# ExoMars 2016 Trace Gas Orbiter

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51st ESLAB, ESTEC, 5 December 2017

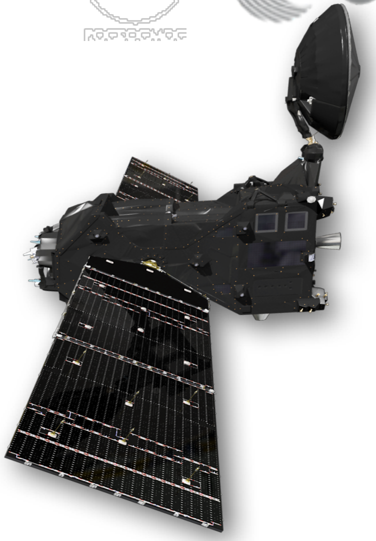
# The ExoMars 2016 mission

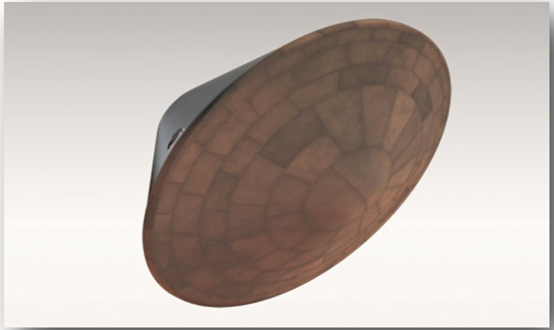
- The Trace Gas Orbiter, TGO, - an orbiter focussing on the detection and characterisation of trace gasses and their isotopes, searching for sinks and sources, and seasonal and spatial variations. It will also map subsurface water.

- Schiaparelli – an Entry, Decent and Lander Demonstrator Module (EDM), including a short lived surface meteorology package

- Both spacecraft ware launched together on a Proton-M/Breeze-M vehicle from Baikonur on 14 March 2016 and arrived at Mars on 19 October 2016.

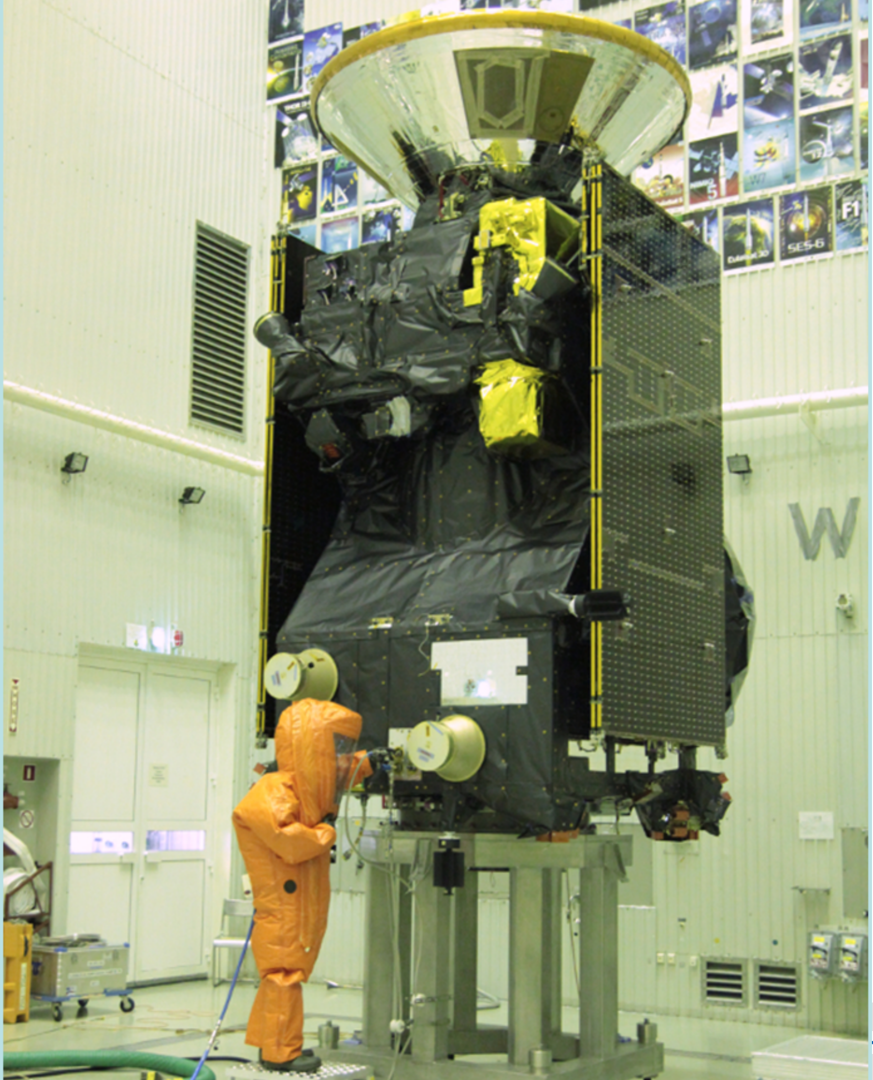
- TGO will also act as a relay orbiter for the 2020 Rover and Surface station and for NASA’s rovers and landers.





# ExoMars and the Trace Gas Orbiter

- The TGO is the first part of the ExoMars mission, to be followed by the ExoMars Rover and Surface platform to be launched in July 2020
- ExoMars is an ESA - Roscosmos joint programme
- ExoMars is funded within the European Exploration Programme Envelop Programme (E3P) and is a part of the ESA HRE directorate with support from SCI
- The TGO is a very large spacecraft, with a total mass of 3700kg. The launch mass was 4300kg (including the Schiaparelli, the Entry Descent and Landing Demonstration Model). The height of TGO is about 3.2 m and the Solar array tip-to-tip length is 17.5m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# Trace Gas Orbiter

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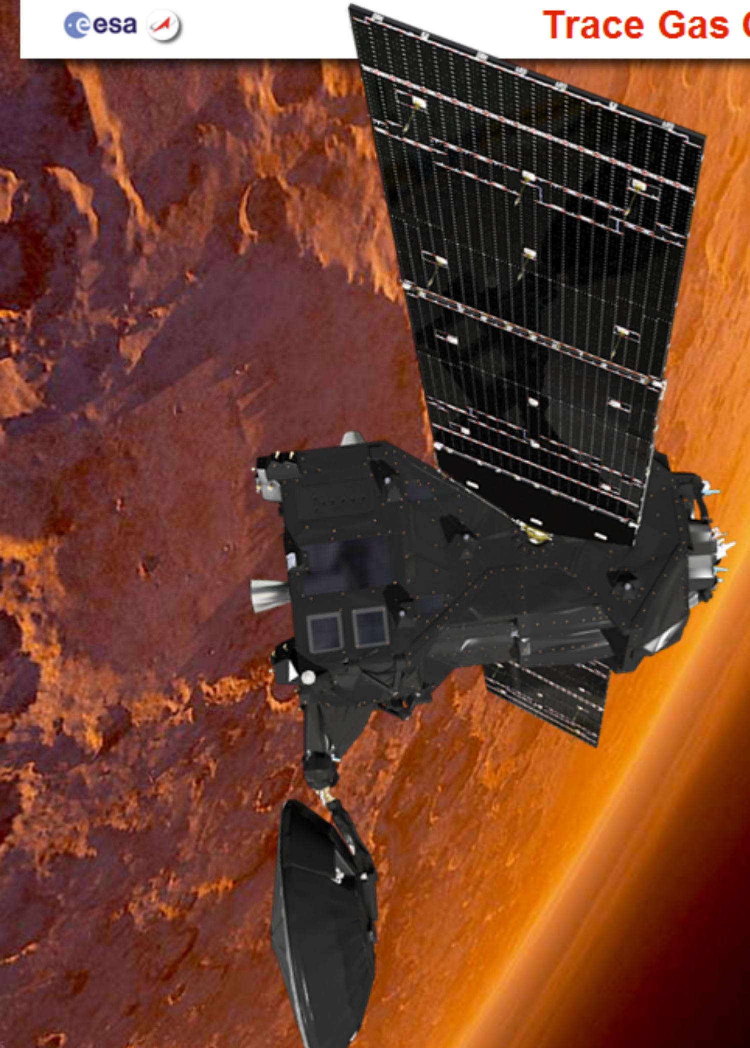


