CaSSIS on the ExoMars Trace Gas Orbiter: Operational approach. N. Thomas[1], G. Cremonese[2], M. Almeida[1], J. Backer[3], P. Becerra[1], G. Borrini[1], S. Byrne[4], M. Gruber[1], P. Gubler[1], R. Heyd[4], A. Ivanov[5], L. Keszthelyi[3], C. Marriner[6], G. McArthur[4], A.S. McEwen[4], C. Okubo[3], M.R. Patel[6], J. Perry[4], A. Pommerol[1], C. Re[2], M.R. Read[1], C. Schaller[4], S. Scheidt[4], E. Simioni[2], S.S. Sutton[4], S. Tulyakov[7], and C. Zimmermann[1].
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Introduction: The ExoMars Trace Gas Orbiter (TGO) was launched on 14 March 2016 and entered Mars orbit on 19 October 2016. The spacecraft reached its primary science orbit (360 km x 420 km at an inclination of 74°) on 9 April 2018. TGO carries a high resolution colour and stereo camera system called the Colour and Stereo Surface Imaging System (CaSSIS).

The technical characteristics of CaSSIS include (1) acquisition of imaging observations at a scale of <4.5 m/px, (2) production of images in 4 broad-band colours optimized for Mars photometry, (3) acquisition of a swath up to 9.5 km in width, and (4) acquisition of quasi-simultaneous stereo pairs over the full swath width for high resolution digital terrain models. A full instrument description has been provided [1]. Details on the ground calibration of the instrument are provided in [2]. Spectral-image simulations to assess the colour and spatial capabilities of the instrument are shown in [3]. The full payload is described in [4].

The spacecraft has been in its primary science orbit since March 2016 and entered the primary science phase in April 2018 [5]. CaSSIS uses planning tools based on the highly successful planning approach of HiRISE [6]. The elements specific to CaSSIS are covered by a set of IDL programs designed to generate the commands needed by the Science Operations Centre (SOC) in Madrid and the Mission Operations Centre (MOC) in Darmstadt. The data returned are then passed to an IDL pipeline for telemetry conversion and reduction. The output is in a pseudo PDS4 format (XML plus binary data files) that can be read into the ISIS3 software environment to produce mosaics and colour products.

Uplink: The first step is time-independent target suggestions using the CaSSIS targeting tool (CaST), which is derived from HiWISH (https://www.uahirise.org/hiwish/).

The detailed targeting tools are based around a GUI called PLAN-C – a derivative of the HiRISE tool, HiPLAN, in turn built on JMARS (https://jmars.asu.edu/). PLAN-C is seen as a layer within the JMARS environment and hence the user targeting CaSSIS has full access to the different layers available in JMARS for viewing maps and specific properties of the Martian surface. The user imports a state file that describes the TGO orbit using predicted SPICE kernels prepared by the SOC. The user can then place targets along the orbit for CaSSIS to acquire (Figure 1). This is supported by the target database, CaST. This can be imported as a separate layer into the JMARS environment and interacts with PLAN-C to support accurate targeting of interesting areas. PLAN-C also allows the setting of CaSSIS instrument parameters through a sub-element called the CaSSIS Observation Generation GUI (COGG). Here, filters may be chosen, the number of exposures in a sequence can be set, and the data compression selected. The result is a CaSSIS Target File (CTF) that has one line per image (a stereo pair produces two lines in the CTF). This file can be passed to an IDL code called C_CTF2ITL. This produces the Instrument Timeline File (ITL) that the SOC needs to generate the spacecraft command files for all instruments on TGO. C_CTF2ITL performs detailed error checking and ensures that data rate limits at bottlenecks within the instrument are not exceeded. The user can also program instrument reboots and other activities. The code automatically sets the timings of the commands within the timeline, opens and closes files in the spacecraft payload data handling unit (PDHU), and tracks the data volume which is an input to the SOC. In order to achieve the highest precision image ac-quisition the code is also able to update the com-mand execution time and parameters using the latest timing information from the spacecraft in less than 30 seconds so that commands can be uploaded to the spacecraft at the last possible time.

