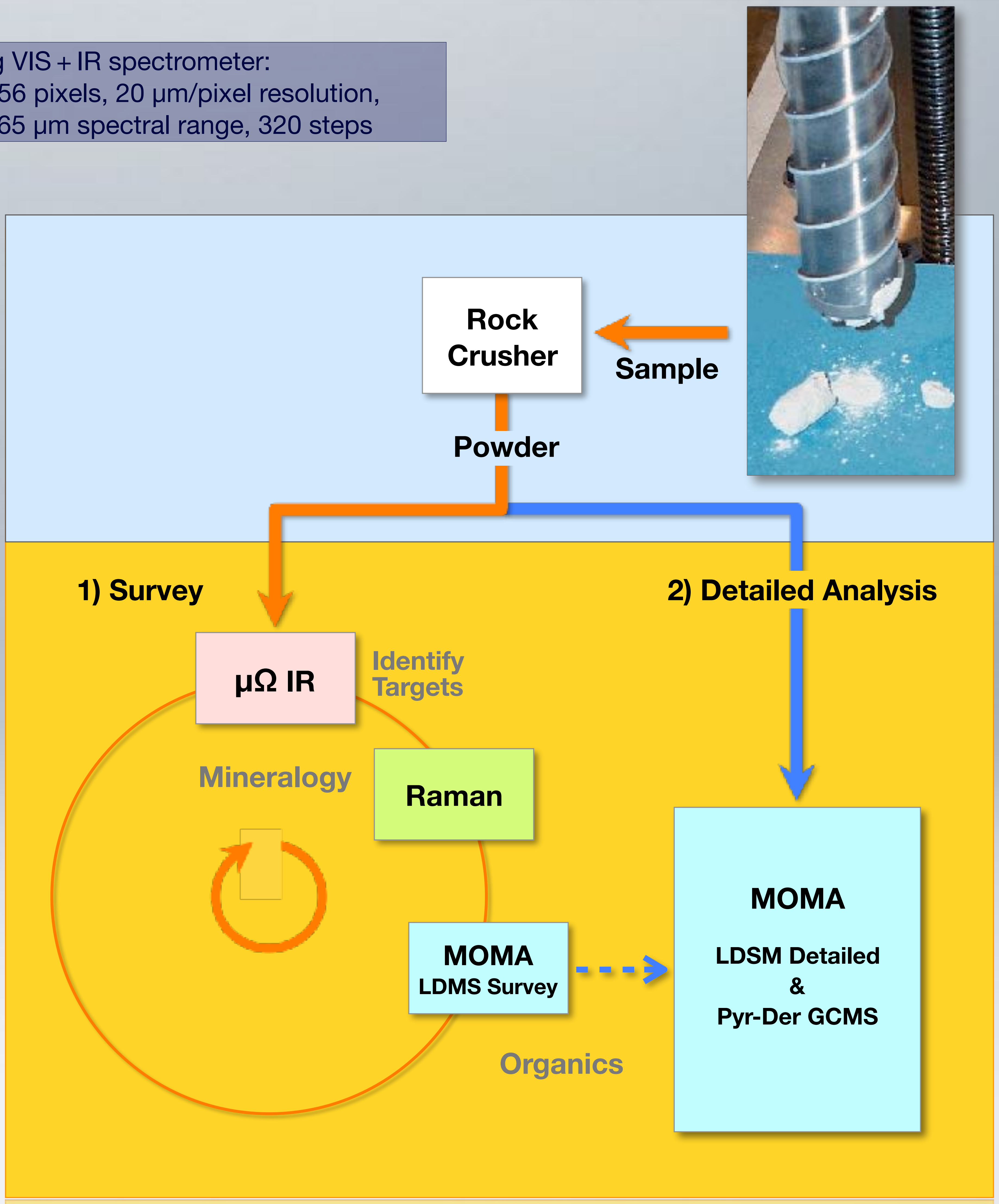
Credit: OHB

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

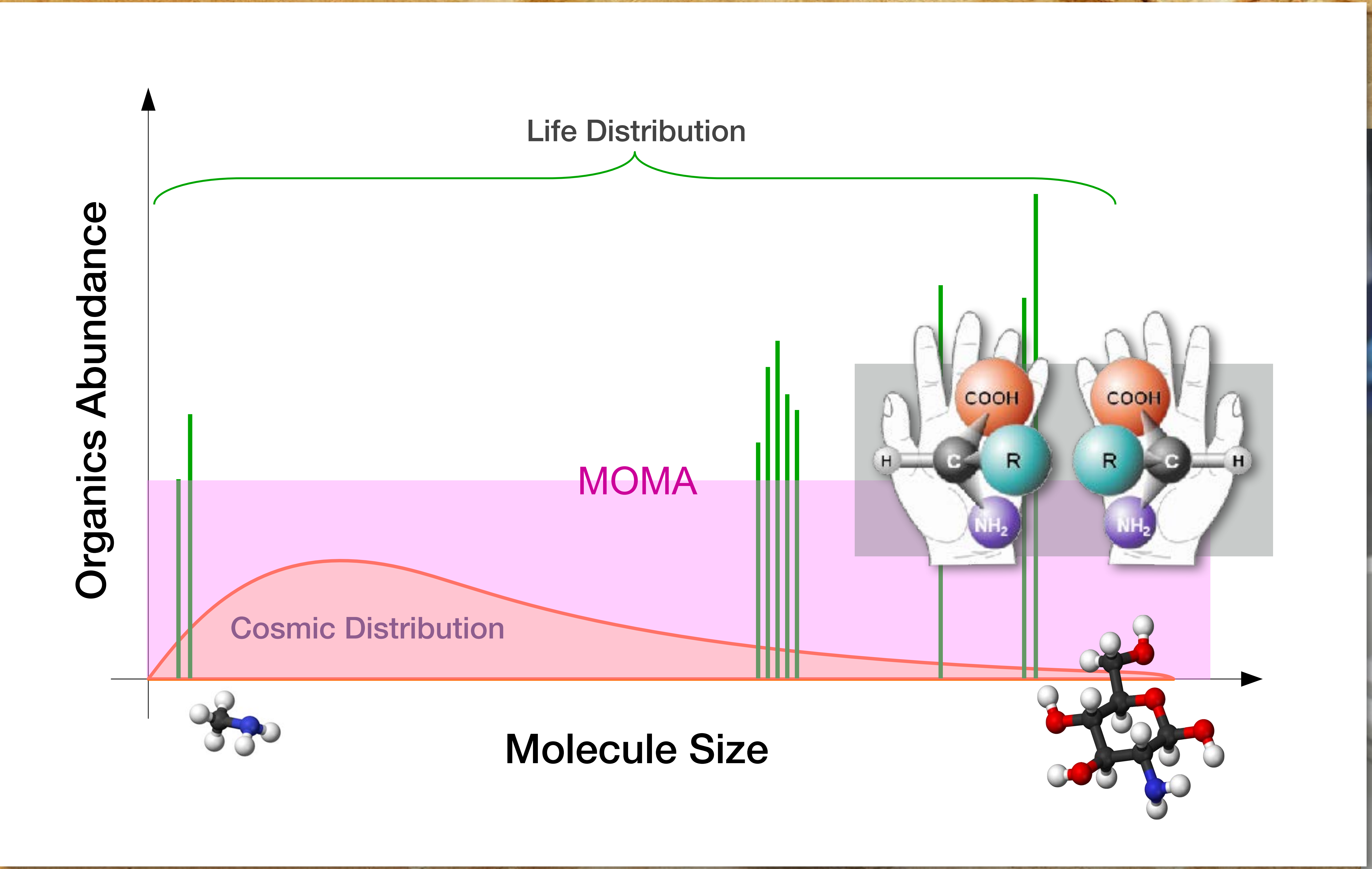


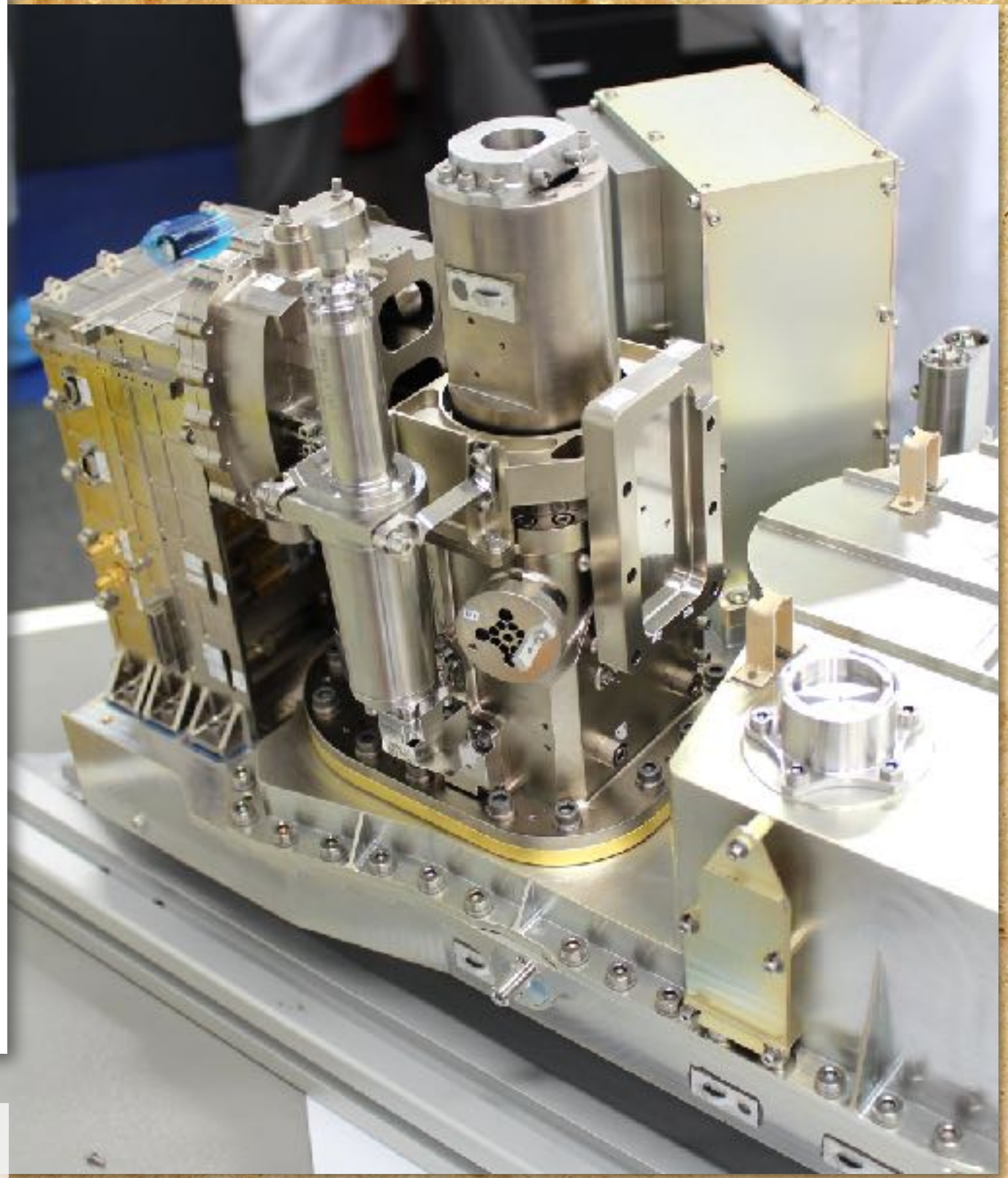


Raman: Spectral shift range 200–3800 cm^{-1}
Spectral resolution: 6 cm^{-1}

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

Characterisation of Organic Molecules





Broad identification range (50–1000 Da), including distribution, and chirality.
High sensitivity (≤ 1 pmol/mol in TV-CGMS, ≤ 1 pmol/mol/mm² in LDMS).
Resolution ≤ 1 Da over 50–500 Da range, ≤ 2 Da thereafter.
Ability to perform MS-MS analysis on trapped fragments.
LDMS mode appears not to be disturbed by perchlorates.

