European Exploration of Mars
From Mars Express to ExoMars and beyond

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European Space Agency (ESAC/ESTEC)
Housekeeping for Attendees

• Session Length: 40 minutes

• Recorded Session: Webinar is recorded and will be available online.

• Webinar Session: All attendees are muted

• Discussions:
  – Session showcase: chat disabled, questions via Q&A (if time allows)
  – Individual presentations: via comments
  – Especial attention to Early Career Scientists

• Reminder of code of conduct and reporting procedures:
Session Summary

43 abstract contributions

(12 by Early Career Scientists)

• Mars Express : Dmitrij Titov
• ExoMars TGO : Håkan Svedhem
• ExoMars RSP : Jorge Vago
• MSR and future : Gerhard Kminek
Mars Express highlights and status

Dmitrij Titov
Mars Express Project Scientist
/on behalf of the Mars Express Team/

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1. Geology, interior and history

- Discovery of a stable body of **liquid water** under the southern polar layered deposits
- Geology and composition of Jezero crater and its vicinity
- Evidence of a **planet-wide ground water system**
- Map and catalogue of **chemical alteration features** with resolution of 200 m/px
- New **Digital Elevation Models**
2. Meteorology and climate

- Depth of the planetary boundary layer from MEX radio-occultations
- **Methane**: enigma continues
- Longest record of atmospheric ozone (SPICAM)
- Monitoring of CO₂ clouds
- Long orographic cloud at Arsia Mons

**Images:**
- CO₂ clouds
- Long orographic cloud at Arsia Mons
- Methane in Gale crater
3. Aeronomy and plasma environment

- **Topology of the plasma boundaries** as function of the solar cycle, crustal magnetic field and dust loading
- Analysis of interaction of Siding Spring comet with Mars plasmosphere completed
- **Ion escape rate** dependence on EUV flux, solar wind density and velocity
- Atmospheric loss over the planet history <10 mbar → **Ion escape is NOT the main loss mechanism**
- First **active plasma sounding** at another planet
- Validation of egress radio-occultations

![Plasma boundaries and ion escape](image)
4. Phobos investigations

- In 2019-2020 ~20 flybys of Phobos at <1000 km: augmenting the spatial and spectral coverage, constraining the age of Stickney crater and Phobos surface properties

- Almost all instruments operated during the flyby on March 13

- Working Group in support of MMX mission, lead by T. Duxbury, MEX IDS

Flyby on 13 March 2020

HRSC
Publication statistics
/status June 2020/

- >30 Tbytes of data archived including high level data products
- ~1300 papers
- ~55% are from ESA member states
- >35000 total citations
- 148 theses

- **COSPAR-2018 awards to S. Barabash and J.-P. Bibring**
- **EGU-2018 award to Y. Langevin**
- **EGU-2019 award to J. Carter**
- **EGU-2020 David Bates medal to A. Sanchez-Lavega**
Mission extension: geology and meteorology

Geology, interior and history

- High-res stereo coverage to >95%
- Image mosaics with up to 12 m/pixel resolution for the full equatorial range (±30°), both poles and most of the mid-latitude areas
- Multi-orbit DEMs (50 m/px)
- Completion of mineralogical mapping in collaboration with CRISM/MRO
- High-res radar sounding of the polar layered deposits in collaboration with Chinese Tianmen-1 mission
- Support to in situ missions by continuously improving the local and regional context of topography (DEM), multispectral imaging, and geology in collaboration with CASSIS/TGO

Meteorology & climate

- Continue monitoring atmospheric parameters, and their variations and filling gaps in the coverage, that is essential for climatology
- Study of couplings between the lower and middle atmosphere and dust impact on the atmospheric state using coordinated MEX-TGO spectroscopic and radio-occultation observations
- New “scan” pointing mode to study diurnal variations of atmospheric parameters over specific regions of interest (e.g., Tharsis, Hellas basin)
- Coordinated PFS-SPICAM observations to constrain H2O vertical distribution
Mission extension: aeronomy and plasma

