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CaSSIS – Targeting, Operations, and Data Reduction

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Abstract

CaSSIS (Colour and Stereo Surface Imaging System) is the main imaging system for the ExoMars Trace Gas Orbiter (TGO) mission. A scientifically compelling instrument was completed in October 2015 and launched in March 2016 [1]. This abstract describes the targeting, operations, and data reduction pipelines used to produce calibrated observations of selected targets.

1. Introduction

The scientific objectives of CaSSIS are to (1) characterize sites which have been identified as potential sources of trace gases, (2) investigate dynamic surface processes (e.g. sublimation, erosional processes, volcanism) which may help to constrain the atmospheric gas inventory, and (3) certify potential future landing sites by characterizing local (down to ~10 m) slopes.

The technical aims foreseen were to (1) acquire imaging observations at a scale of <5 m/px, (2) produce images in 4 broad-band colours optimized for Mars photometry, (3) acquire a swath width >8 km, and (4) obtain quasi-simultaneous stereo pairs over the full swath width for high res. digital terrain models. These technical aims combined with programmatic constraints drove the design.

The spacecraft has been in its primary science orbit since March 2016 and recently entered the primary science phase. CaSSIS uses planning tools based on the highly successful planning approach of HiRISE [2]. 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 is 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 ISIS software environment to produce mosaics and colour products. We describe here briefly the key elements of the operations.

2. Uplink Tools

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 orbit of TGO. The state file refers to planning SPICE kernels prepared in advance by the SOC. The user can then place targets along the orbit for CaSSIS to acquire. This is supported by a target database from CaST. The database 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 COGG. In this element, the filters may be chosen, the number of exposures in the 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).

Once the CTF has been produced, the 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 volume limits at bottlenecks within the instrument are not exceeded. The user can also program in instrument reboots and other activities from the command line. 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 final data volume which is an input to the SOC.

3. Operations Monitoring and the Ground Reference Model

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 semi-automatically from Darmstadt and is passed to an Influx database to which a Grafana interface has been written.

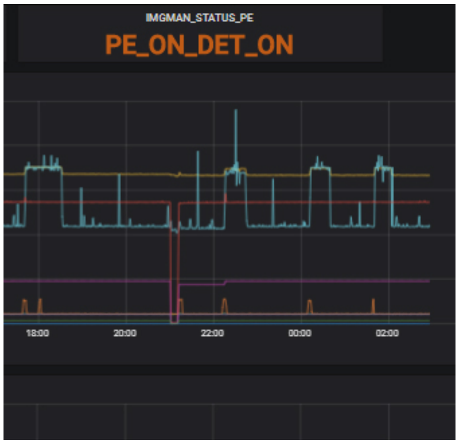

Figure 1: Part of the Grafana HK monitoring interface showing a system reboot (at 21:00) and image acquisitions increasing the current on the digital processor's 3.3 V line (in cyan).

The time available to build CaSSIS was extremely short and test time was reduced to a minimum to maintain the spacecraft schedule. The instrument has occasionally gone into safe mode during operations for reasons that might have been at first unclear. The Ground Reference Model (GRM) has been used to debug the system in these cases supported by the telemetry monitor.

4. Calibration Pipeline

Once the acquired data has 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 (J. Fernando, pers. comm.) suggest good agreement with other instruments based on analysis of Phobos observations. 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.

5. Geometry Processing – ISIS3 and DTM production

After completion of the radiometric calibration, the data can be assembled into mosaics. The SPICE I and F kernels 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 mosaiked products should be reasonably straightforward in this environment. Final product definition is being agreed at the time of writing.

The generation of digital terrain models (DTM) will be performed by individual institutes on a best effort basis. However, significant progress has been made (see elsewhere in this conference).

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