Publication Year	2016
Acceptance in OA@INAF	2020-06-11T15:17:14Z
Title	The ExoMars DREAMS scientific data archive
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DOI	10.1117/12.2233467
Handle	http://hdl.handle.net/20.500.12386/26006
Series	PROCEEDINGS OF SPIE
Number	9913

The ExoMars DREAMS scientific data archive

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ABSTRACT

DREAMS (Dust Characterisation, Risk Assessment, and Environment Analyser on the Martian Surface) is a payload accommodated on the Schiaparelli Entry and Descent Module (EDM) of ExoMars 2016, the ESA – Roscosmos mission to Mars successfully launched on 14 March 2016. The DREAMS data will be archived and distributed to the scientific community through the ESA's Planetary Science Archive (PSA). All data shall be compliant with NASA's Planetary Data System (PDS4) standards for formatting and labelling files. This paper summarizes the format and content of the DREAMS data products and associated metadata. The pipeline to convert the raw telemetries to the final products for the archive is sketched as well.

Keywords: Data Handling, Archive, Space Mission, Mars

1. THE EXOMARS MISSION

On 14 March 2016, the European Space Agency (ESA) and the Russian Roscosmos launched the ExoMars 2016 mission to Mars, including an orbiter (the Trace Gas Orbiter - TGO) and a lander (Schiaparelli), on a Proton rocket from Baikonur (Kazakhstan). This launch marked the first phase in the European-Russian ExoMars cooperation which will include a second mission in 2020.

Once orbiting Mars, the TGO will measure the abundance and distribution of trace gases in the atmosphere with its sophisticated sensors (of particular interest is methane, which could point to active geological or biological processes on the planet). Meanwhile, Schiaparelli will demonstrate the technology to make a controlled landing on the planet, set for 19 October 2016, and will make scientific measurements through its DREAMS payload.

In the weeks following the launch, engineers and scientists from ESA and instrument teams checked the Trace Gas Orbiter and the Schiaparelli entry, descent, and landing demonstrator to ensure they survive to launch and will be ready for operations on Mars in October. The science instruments successfully underwent all initial checks.

2. THE DREAMS PAYLOAD

DREAMS [1][2] is an autonomous surface payload package on the Schiaparelli EDM. It is a meteorological station with the additional capability to perform measurements of the atmospheric electric fields close to the surface of Mars. The instrument package will make the first measurements of electric fields on Mars, providing data that will be of value in planning the second ExoMars mission in 2020, as well as possible future human missions to the red planet. Actually, still we don't know if electrical discharges occur on Mars. It is generally thought that strong electric fields can be generated through the triboelectric effect during the collisions of wind-blown dust particles of different sizes, which generate positive and negative charges [3]. DREAMS will help to understand if wind-blown dust can cause dangerous electrical discharges.

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Software and Cyberinfrastructure for Astronomy III, edited by Gianluca Chiozzi,
Juan C. Guzman, Proc. of SPIE Vol. 9913, 99134F · © 2016 SPIE
CCC code: 0277-786X/16/$18 · doi: 10.1117/12.2233467

The Schiaparelli EDM will reach Mars during the statistical dust storm season, so DREAMS will characterize the Martian environment in this dust loaded scenario. In more details, DREAMS will perform:

- meteorological measurements by monitoring pressure, temperature, wind speed and direction, humidity and dust opacity during a Martian sol at the landing site;
- characterization of the Martian boundary layer in dusty conditions;
- hazard monitoring by providing a comprehensive dataset to help engineers to quantify hazards for equipment and human crew: velocity of windblown dust, electrostatic charging, existence of discharges, and electromagnetic noise potentially affecting communications, intensity of UV radiation;
- the first ever investigation of atmospheric electric phenomena at Mars.