Credit: 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

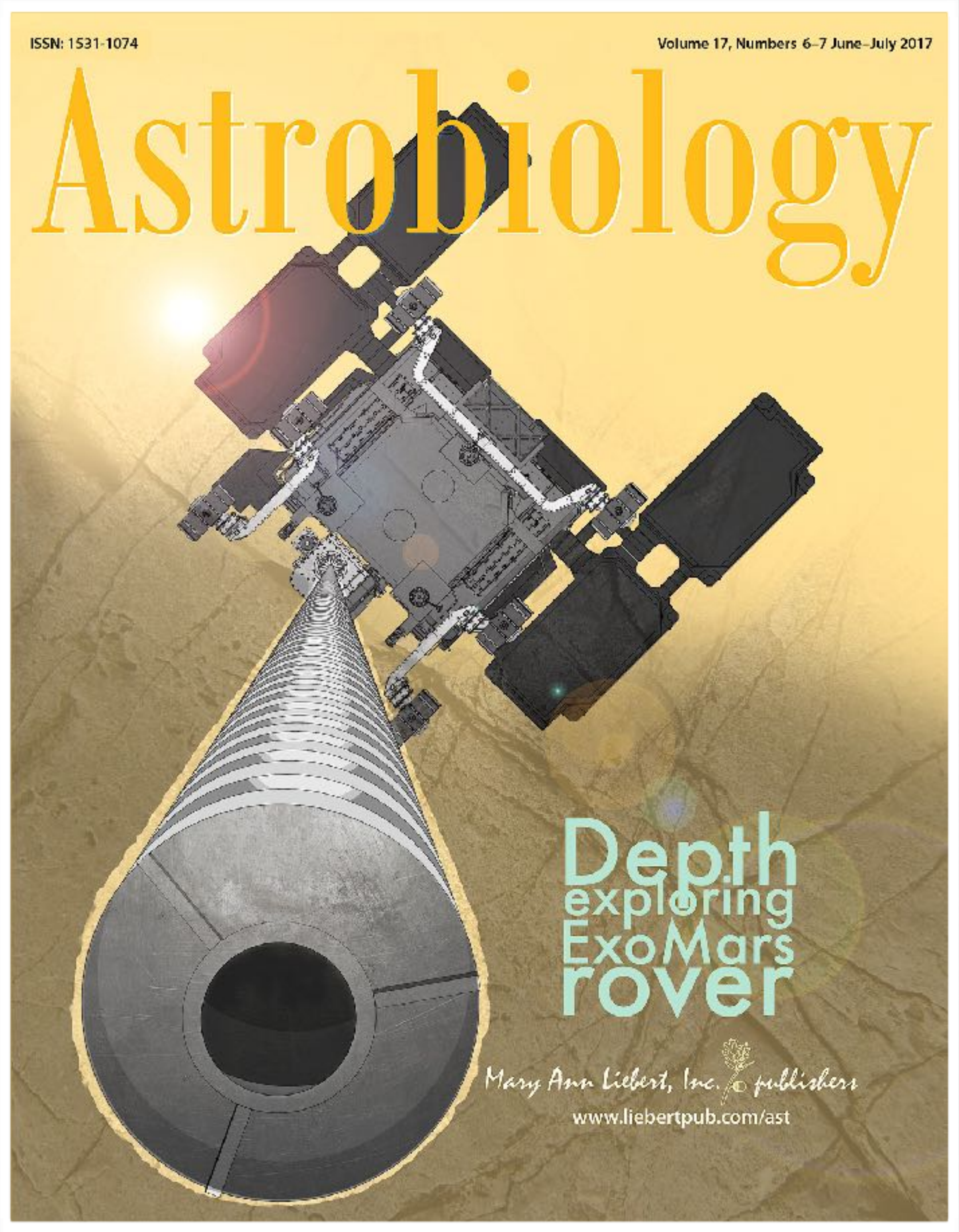
Result of first blank chemical check: (prior to beginning sample analysis)	Factor
No organics, clean background	1.0–0.9
OR Few, well known spacecraft organics in background	0.8–0.5
OR Background heavily compromised by contamination	0.2–0.0