## NOMAD

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 |
| Mid-IR (2.3 – 4.5 μm) λ/Δλ ~50,000 | | | SO |

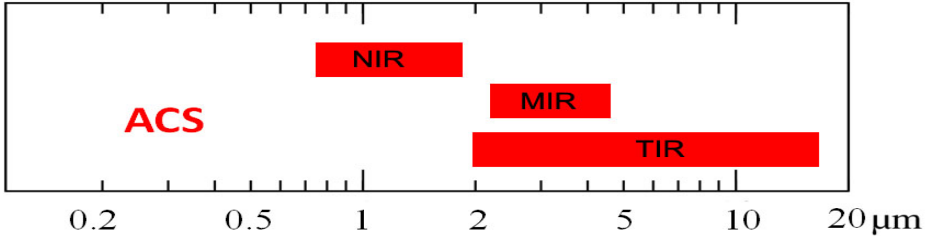
## FREND

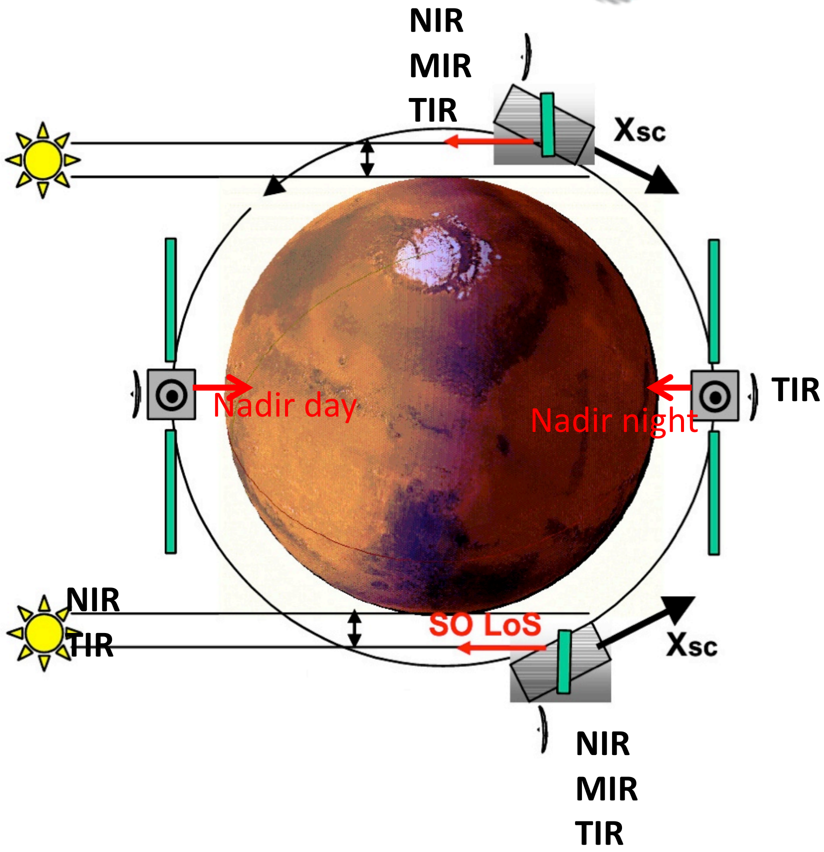
Collimated neutron detector

*Mapping of subsurface water and hydrated minerals*

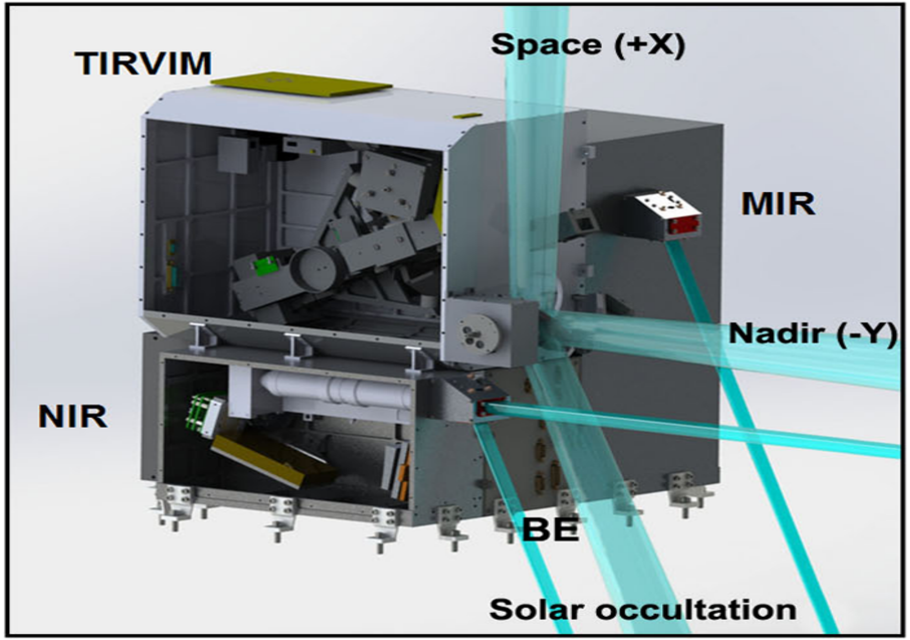
# ACS (Atmospheric Chemistry Suite)