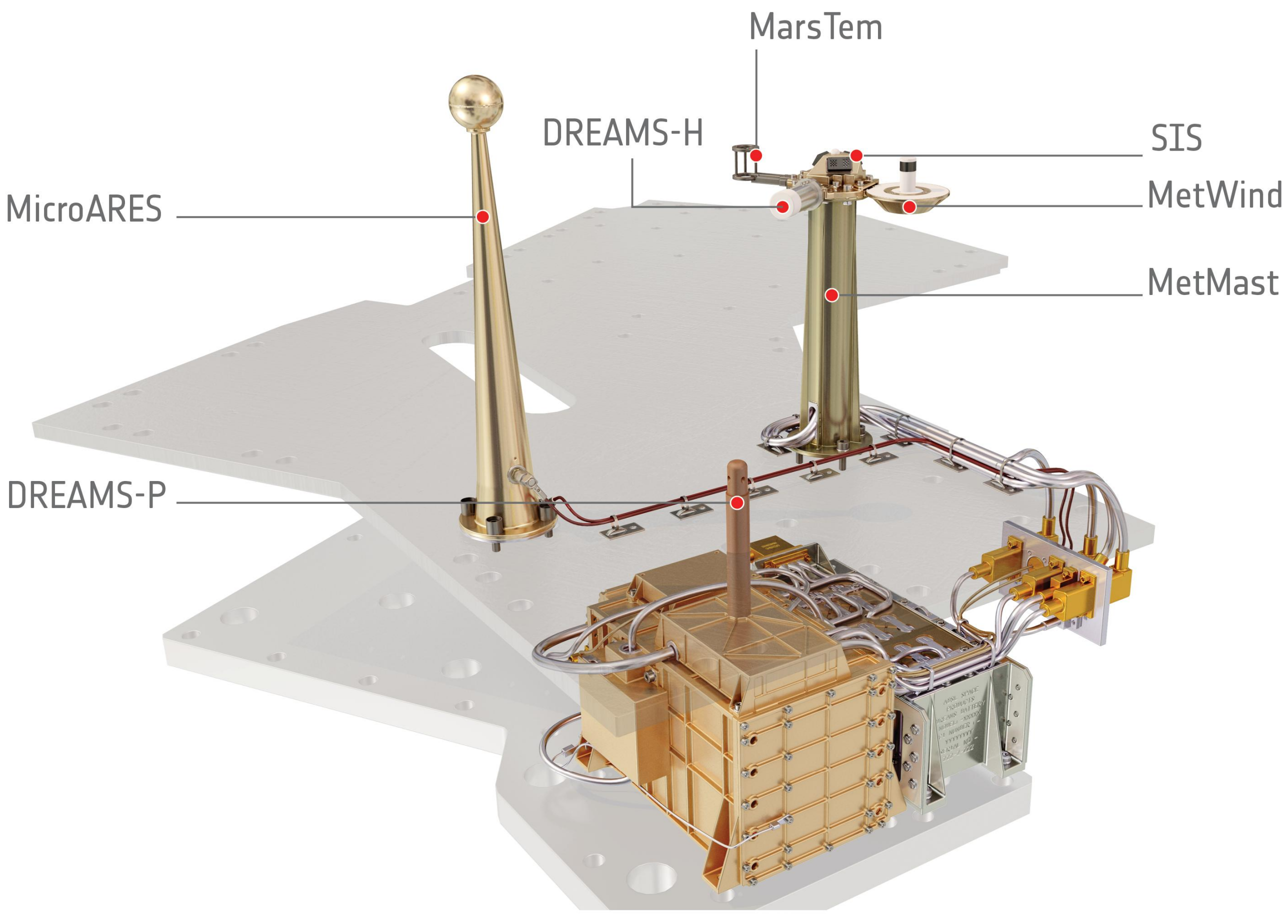

Figure 1. DREAMS science package on Schiaparelli (Credit: ESA/ATG medialab).