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

× + Score

Credit: Mamers Valles, MEX/HRSC

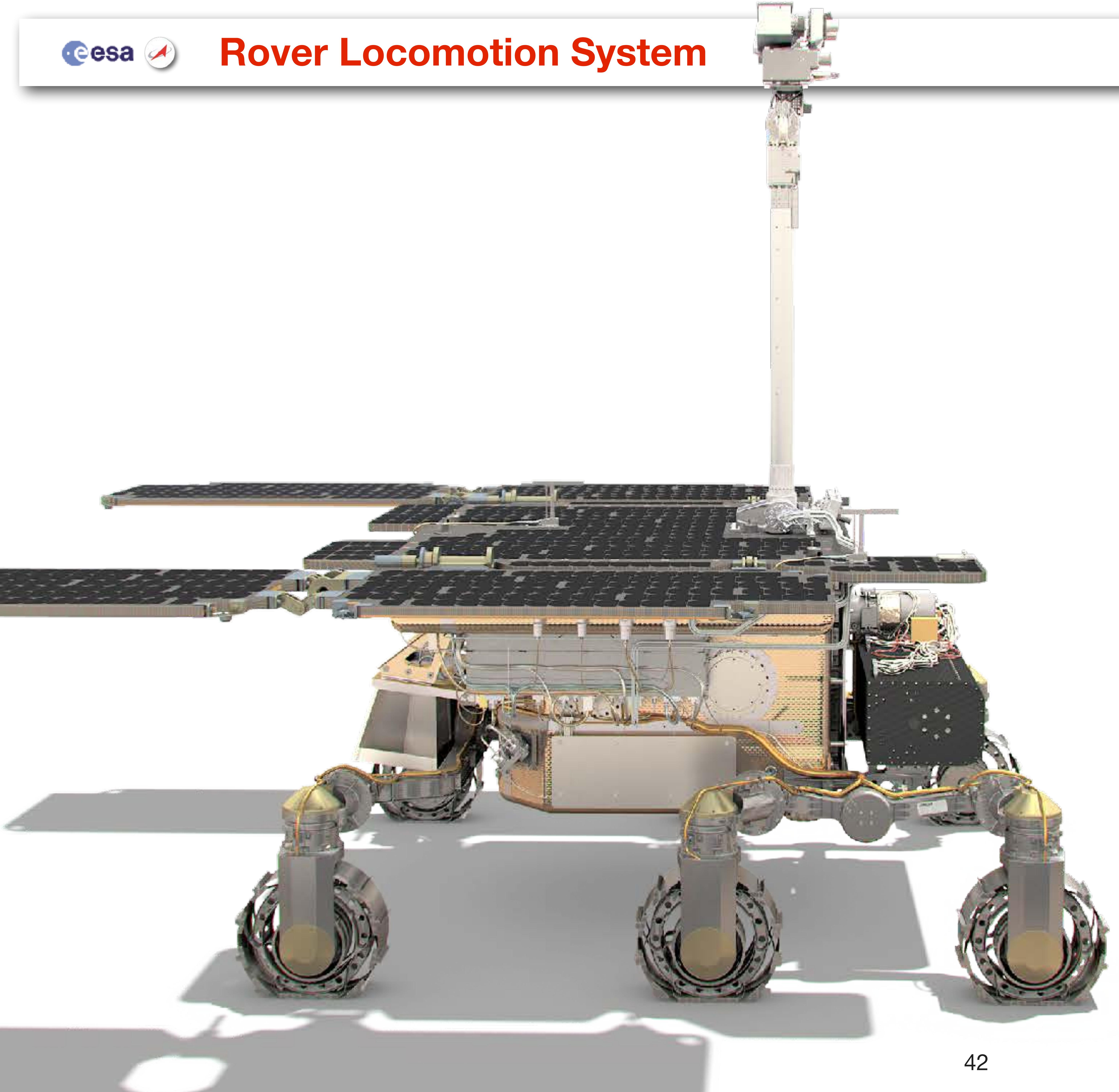


ExoMars Rover Issue

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

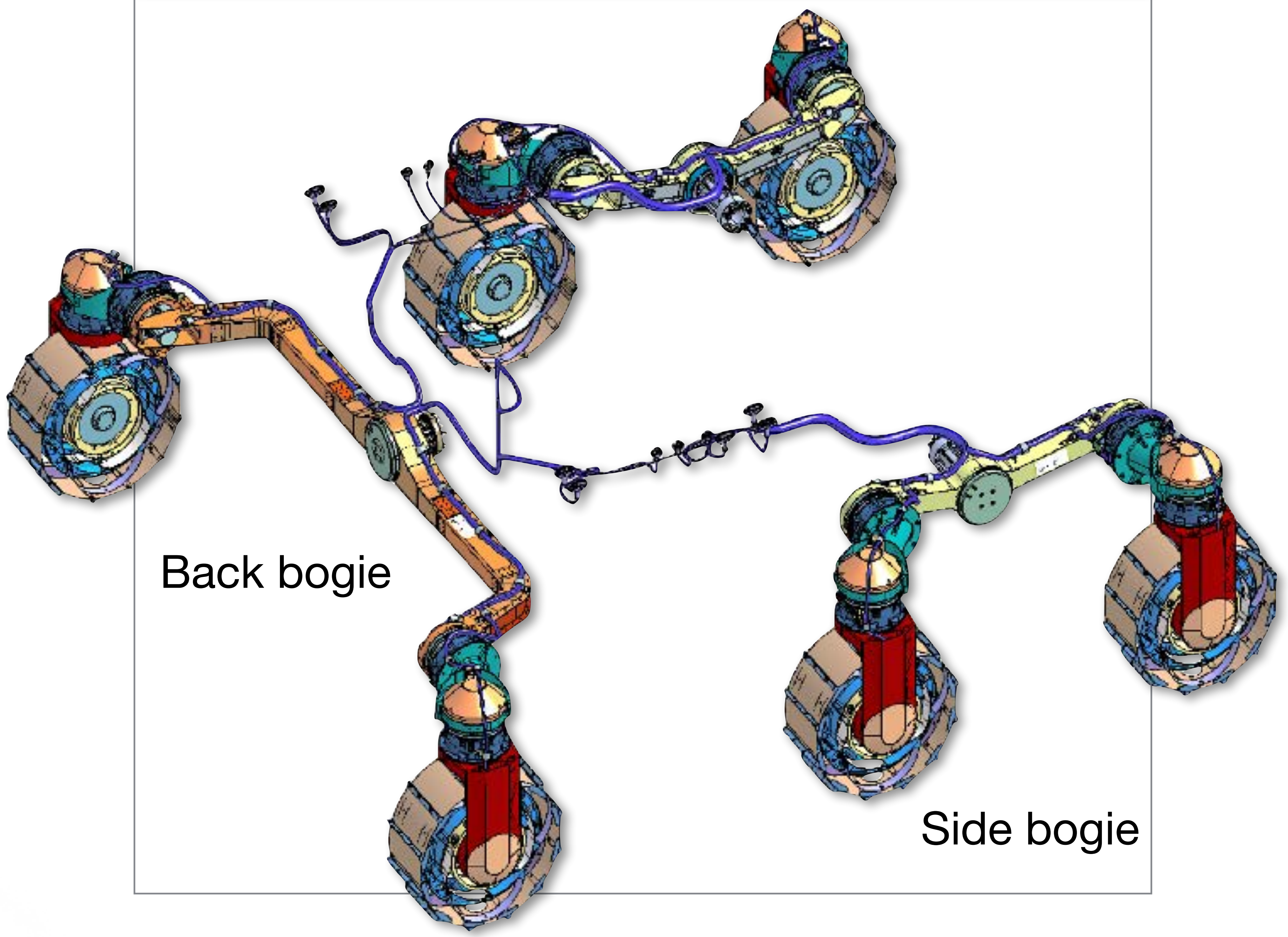
Credit: Sand dunes near the north pole, MRO/HiRISE