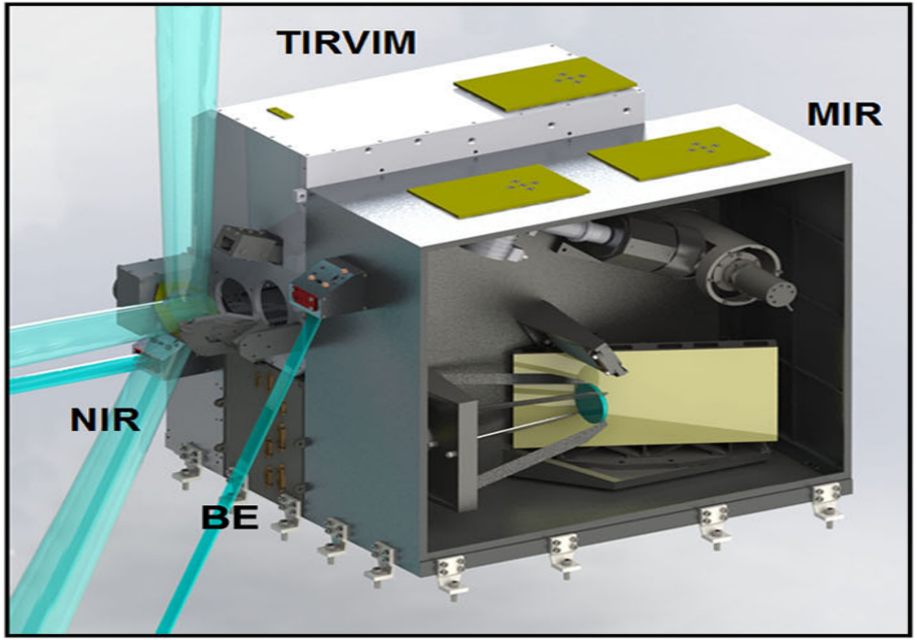
| | Spectral range | Inst. range | Spectral resolution |
|---|---|---|---|
| ACS/MIR | 2.3-4.2 µm | 0.1-0.25 µm | >40 000 |
| ACS/NIR | 0.75-1.7 µm | ~0.17 µm | >24 000 |
| ACS/TIRVI M | 1.7-17 µm | full range | $0.25 cm^{-1}$ occ<br>$1.6 cm^{-1}$ nad |



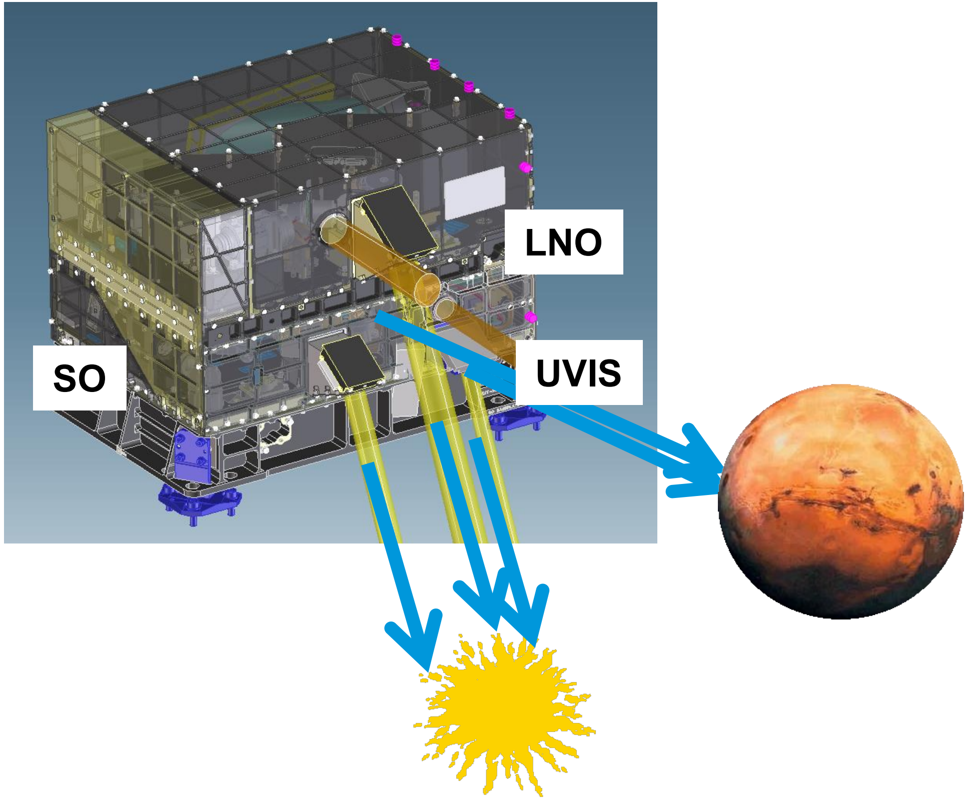
# ACS




2x Echelle spectr. + 1 x Fourier spectr.

# NOMAD (Nadir and Occultation for MArs Discovery)




**SO** Solar Occultation

IR : 2.2-4.3 μm

Resolution ~ 0.15 $cm^{-1}$

Resolving power = 22000

**LNO** Nadir, Limb, Solar Occultation

IR : 2.2-3.8 μm

Resolution ~ 0.3 $cm^{-1}$

Resolving power = 11000

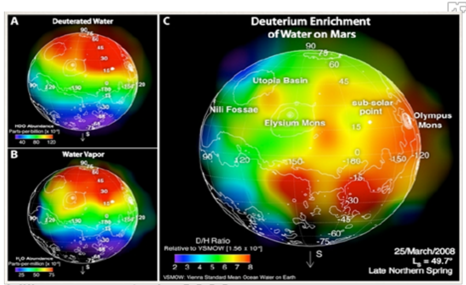
**UVIS** Nadir, Limb, Solar Occultation

UV-vis : 200-650 nm

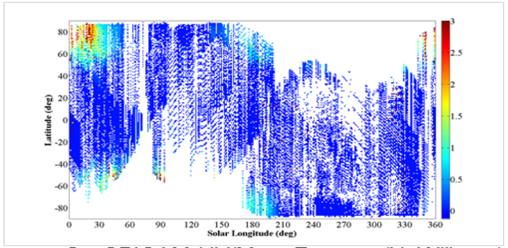
Resolution ~ 1 -2 nm

# NOMAD science objectives

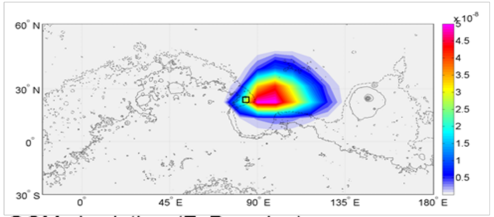
- Chemical composition
  - Detection of a broad suite of trace gases and key isotopes
    - $CO_2$, $CO$, $O_3$
    - $CH_4$ related : $CH_4$, $^{13}CH_4$, $CH_3D$, $C_2H_2$, $C_2H_4$, $C_2H_6$, $H_2CO$
    - Escape processes : $H_2O$, $HDO$ -> D/H
    - Volcanism related : $SO_2$, $H_2S$, $HCl$
- Mars Climatology & Seasonal cycles
  - 3D spatial & temporal variability of trace gases and aerosols
  - Climatology of $O_3$ and UV radiation levels
- Sources & Sinks
  - Analyse correlation trace gases – dust – clouds – T&P
  - Use GCM for interpretation