The instrument package (Figure 1) includes the following sensors:

- MarsTem (thermometer)
- DREAMS-P (pressure sensor)
- DREAMS-H (humidity sensor)
- MetWind (wind sensor)
- µAres (electric probe)
- SIS (Solar Irradiance Sensor)

DREAMS is developed by several European scientific institutes (PI: F. Esposito; Co-PI: S. Debei):

- INAF - Osservatorio Astronomico di Capodimonte - Napoli (I)
- CISAS - Università di Padova – Padova (I)

- CNRS - LATMOS – (FR)
- ESA – Estec (The Netherlands)
- Oxford University – Oxford (UK)
- Finnish Meteorological Institute – Helsinki (FI)
- INTA – Madrid (ES)

ASI (Agenzia Spaziale Italiana) is the leading funding agency.

In preparation to the launch, the scientific team had carried on a field test campaign in the Moroccan desert around Merzouga, finalized to the study of the response of meteorological and electric field sensors during the period of frequent dust storms in the area [3]. The Moroccan desert was chosen for its similarity to the Martian surface. Acquired data will help to interpret data acquired by DREAMS in a dust loaded scenario.

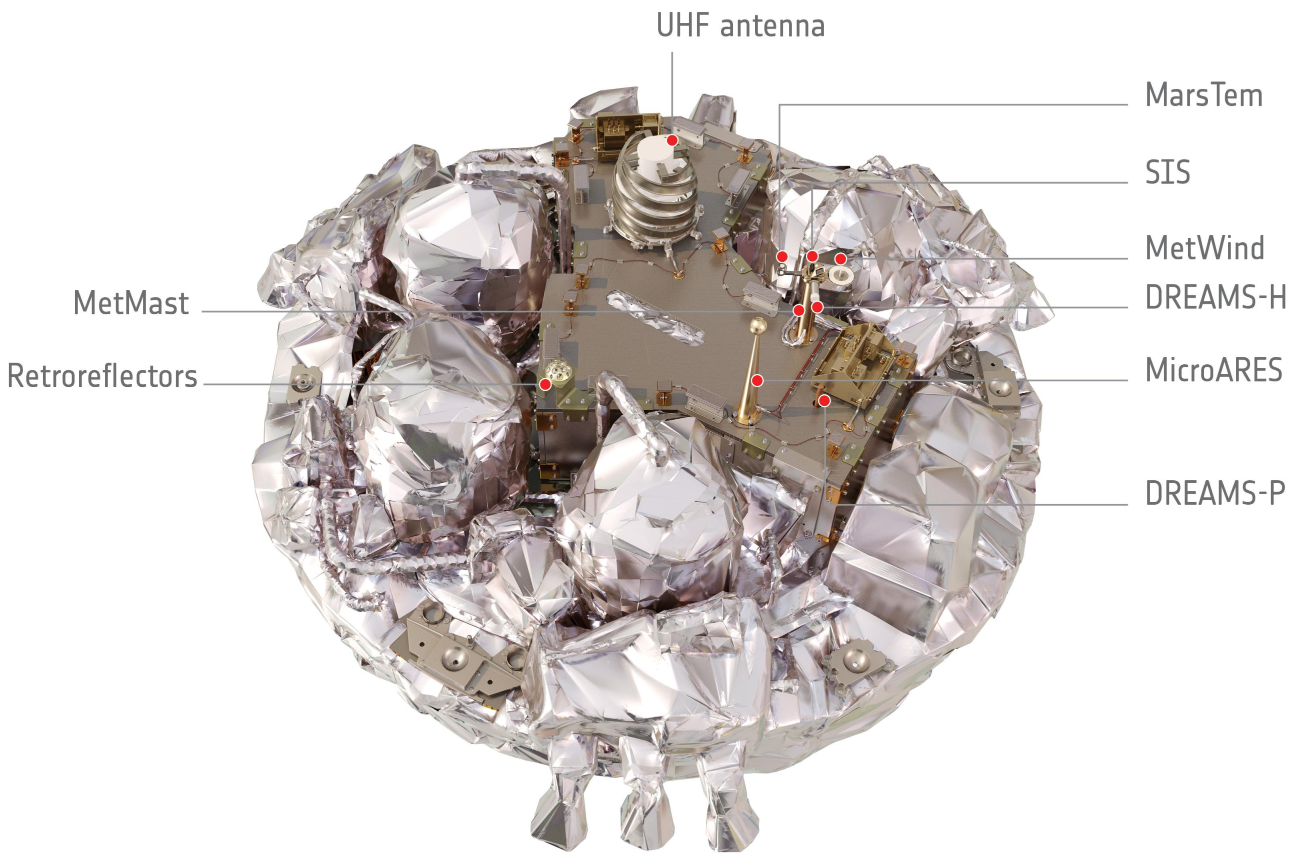

Figure 2. The DREAMS sensors accomodated on the Schiaparelli entry, descent and landing demonstrator module (artist's impression). Other devices are a compact array of laser retroreflectors, attached to the zenith-facing surface of Schiaparelli (that can be used as a target for Mars orbiters to laser-locate the module) and a UHF antenna, used for communicating with the Trace Gas Orbiter. (Credit: ESA/ATG medialab)

