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Long-Term Planning strategy evolution for Trace Gas Orbiter (TGO) spacecraft

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ExoMars Trace Gas Orbiter (TGO) was launched by the European Space Agency in March 2016 and started operating around Mars in April 2018 after the nominal science orbit was reached. Four instruments are mounted on the spacecraft: The Atmospheric Chemistry Suite (ACS), the Colour and Stereo Surface Imaging System (CaSSIS), the Fine Resolution Epithermal Neutron Detector (FREND), and the Nadir and Occultation for MArs Discovery (NOMAD) instrument. The ACS and NOMAD instruments are dedicated to studies of the Martian atmosphere. The CaSSIS visible camera is equipped with a rotation mechanism allowing to acquire images of the same target with different viewing angle in the same overflight pass, enabling stereo images. Specific regions can be targeted by rolling the spacecraft in across-track direction. The FREND instrument requires nadir or near-nadir pointing during a large fraction of time to map the hydrogen abundance in the sub-surface.

The Science Operations Centre (SOC) based at the European Space Astronomy Centre (ESAC, Spain) is responsible for the implementation of science operation timelines, considering the instrument team requests and the mission's science priorities, while at the same time complying with spacecraft and operational constraints (B. Geiger et al., 2018, M. Ashman et al., 2018). We describe here the overall planning strategy for TGO and its evolution. The planning is divided into specific segments: long, medium, and short term, corresponding to 6-months, 4-weeks and 1-week planning periods. The strategy is set for a long-term planning period (LTP) and revised if/when necessary. For each 6-month or LTP period, the planning is such that solar occultations opportunities are computed for the overall period. On average, since the beginning of the mission, we find that a LTP period comprises ~3500 occultations opportunities amongst which ~60% are eventually scheduled. The scheduled occultation pointings are partitioned between the ACS and NOMAD instrument. Additionally, it is possible to indicate in the schedule that ACS can ride-along a percentage of prime occultations allocated to NOMAD.

Depending on the location at the surface and/or the Solar Longitude (L_s, *i.e.*, the local season) the occultations can be considered with higher priority. Starting from MTP012 (in February 2019), occultations covering the equatorial regions were considered with highest priority. Thus, no other type of observations can be implemented during periods of equatorial occultations. Moreover, based on instrument teams requests a list of regions of interest (ROI) is also used to flag amongst the

occultations opportunities the ones with high priority. This list was started during MTP020 in October 2019 and the last addition to the list is dated to April 2024. We do not exclude that this list will evolve in the future to respond to scientific requirements/discoveries. To this day, 7 ROIs are defined: Gale Crater, Jezero Crater, Green Valley, Utopia Planitia, Elysium Planitia, Alba Mons and Arsia Mons (for the detection of Elongated Clouds). Nominally, the instrument allocation for "highly valuable occultations" on ROIs is 50/50 between the ACS and NOMAD instruments while trying to get similar spatial coverage on each region for both instruments.

The CaSSIS instrument team provides a list of images (Nadir pointing or targeted pointing, the latter resulting in off-nadir angle) at Medium Term planning (MTP). On average ~2500 nadir images and ~1400 targeted images are acquired per LTP-period. Targeted images are important to fill gaps on the surface and/or to point to locations that cannot be reached while observing in Nadir mode. Although this puts constraints on the space-craft operations, the off-nadir angle allowed for these observations have recently been increased from 5 to 7 degrees to allow for better access to regions that can rarely be observed.

At MTP-level, other types of observations can be implemented. Mostly, observations that are not part of the standard repetitive pointing timeline and that result in large off-nadir angle. These specific observations, labelled as "Special Pointings", are limited in number to 5 per STP (*i.e.*, per week) due to their operational constraints. They correspond to calibration measurements, Phobos or Deimos observations and limb observations. Special pointing calibrations measurements were included in the planning strategy since the beginning of the mission with an allocation of 1 special pointing per STP. This number has increased with time (5 to this day) thanks to the scientific benefit of these pointings. The first limb measurement occurred in MTP014, in April 2019; the first Phobos measurement occurred in MTP045, in September 2021 and the first Deimos measurement took place in MTP049, in December 2021. The limb measurements are usually used by the NOMAD instrument to detect and characterise airglow (day- or night- glow) and auroras (Gérard et al., 2020a,b; Soret et al., 2022; Soret et al., 2023; Gérard et al., 2023). Recently, experimental measurements for limb observations with CaSSIS were also carried out. These CaSSIS observations are promising (Thomas et al., 2024) and are implemented as special pointings on the basis of ~1 per MTP. Based on instrument team requests, moon observations for ACS have stopped in May 2022.

Reference: B. Geiger et al., Long Term Planning for the ExoMars Trace Gas Orbiter Mission: Opportunity Analysis and Observation Scheduling, 2018 Space Ops. Conference; M. Ashman et al., Science Planning Implementation and Challenges for the ExoMars Trace Gas Orbiter, 2018 Space Ops. Conference; Gérard et al., 2020, Detection of green line emission in the dayside atmosphere of Mars from NOMAD-TGO observation, Nature Astronomy Letters; Gérard et al., 2020, First Observation of the Oxygen 630 nm Emission in the Martian Dayglow, GRL; Soret et al., 2022, The Mars Oxygen Visible Dayglow: A Martian Year of NOMAD/UVIS Observations, JRG Planets; Soret et al., 2023, The Ultraviolet Martian Dayglow Observed With NOMAD/UVIS on ExoMars Trace Gas Orbiter, JGR Planets; Gérard et al., 2023, Observation of the Mars O2 visible nightglow by the NOMAD spectrometer onboard the Trace Gas Orbiter, Nature Astronomy. N. Thomas et al., CaSSIS observations of atmospheric forward scattering from limb pointings, 2024, 10th Mars Conference.