Villanueva et al., 2008



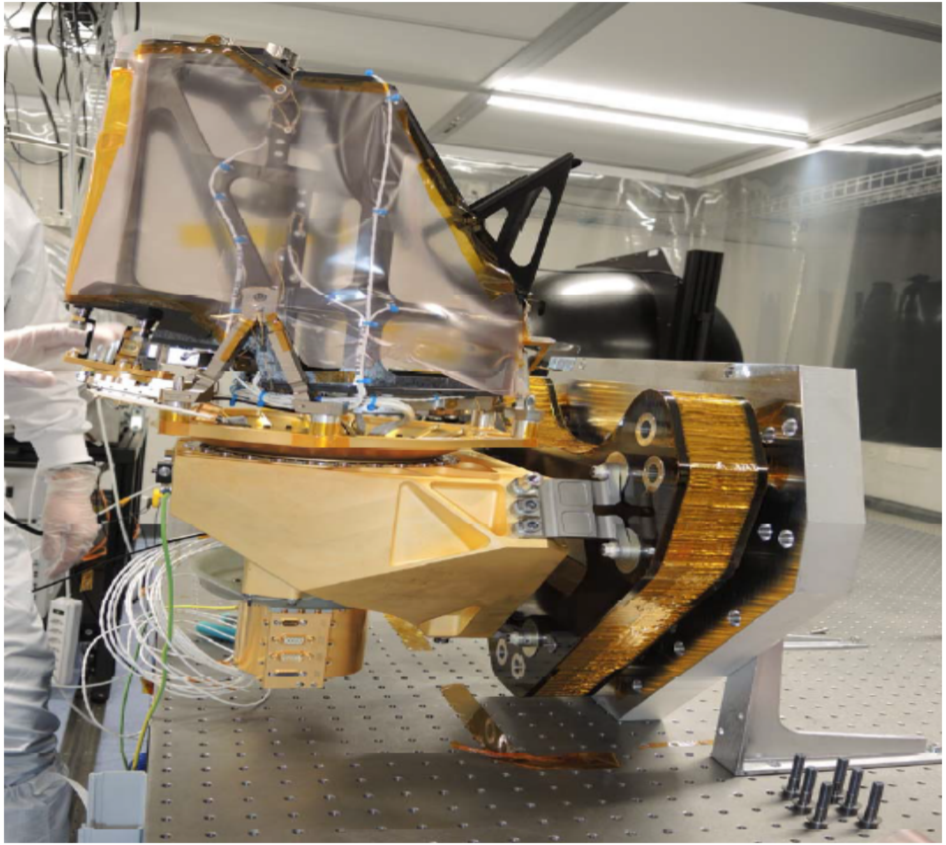

$O_3$- SPICAM-UV/Mars Express (Y. Willame)

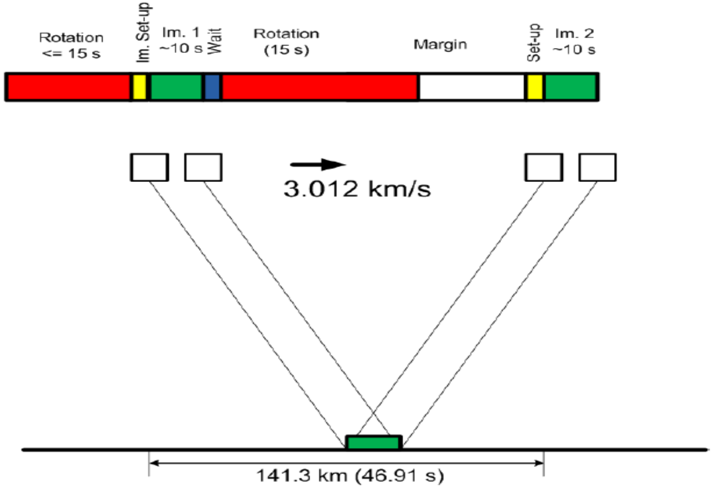



GCM simulation (F. Daerden)

| NOMAD expected performance | | 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]<br>< 0.7 ppb [g] | 0.03 ppb | 0.02 ppb | 11 ppb | | |
| **HCl** | < 3 ppb [e]<br>< 0.2 ppb [f]<br>< 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]<br>< 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]<br>< 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]<br>< 3.9 ppb [g] | 0.04 ppb | 0.03 ppb | 16 ppb | 7.5 ppb | 150 ppb |
| **$NH_3$** | < 5 ppb [h]<br>< 60 ppb [g] | | | | 1 ppb | - |
| **$SO_2$** | < 1 ppb [i]<br>< 2 ppb [j,k] | | | | 0.5 ppb | 18 ppb |

# CaSSIS (Colour and Stereo Surface Imaging System)






**Three-mirror anastigmat system (off-axis) with a fold mirror**

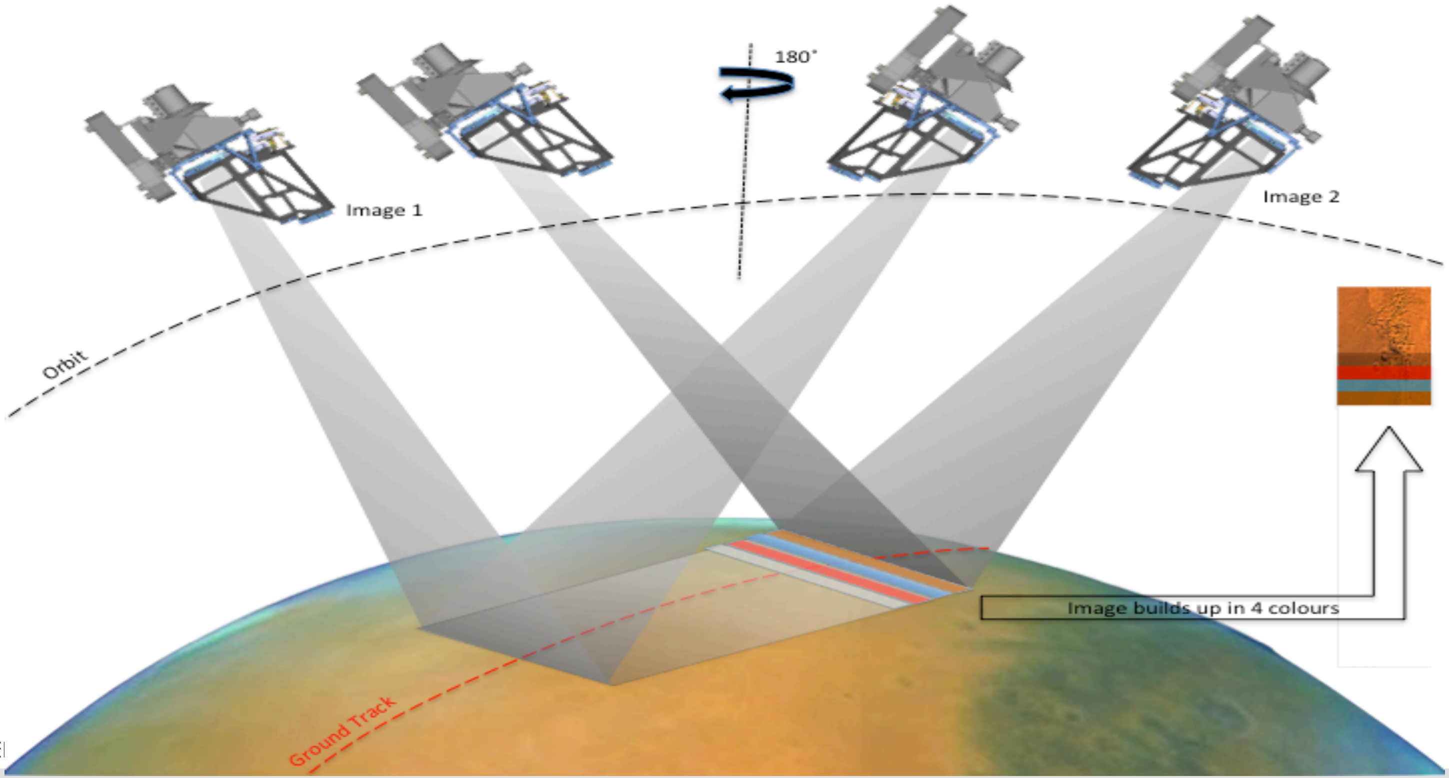
**Wavelength bands: Pan, Blue/Green, Red, IR**