Rover Locomotion System

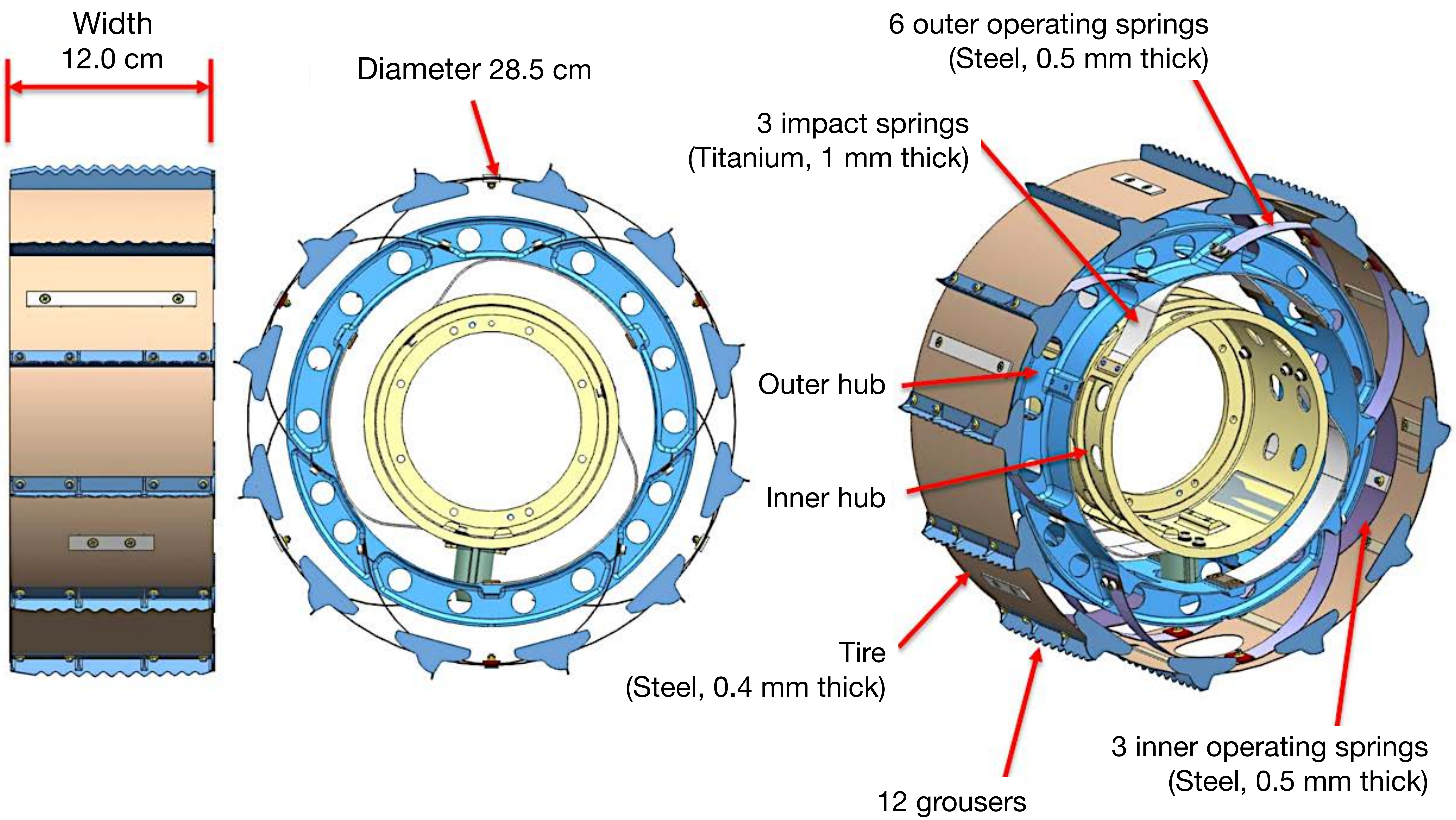


Locomotion formula: 6 x 6 x 6 + 6

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

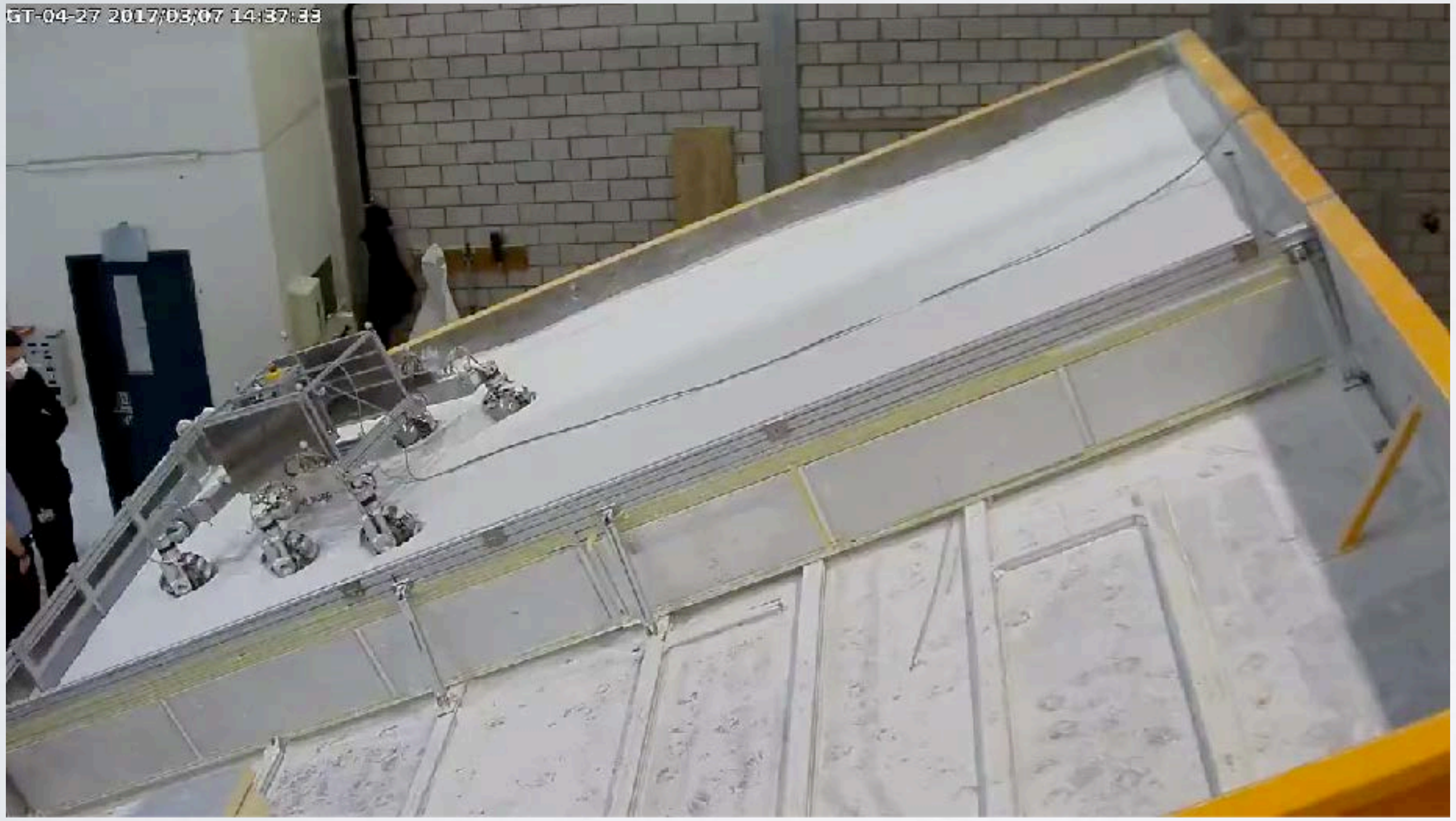