- Solar cycle #25 and its comparison to the cycle #24
- Ionospheric sounding by MEX-TGO radio occultations
- Active sounding of the local plasma by ASPERA-MARSIS
Mars Express status

- **Spacecraft, operations and archiving are nominal**
  - 16 years of science operations
  - Since April 2018 in “gyroless” AOCS mode
  - The spacecraft is in good health and ready to continue science mission till at least 2025

- **Mission extension**
  - Extension till the end of 2020 is approved
  - Extension till the end of 2022 is to be confirmed
  - Extension in 2023-2025 is requested
  - SPC decision is expected in October 2020

- **Team and community**
  
  New ideas, suggestions, collaborations are welcome!
Please visit and comment presentations (especially those by Early Career Scientists!):

Mars Express
• **Dmitrij Titov**, Mars Express science highlights and future plans
• **Julia Marín-Yaseli**, Challenges for the New Science Campaigns in Mars Express future Mission Extensions
• **Eleni Ravanis**, From engineering to science: Mars Express Visual Monitoring Camera's first science data release
• **Anna Fedorova**, Multi-annual monitoring of the water vapor vertical distribution on Mars by SPICAM on Mars Express
• **Sebastian H.G. Walter**, Seamless albedo mosaic maps from Mars Express High Resolution Stereo Camera (HRSC) imagery

MAVEN
• **Quentin Nénon**, Implantation of ions escaping the atmosphere of Mars within the regolith of Phobos, and Phobos’ surface ion weathering *(MAVEN data, possibly related to MEX/ASPERA investigations)*

*(more in sessions for Mars surface, atmosphere, clouds, ionosphere, magnetosphere, etc)*
The ExoMars Trace Gas Orbiter - First Martian Year in Orbit

H. Svedhem & TGO Science Team

EPSC, Virtual meeting, 25 Sept 2020
ExoMars TGO Facts

- The Trace Gas orbiter is the first mission of the ESA/ROSCOSMOS ExoMars programme.
- Spacecraft is 3.2 m × 2m × 2m with solar wings spanning 17.5 m tip-to-tip, and mass of 3700 kg
- Launched from Baikonur on 14 March 2016
- Arriving at Mars 16 October 2016
- Aerobraking into a 400 km orbit was finished 7 April 2018
- The orbital period is 2 hours
- Science observations started late April 2018.
- First Martian Year of Science observations completed in March 2020
Data Relay

TGO will be the relay orbiter for the ExoMars 2022 Rover and Surface Platform, due to be launched mid 2022, arriving at Mars spring 2023.

TGO is presently relaying data from NASA’s MSL and Insight and will relay data from Perserverence after its arrival early 2021.
TGO Status (1)

- The present status of the TGO spacecraft, subsystems and the four science instruments is excellent
- After the end of life of the cryo-cooler in the TIRVIM channel on ACS, and the subsequent investigation, this channel is not operated anymore. Performance of the two other channels is not affected
- Fuel is sufficient for continued operations well of a decade
Major Results to be discussed at this conference

• No sign of Methane, Very low upper limits determined
  • Montmessin, >30000 ASC spectra Upper limit of CH4 10 pptv, 50 pptv
• Nomad, a large number of results introduced by
  • Vandaele (P, T, O3 Oxygen Green line detection, HCl detection, Dust/water, D/H Dust and Ice, Surface Ice
• First detection of HCl
  • Olsen, Trokhimovskiy (Cl isopic ratios)
• Subsurface water detections by FREND
  • 7 areas in +/- 30 deg latitude with up to 100 % water content
• CaSSIS imaging
  • Ganesh Rangaraja (Gasa Crater Gullies and evolution)
Major Results to be discussed at this conference (2)

- Water vapour profiles
  - Aoki (Climatology, Nomad), Belyaev (High Altitude, ACS)
- D/H ratio
  - Alday (measurements), Rossi (Modelling)
- First detection of HCl
  - Olsen, Trokhimovskiy (CI isopic ratios)
- Ozone profile retrieval
  - Picialli (Impact of gradients, com with SpicaM/MEX)
- Nomad/ACS Cross validation
  - Loez-Valverde (General agreement, 3 important improvements proposed)
ACS MIR data, - Ozone detection, new CO2 lines
First observation of Oxygen Day-Glow
Oxygen Day-Glow, observed by NOMAD-UVIS
Possible HCl cycles