# CaSSIS (Colour and Stereo Surface Imaging System)

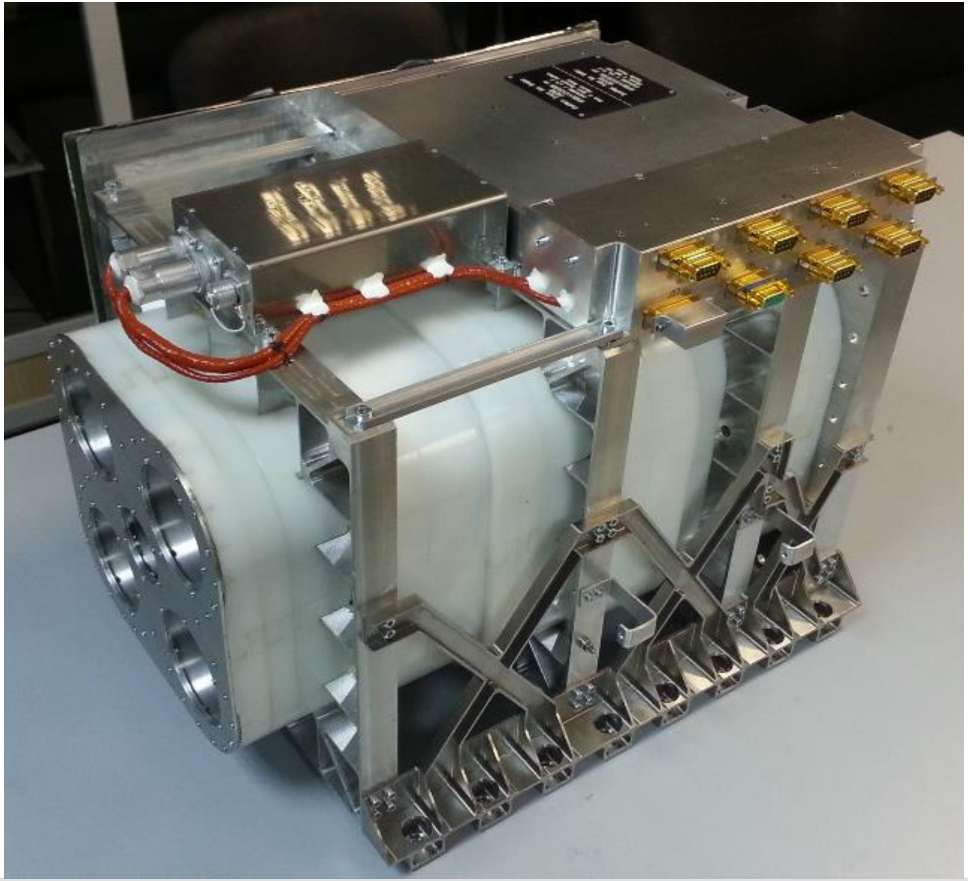
Science Objectives

- Image and analyze surface features possibly related to trace gas sources and sinks in order to better understand the broad range of processes that might be related to trace gases.
- Map regions of trace gas origination as determined by other experiments to test hypotheses.
- Search for and help certify the safety of new candidate landing sites driven by TGO and other mission’s discoveries.

# CaSSIS stereo imaging



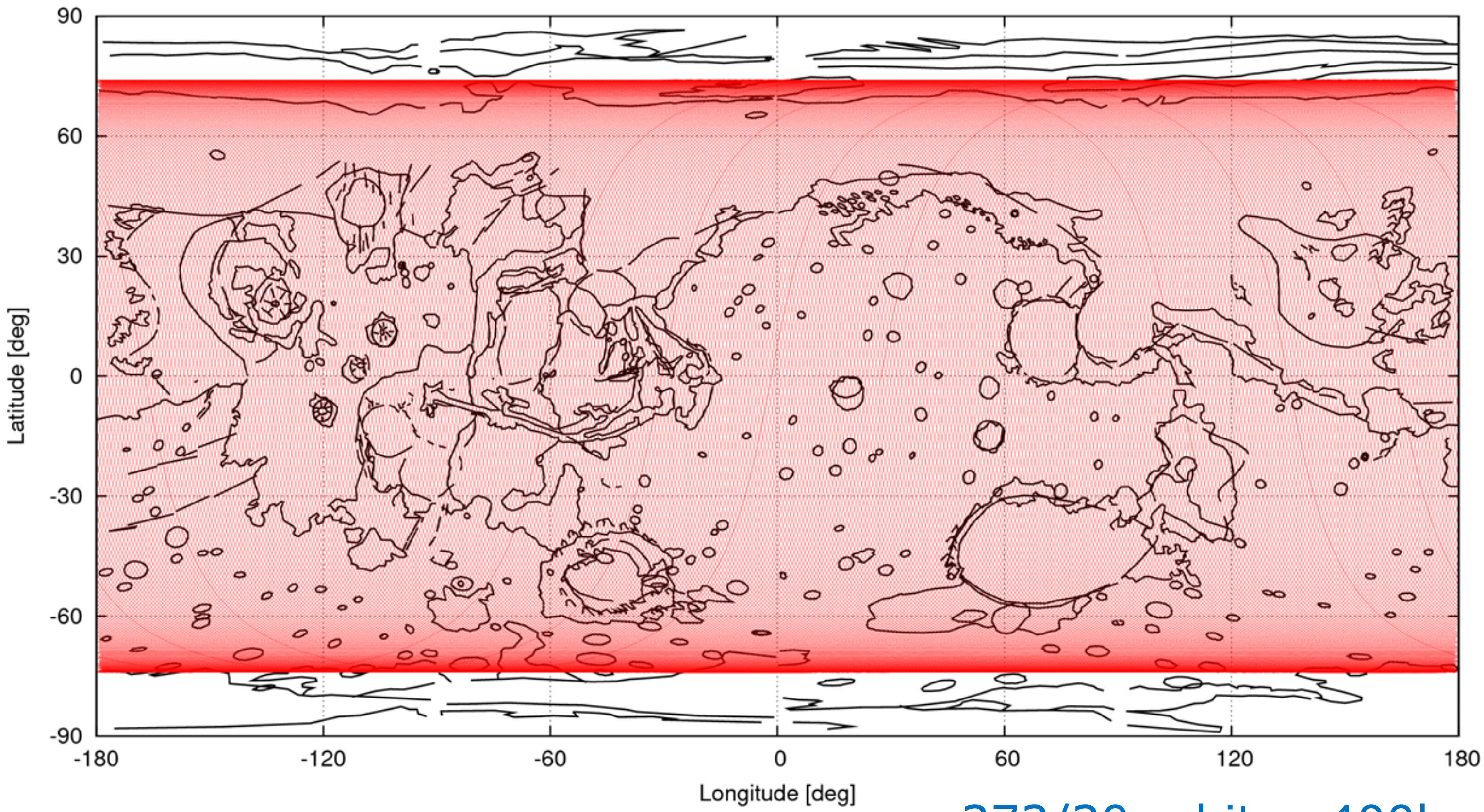
# FREND (Fine Resolution Epithermal Neutron Detector)