Flexible Wheels



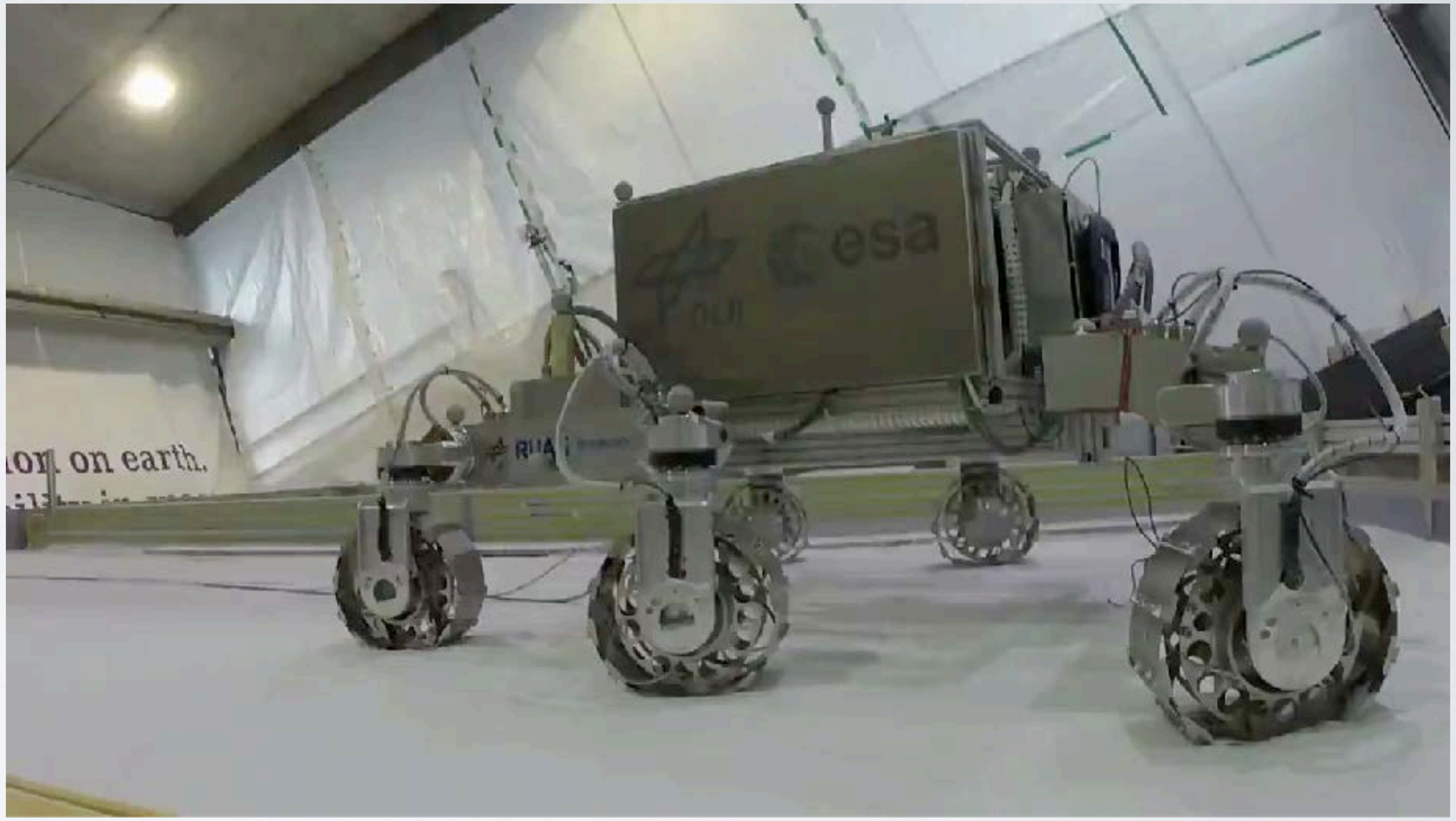
ES2 Soil - 21° Upslope - Back & Forth

Vivotec camera (GT-04-27)



video accelerated x25

GoPro camera (GT-04-27)