3. DATA COLLECTION

With reference to the mission phase definitions, the DREAMS experiment operations and checkout sessions are foreseen during the following phases:

- Near Earth Commissioning Phase (NECP)
- Interplanetary Cruise Phase (ICP)
- Primary Science Phase (PSP)

During NECP and ICP, the functionality of DREAMS is tested through checkout sessions and Mission TimeLine (MTL) dumps. At the time of writing, the checkout session of the Near Earth Commissioning Phase has been successfully completed and the next checkouts of the Interplanetary Cruise Phase are forthcoming.
DREAMS will then perform real scientific measurements after landing on Mars, i.e. the instrument will start the science phase promptly after the touchdown. After its activation on the Martian surface, DREAMS will operate according to its own pre-planned timelines. An example of DREAMS operations timeline is shown in Figure 4.
The acquisition of data is organized in measurement slots, defined in the timeline. Any measurement slot includes a set of measurements with predefined start time and duration. Within each slot, any individual sensor produces samples at a predefined frequency.

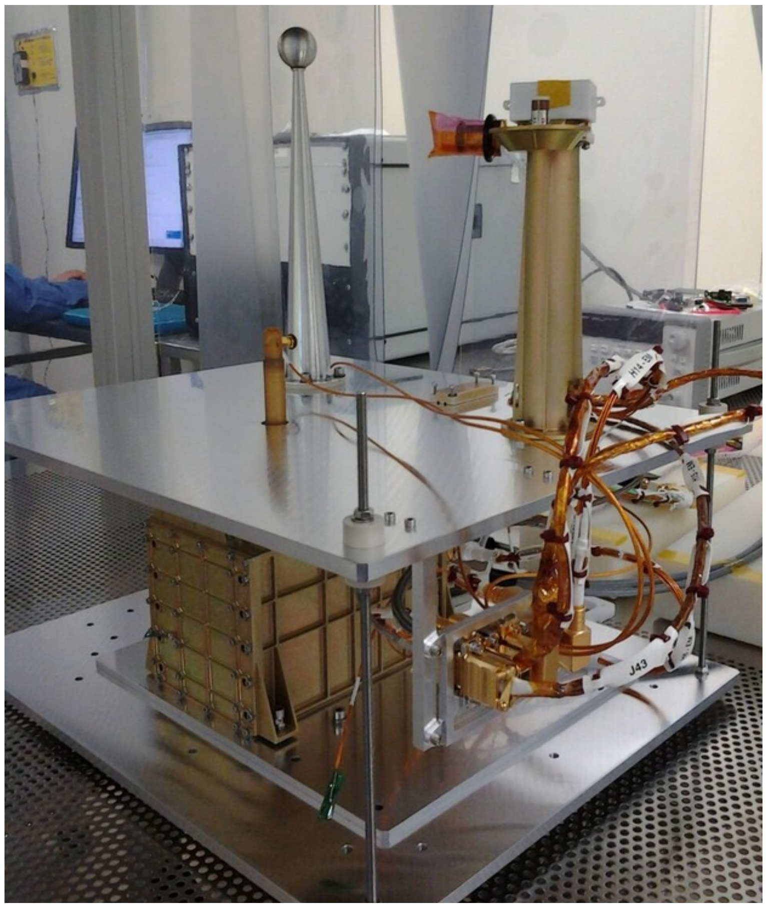

Figure 3. DREAMS flight model along with its mechanical ground segment equipment, prior to integration with the ExoMars Schiaparelli module (Credit: ASI & DREAMS Team).