- Provide maps of Hydrogen concentration in the Martial soil with high spatial resolution and searching for its seasonal variations

- Monitor neutrons and charged particles fluxes at broad energy ranges during periods of quiet Sun and during Solar Particle Events

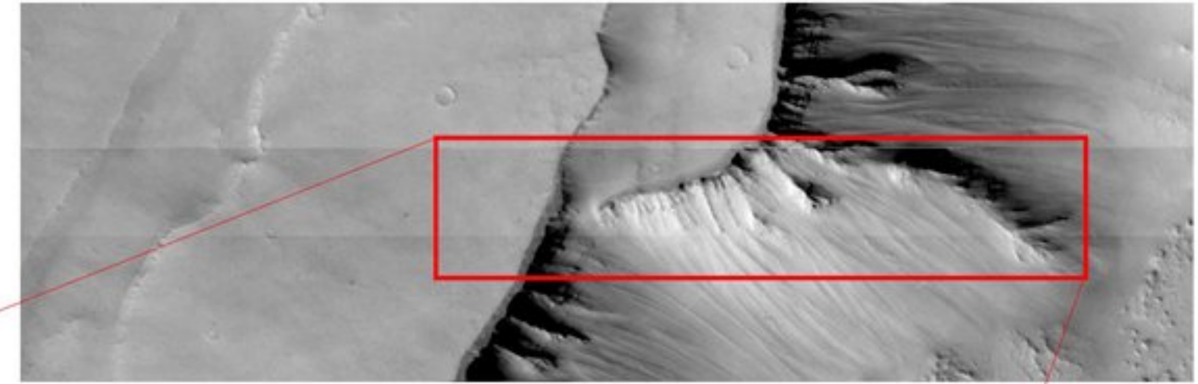
- Radiation survey (fluxes and dose compositions of different particles) in cruise and on Martian orbit.

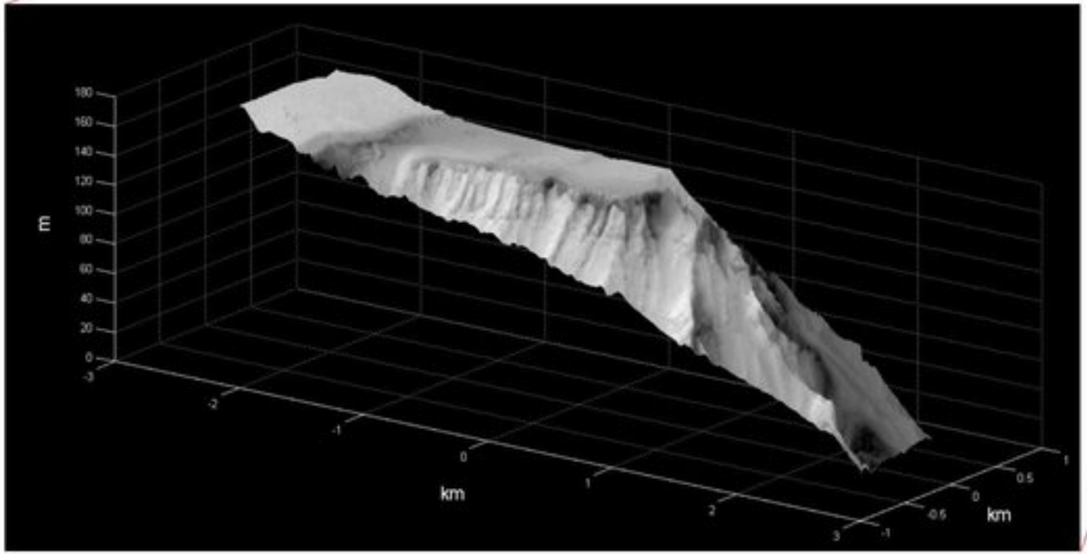



373/30 orbit, ~400km, 74deg incl.
ground track spacing 28.6 km

# TGO present status

- The spacecraft is in an excellent condition
- The payload was last checked out in March this year and was confirmed to be in an excellent state, just before the aerobraking phase started. The spectrometers have however not yet been used in occultation mode.
- The aerobraking is proceeding well and the period has been reduced to about 5.5 hours. A temporary suspension in the aerobraking was done during the Mars solar conjunction this summer.
- The final orbit is expected to be achieved in April 2018.