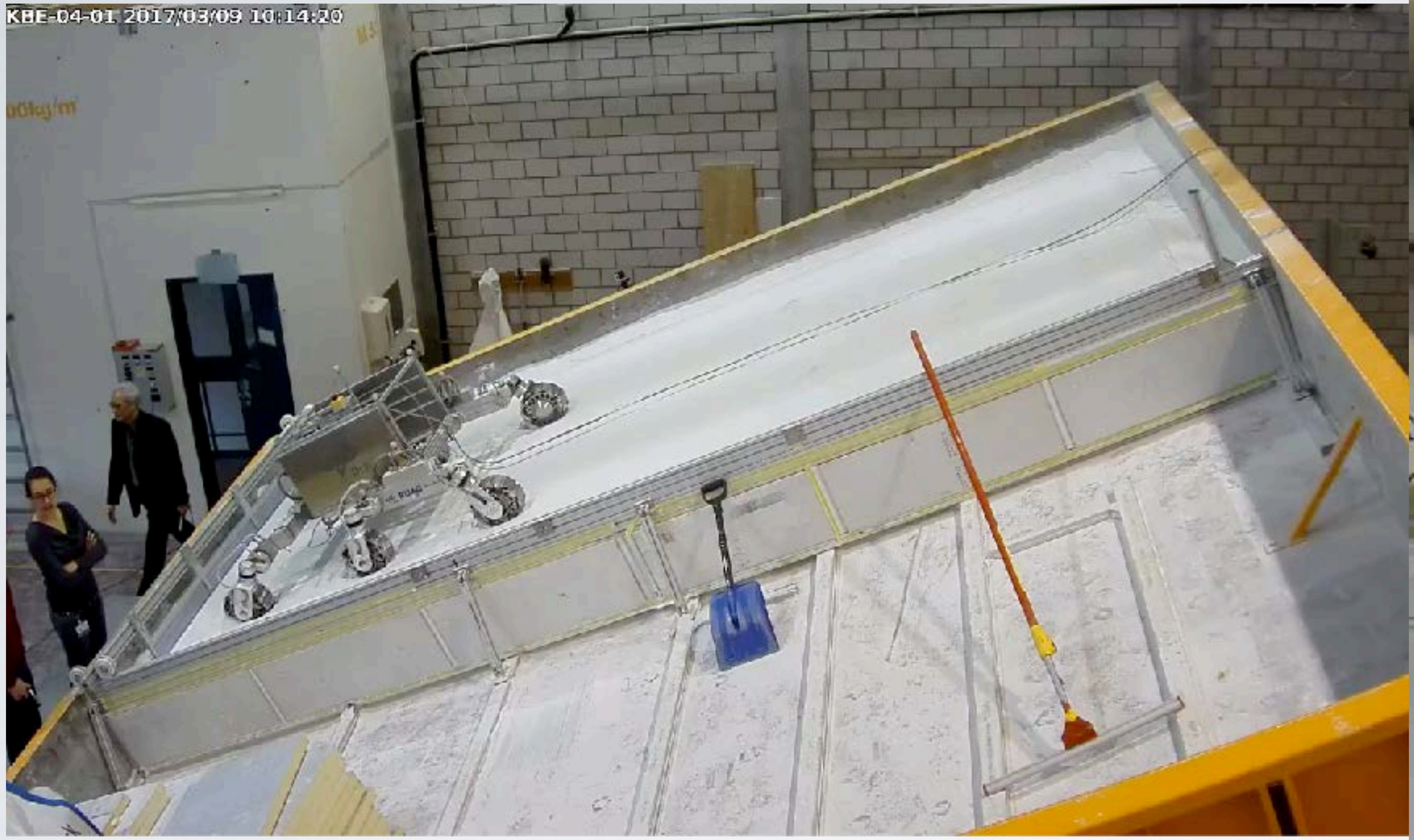
video accelerated x25

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)