The overall data acquired by DREAMS come from its suite of separate sensors, each measuring different meteorological and physical parameters:

- wind speed and direction (MetWind)
- humidity (DREAMS-H)
- pressure (DREAMS-P)
- atmospheric temperature (MarsTem)
- transparency of the atmosphere (Solar Irradiance Sensor, SIS)
- atmospheric electrification (Atmospheric Radiation and Electricity Sensor, µAres).

The scientific results will come from data obtained from individual sensors as well as from the combination of different sensor measurements. The scientific data are organized in the archive in different files containing text tables, divided by sensor and by measurement slot.

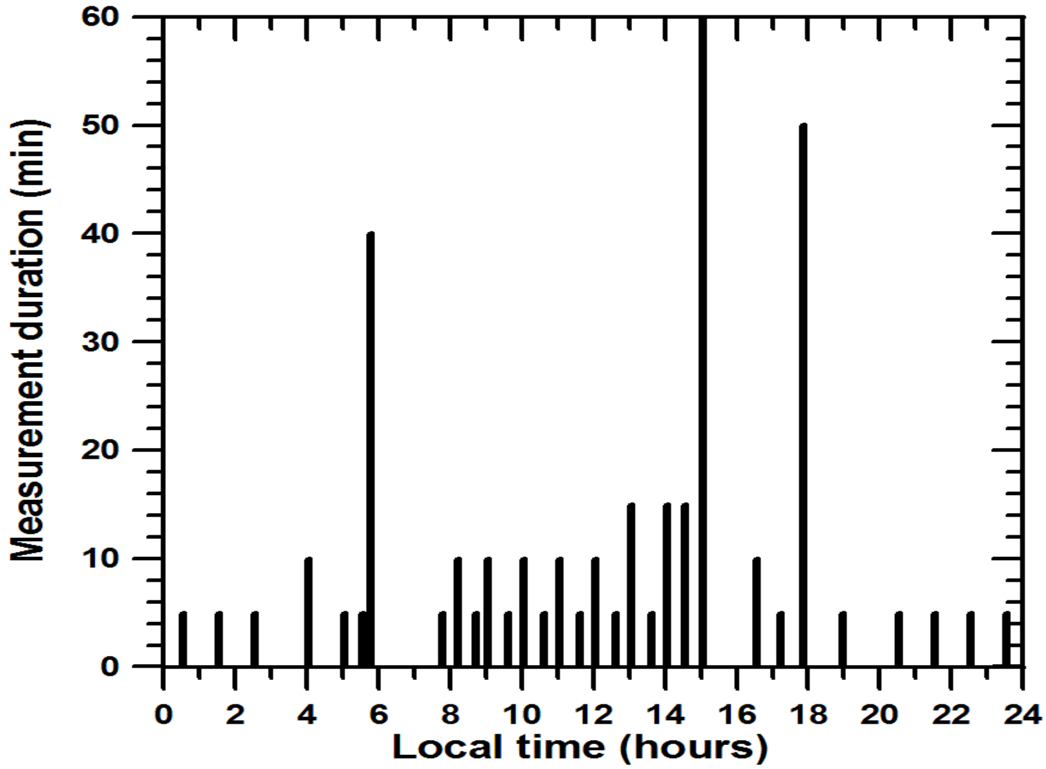

Figure 4. Example of a DREAMS timeline (overall duration: 1 sol). The vertical bars represent the measurement slots with their duration on the ordinates. During a slot, all scientific sensors are in measurement mode.

4. ARCHIVING STANDARDS

The DREAMS data are to be archived into the European Space Agency's Planetary Science Archive (PSA), the central repository for all scientific and engineering data returned by ESA's Solar System missions. The ExoMars mission and consequently the DREAMS archive adopts the NASA's Planetary Data System (PDS) standards as a baseline for the formatting and structure of all data.