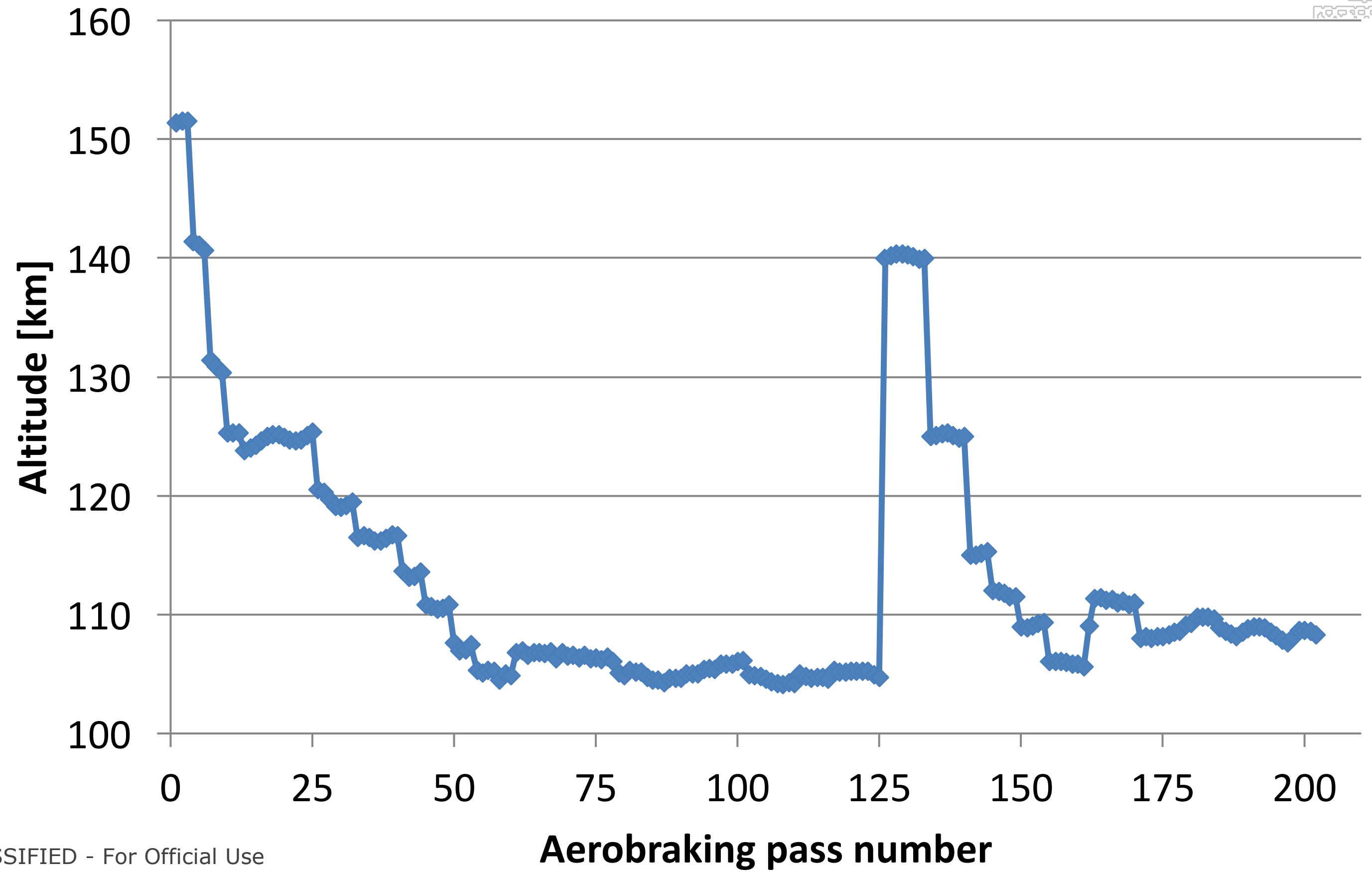


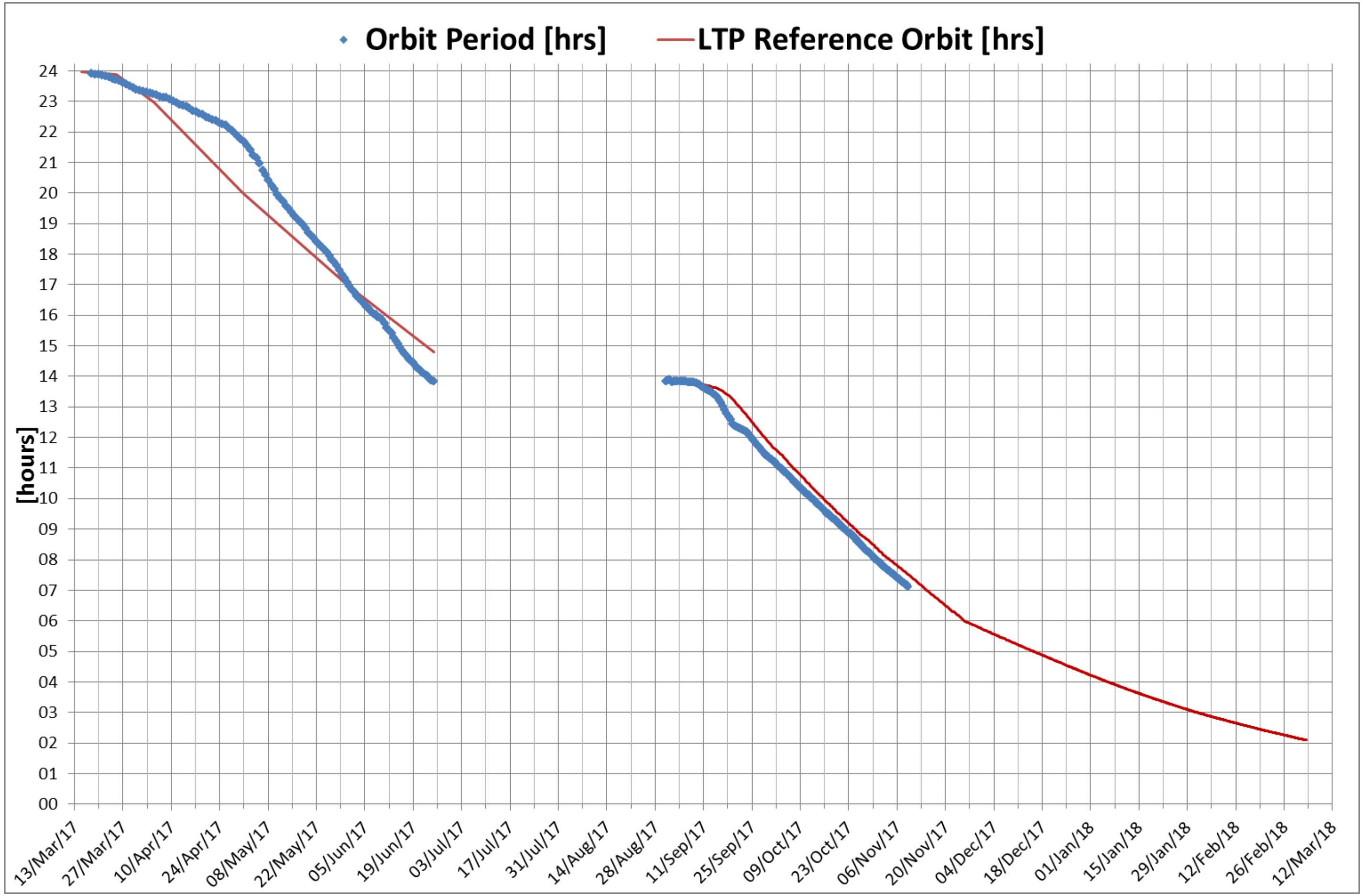

The first CaSSIS stereo reconstruction of a small area in Noctis Labyrinthus. Altitude resolution is better than 20 m.

# Features of Aerobraking

- The objective of the one year aeobraking period is to reduce the orbital period from 24 hours to 2 hours without using a significant amount of fuel.
- As a bonus, a great deal will be learned from the atmosphere in a region difficult to sample remotely. Atmospheric Density, and its short, medium and long term variability will be derived. Atmospheric waves may be observed. Comparison with and refinement of existing models will be made.
- Driving parameters are Dynamic pressure, Heat flux and Accumulated heat load. Limits for these are set by the spacecraft manufacturer. Limits are applied with typically a factor 2.5 margin, by the spacecraft operators at ESOC.
- Operational challenges appear during the late phase of the aerobraking, where a lot of activities have to be performed in the near two hour limit, with a heavy and not very agile spacecraft.