During execution and when the spacecraft is in ground contact, CaSSIS can be monitored through housekeeping telemetry (HK) transmitted on the 1553 bus. The HK is read automatically from Darmstadt and is passed to an Influx database to which a Grafana interface has been written.

Calibration: Once the acquired data have been transferred from the MOC, it is passed to a calibration pipeline. This pipeline extracts the science telemetry packets and converts the data into a pseudo-PDS V4 format (binary data files with XML header information) which is then passed to the radiometric calibration element of the pipeline. The conversion is performed on a framelet basis and is directly into reflectance (I/F). Preliminary studies suggest good agreement with other instruments based on analysis of Phobos observations [7]. The XML headers are also filled with geometry information. This information is based on SPICE kernels from the SOC. The orientation of the telescope is also required. C_CTF2ITL generates the input for a C-kernel (produced using the SPICE toolkit) and this kernel can then be added to the SPICE kernel library to determine the pointing of CaSSIS. This allows the production of simple browse images (no instrument geometric distortion correction) of reasonable quality at a very early stage for validation purposes.

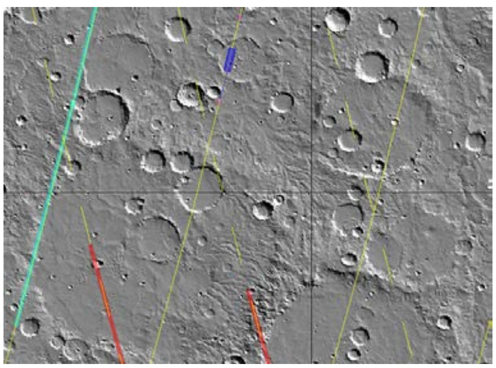

Figure 1 Extract from a PLAN-C screen showing targeting opportunities for CaSSIS. The ground-track over the dayside (yellow solid lines) and the nightside (yellow broken) are shown. Exclusions (when solar occultations for NOMAD and/or ACS occur, spacecraft manoeuvres are made or comms passes with landers occur) are also shown. A CaSSIS image is planned in the top centre (dark blue block).

Geometry processing: After completion of the radiometric calibration, the data can be assembled into mosaics. The SPICE CaSSIS-specific Instrument and Frame kernels (ik and fk, respectively) have recently been improved. ISIS3 (https://isis.astrogeology.usgs.gov/) importers for CaSSIS data files have been written and tested. Export will be into a PDS4 compatible format. Tests with ISIS3 suggest that routine production of mosaicked products should be reasonably straightforward in this environment. Final product definition is being agreed at the time of writing. Digital Terrain Models (DTMs) will be generated by individual institutes on a best effort basis and archived at INAF-Padova(https://cassis.oapd.inaf.it/archive/). However, significant progress has been made (see elsewhere in this conference).

Conclusion: CaSSIS operations are approaching a routine state. Work remains to be done on the geometry pipelines, optimized production of stereo and colour products, and map-based tools to find images of interest. Formal data release will be through the Planetary Science Archive of ESA. The raw observations and the first processed data sets from the in-orbit commissioning (pre-primary science orbit) have already been released through the PSA. A review of the first primary science orbit data release is expected in June 2019.

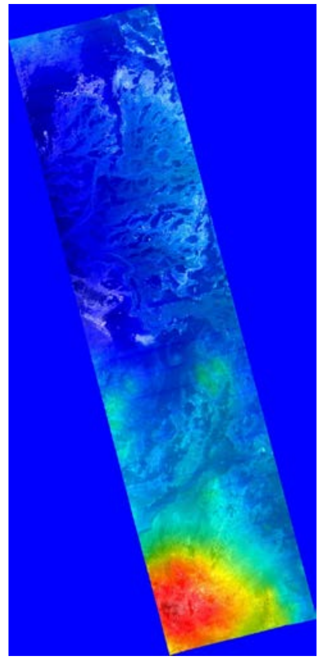

Figure 2 Texturized DTMof Eberswalde delta (MY34_004384_206_1) with a grid size of 3 pixel corresponding to 14.3 m and a vertical precision of 4.7 m. The images were acquired in November 2018. The DTM has been generated by INAF-Padova pipeline [8] from CaSSIS data.

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