The PDS standard provides guidelines on how the DREAMS team should construct a data set suitable for long-term archiving. This standard contains requirements in terms of data set structure and documentation that should allow for any DREAMS data to be used and understood for many years after the end of the mission.

In PDS, each data product is associated to a label containing full details on the structure and content of the product. The users receive many useful information through the labels provided with each product, that contain the meta-data needed for a tool to access and interpret the product.

The ExoMars mission and DREAMS adopt the PDS version 4 standards, acknowledged as PDS4. PDS4 has a modernized approach to archiving data within the PDS; labels are expressed as XML documents that are tied to a centralized, self-consistent model providing uniformity across the PDS.

In order to ensure compliance with the PDS standards and with all of the requirements for ingestion and release in the PSA, several tools are available from ESA and NASA for the data set validation.

5. DATA FLOW OVERVIEW

The data processing pipelines, validation and delivery of the products for the ingestion into the Planetary Science Archive follow the ESA guidelines.

Acquisition of Telemetry Data

Immediately after the data becomes available in the Egos Data Disposition System (EDDS), telemetry packets, housekeeping parameters and any additional information relevant for data processing and analysis are retrieved.

Partially Processed, Calibrated and Derived Data Generation

The instrument team is responsible for generating partially processed, calibrated and derived data products based on the best current calibration factors and analysis routines. The data bundles will be stored in a local data repository as well as sent to ESAC for validation and ingestion to the ESA Planetary Science Archive (PSA).

Figure 5 describes the conversion process from telemetry to data bundles in PDS4 format ready for upload to ESA.

Using the information stored within the telemetry packet headers, a first step of processing is to distinguish the type of the received packet (scientific or housekeeping).

In case of scientific packets, the next operation in the pipeline is to parse and extract from the packet payload the sample of the different sensors and to convert them to PDS4 format at the different data processing level (partially processed, calibrated, derived). Only in the specific case of µAres sensor, there is an intermediate step to uncompress the data.

In case of housekeeping packets, the operations are similar but simplified.