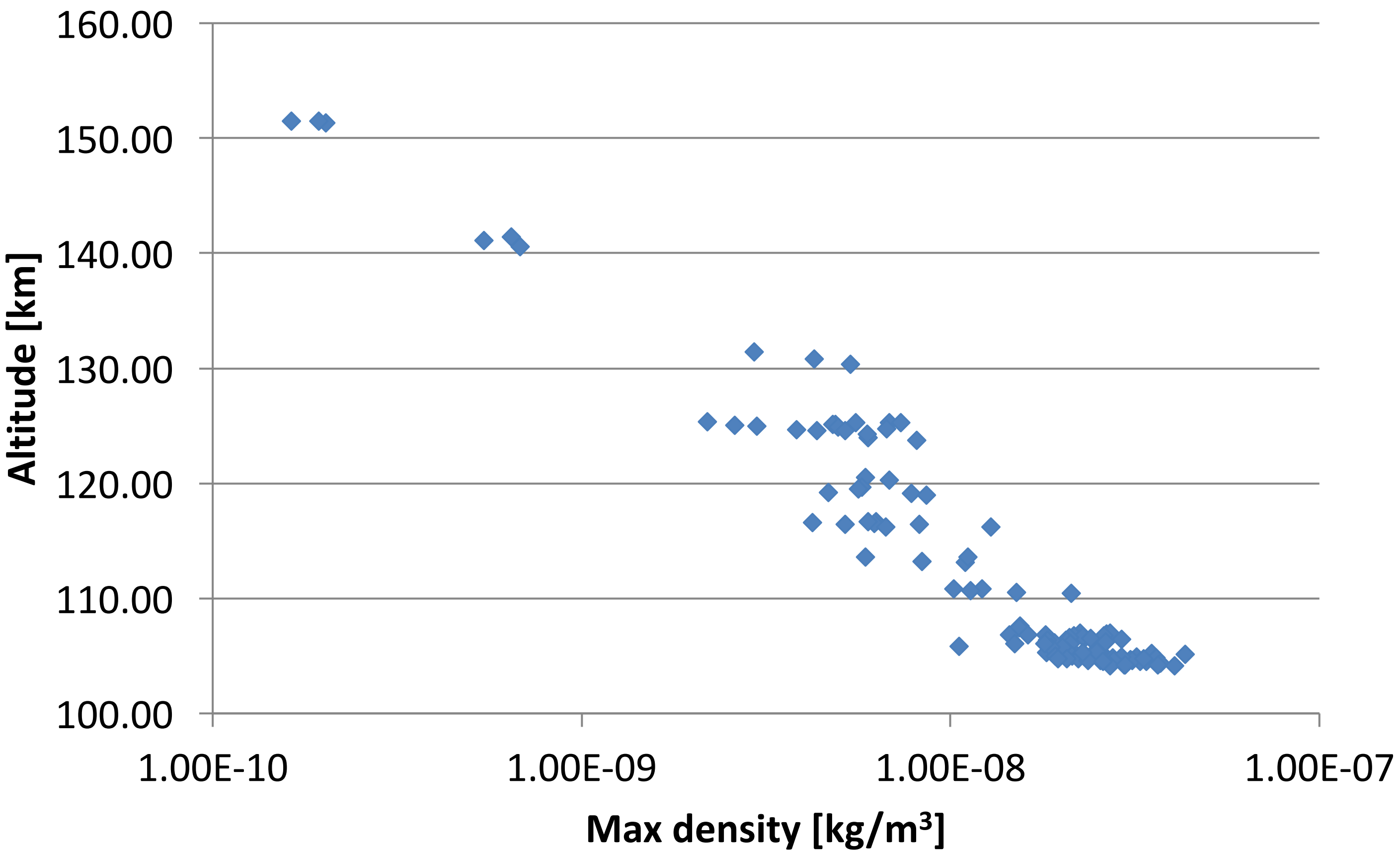
# Aerobraking altitude evolution



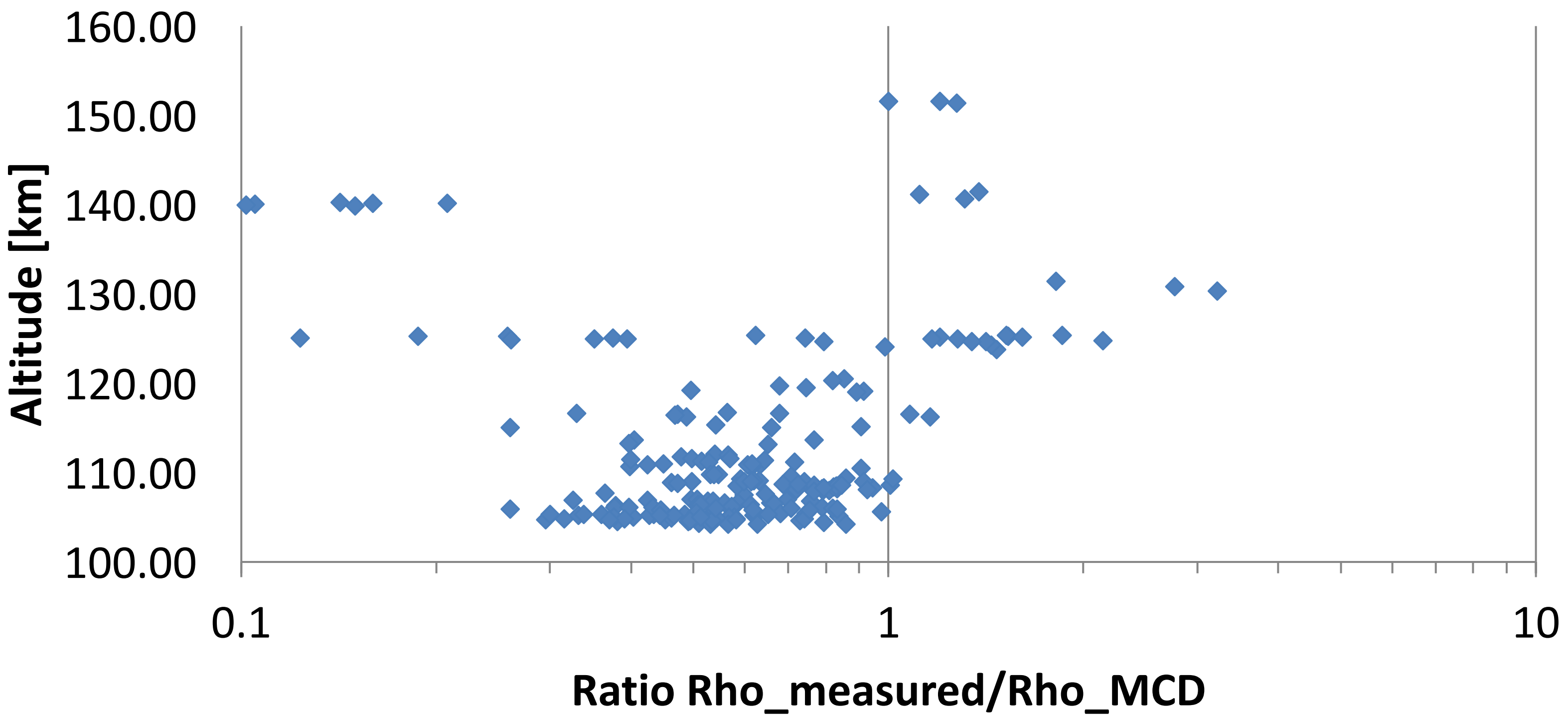



Evolution of orbital period for planned vs actual aerobraking

# TGO Aerobraking , determined max density



# Comparison with model (Mars Climate Database)



## Spacecraft and instrument commissioning will start in April 2018

## Science and data relay will start in June 2018