1. Winds lift dust into the atmosphere. The dust contains NaCl.
2. The dust absorbs sunlight and warms the atmosphere. Water vapour near the surface expands and rises.
3. Dust that contains chloride (NaCl) releases chlorine, possibly via interactions with water.
4. Free chlorine reacts with hydrogen radicals to form HCl.
5. Sunlight breaks HCl down into H and Cl.
6. HCl may bond to dust and fall to the surface (dust).
7. Cl may reform HCl or may form a Cl-O bond, and eventually turn into perchlorate and return to the surface.

[Korablev, SciAdv 2020, in review]
CaSSIS: Springtime in Dune fields @ Green Crater

52.3°S, 351.8°E
Please visit and comment 22 presentations and posters (especially those by Early Career Scientists!):

• Håkan Svedhem, The ExoMars Trace Gas Orbiter - First Martian Year in Orbit

NOMAD

• Ann Carine Vandaele, NOMAD on ExoMars Trace Gas Orbiter: One Martian year of observations
• Shohei Aoki, Water vapor vertical profiles on Mars: Results from the first full Mars Year of TGO/NOMAD science operations
• George Cann, Ares: A retrieval framework Mars model for ExoMars TGO NOMAD solar occultation measurements
• Justin Erwin, Martian Atmosphere CO Vertical Profiles: Results from the First Year of TGO/NOMAD Science Operations
• Anne-Constance Imbreckx, Evolution of Mars polar caps extent from CRISM data (method related to NOMAD)
• Fabrizio Oliva, Mars dust properties by means of TGO/NOMAD UVIS and LNO channels nadir data analysis
• Arianna Piccialli, Impact of gradients at the Martian terminator on the retrieval of ozone from TGO/NOMAD-UVIS
• Loïc Rossi, Modeling of the effect of the MY34 Global Dust Storm on the martian HDO cycle.
• Ian Thomas, NOMAD on ExoMars TGO: Data processing and public release via the ESA Planetary Science Archive
• Luca Ruiz Lozano, Use of TGO-NOMAD nadir observations for ices detection
• Loïc Trompet, Update on CO2 and temperature profiles from NOMAD-SO on board ExoMars TGO

*See more on TP5 Atmospheres and Exospheres of Terrestrial Bodies*
Please visit and comment 22 presentations and posters (especially those by Early Career Scientists!):

ACS

• Franck Montmessin, Hunting for Methane on Mars: one Martian year of survey with ACS on TGO
• Kevin S. Olsen, HCl in the atmosphere of Mars: first detection of a halide gas
• Alexander Trokhimovskiy, HCl in the atmosphere of Mars: chlorine isotopic ratio
• Denis Belyaev, Mesospheric/Thermospheric temperatures and high altitude water on Mars in the MY34
• Juan Alday, Isotopic composition of water vapour in the Martian atmosphere: vertical profiles from ACS MIR on TGO

NOMAD+ACS

• Miguel Angel Lopez-Valverde, CO2 and temperature retrievals in the Mars atmosphere from solar occultation by NOMAD-SO and ACS-MIR: performance and cross validation.

*See more on TP5 Atmospheres and Exospheres of Terrestrial Bodies
ExoMars Trace Gas Orbiter contributions (III)

Please visit and comment 22 presentations and posters (especially those by Early Career Scientists!):

**FREND**
- Alexey Malakhov, Local water-rich areas on Mars found by the FREND neutron telescope onboard ExoMars TGO
- Jordanka Semkova, Update of the radiation environment measurement results aboard ExoMars TGO in May 2018-June 2020

**CASSIS**
- Vidhya Ganesh Rangarajan, Change detection analyses using simulated and actual ExoMars TGO-CaSSIS images
- Adam Parkes Bowen, Using band ratioed CaSSIS imagery and analysis of fracture morphology to characterise Oxia Planum’s clay-bearing unit