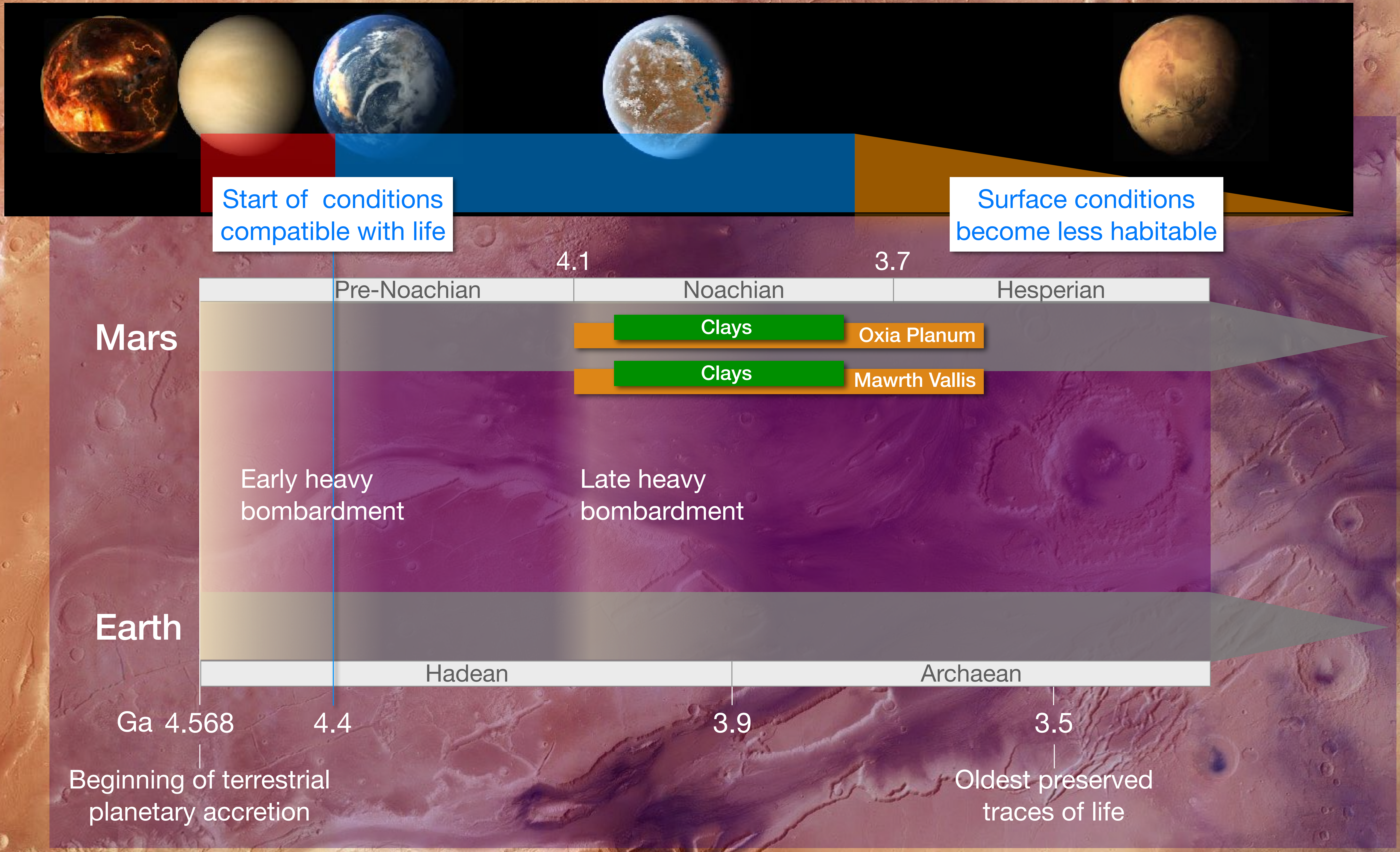
video accelerated x15

Credit: RUAG, Airbus Defence & Space, ESA

The tested WW gait respects all hardware kinematic constraints.

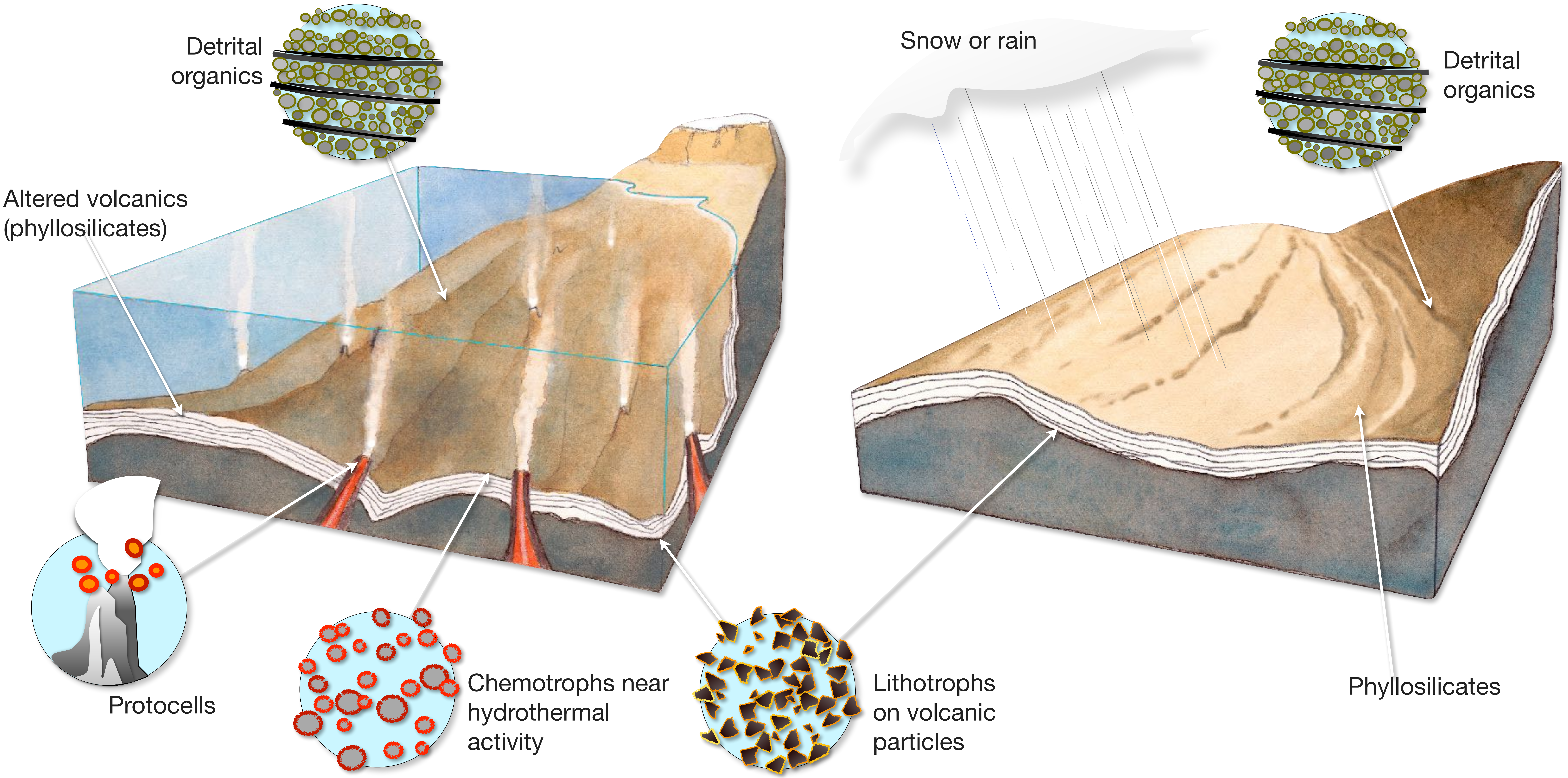
Result: progress of 3 m in 34 mins, low sinkage

Candidate Landing Sites



Credit: Kasei Valles, MEX/HRSC

Mid- to Late-Noachian Settings



Rover and Surface Platform

Credit: ESA/Medialab

Rover and Surface Platform

E X O M A R S

2020: ExoMars Rover and Surface Platform

- Travel back in time 4 billion years to explore the bottom of a Mars ocean.
- 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.

2-m depth

Credit: ESA/Medialab