(see also TP14 Mars Surface and Interior and others ...)
Search for Life on Mars
2022 Mission Objectives

**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.
- Throttled braking engines for planetary landing;
- Russian deep-space communications stations working in combination with ESA's ESTRACK.
Analytical Laboratory Drawer
Rover Locomotion

Locomotion formula: 6 x 6 x 6 + 6
- 6 supporting wheels
- 6 driven wheels
- 6 steered wheels
- 6 articulated knees

Back bogie
Side bogie
ES2 Soil - 21° Upslope - Wheel Walking

video accelerated x15
WW gait selected for flight
Lander Structural Model
Descent Module Tests
Descent Module Tests
Descent Module Tests
ExoMars Rover and Surface Platform contributions

Please visit and comment 12 RSP presentations and posters (especially those by Early Career Scientists!):

- **E. Sefton-Nash**, HiRISE-scale characterization of the Oxia Planum landing site for the Exomars 2022 Mission


- **G. Lopez-Reyes**, RLS spectra acquisition optimization with the RLS FS and RLS ExoMars Simulator

- **J. M. Madariaga**, Temperature transformation of calcium and potassium Martian sulfates as seen by an Exomars 2022 RLS-like instrument


- **A. Frigeri**, Combining ExoMars’ Ma_MISS and Drill data


- **D. Toledo**, Retrieval of martian dust and cloud properties from ground-based radiance dust sensors

- **D. Golovin**, Investigation of martian soil properties by complementary instruments ADRON-EM and RM instruments of ExoMars 2022

- **S. Nikiforov**, Experience of DAN investigation of subsurface water on Mars onboard Curiosity for future ADRON-RM experiment on ExoMars

- **M. Balme**, The ExoFit Rover field trial - simulating ExoMars Rosalind Franklin Rover operations

- **M. Veneranda**, PTAL, ADAMM and SpectPro: novel tools to support ExoMars and Mars 2020 science operations
Future Mars Sample Return

Gerhard Kminek
European Space Agency
MSR Program Scientist (interim)
Mars 2020 Mission – Perseverance Rover

- Returned Sample Science (RSS) Team has been established (9 US, 5 European and 1 Canadian scientists) selected through an open AO
- RSS Team is part of the Mars 2020 Science Team and will support the selection of samples to be transported to Earth by SRL and ERO

Mars Sample Return (MSR) Science Planning Group Phase 2 (MSPG2)

- Group includes European, US, Canadian and Japanese scientists selected in an open AO
- Major tasks are to write a Science Management Plan (SMP) and to identify driving science requirements for ground based receiving, curation and science analysis infrastructure

Mars Sample Return (MSR) Science Management Guiding Principles

- **Transparency:** Access to samples must be fair and the processes defining sample access must be as transparent as possible
- **Science maximization:** Optimize the scientific productivity of the samples via careful selection of science investigations
- **Accessibility:** Multiple opportunities for international scientists to participate throughout the MSR process in a variety of capacities
- **Return on investment:** Agencies providing the investments receive benefits for enabling the samples’ return
- **One return canister - One collection:** The returned samples should be managed as a single collection
Please visit and comment future Mars mission contributions (especially those by Early Career Scientists):

- Claire Parfitt, Small Mars Mission Architectural Study

- Marta M. Sanchez-Garcia, Analysis of the optimization for an Earth to Mars areostationary mission
Please visit presentations in this and other Mars sessions

- TP18 Astrobiology: Fri, 25 Sep, 11:20 **after this!**
- TP7 Ionospheres of unmagnetized or weakly magnetized bodies: Mon, 21 Sep, 17:00
- EXO6 (Exo-)planetary magnetospheres: Mon, 28 Sep, 11:20
- MITM8 Planetary space weather: Thu, 01 Oct, 10:40
- OPS6 Aerosols and clouds in planetary atmospheres: Thu, 01 Oct, 11:20
- TP14 Mars Surface and Interior: Thu, 01 Oct, 17:20
- TP5 Atmospheres and Exospheres of Terrestrial Bodies: Fri, 02 Oct, 17:00