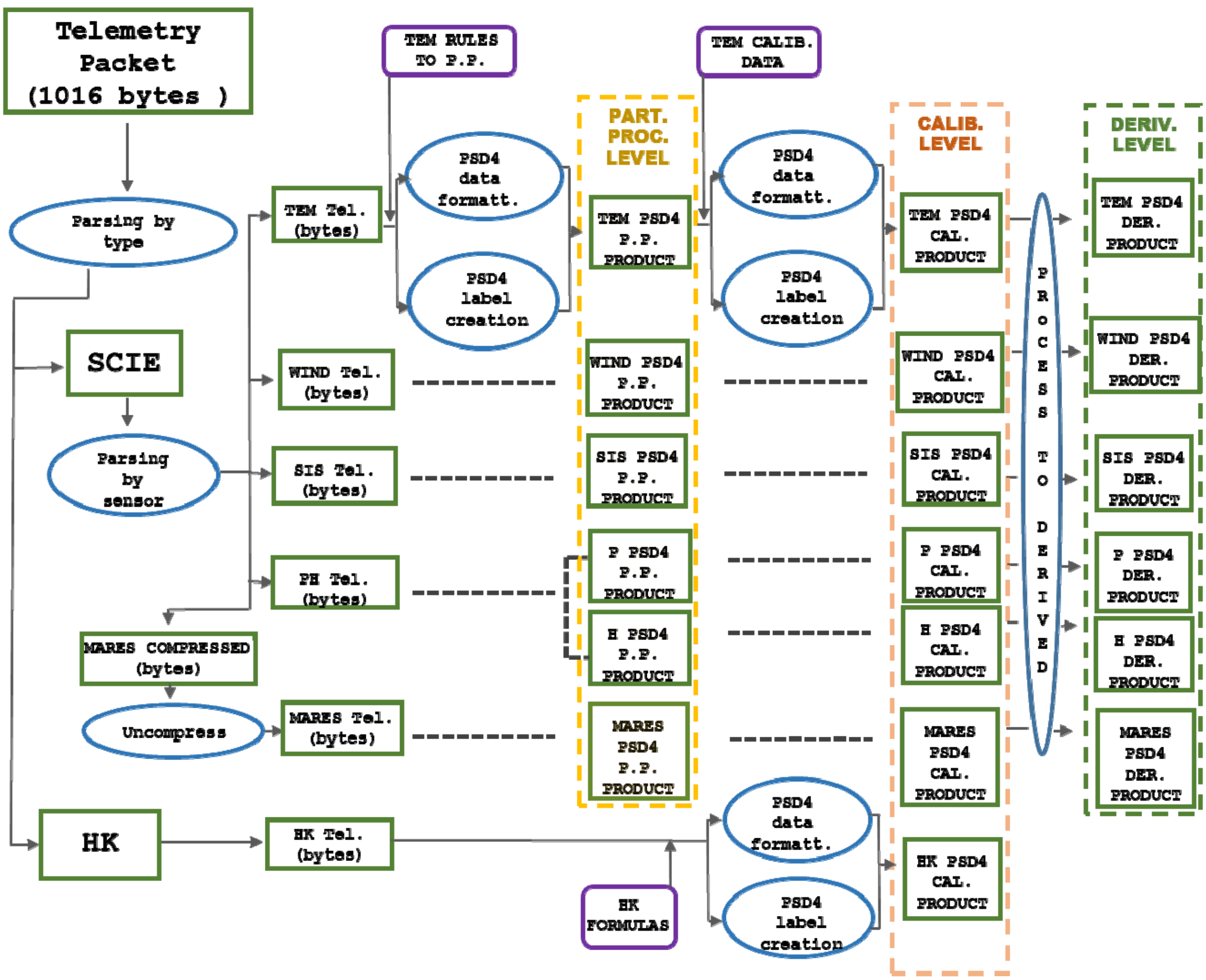

Figure 5. DREAMS Pipeline Block Diagram

6. DATA GENERATION

The data transfer between DREAMS and the spacecraft is implemented using the CANOpen protocol. Within the CANOpen framework, data are transferred in the form of Service Data Objects (SDOs) or Process Data Objects (PDOs).

The PDOs are 8 byte data packets; they are adopted in DREAMS, e.g. to transmit housekeeping information to the S/C. The SDOs are buffers of 1016 bytes, consisting of a 16 byte "header" field and a 1000 byte "payload" field. The SDOs can contain scientific or housekeeping data (or dump of timelines, which are not relevant for the archiving).

6.1 Raw Data Generation

The generation of raw level products from telemetries implies a basic knowledge of the telemetry buffer structure. The structure of telemetries coming from DREAMS are used to develop the conversion software, which is implemented by ESAC.

6.2 Partially-Processed Data Generation

The generation of next level products implies a detailed decoding of the telemetry buffers. The DREAMS partially processed data are values converted from ADC units to engineering units (e.g. Volts). They are at an intermediate level, one step before the conversion to calibrated values. Algorithms provided by the sensor teams are used for these conversions. From partially processed data level on, the data tables have a time field computed from raw data, sensor configuration files and timelines.

6.3 Calibrated Data Generation

The calibrated data are obtained by converting engineering units (e.g. Volts) to physical units (e.g. m/s). Calibration data and algorithms are provided by the sensor teams.

7. DATA ORGANISATION

The data format and conventions follow the PDS4 rules and the ExoMars definitions and conventions. One bundle is foreseen, including all the mission phases, possibly with several versions. The bundle will contain several collections of the types described below.

- A calibration collection that contains data and files necessary for the calibration of basic products.
- A context collection, i.e. the list of products comprising various objects, identified within the PDS4 registry, that are specific to the science bundle. These include physical objects such as instruments, spacecraft, and planets and conceptual objects such as missions and PDS nodes.
- Several data collections that contain observational products, generated according to processing level, target, instrument mode, etc.; these are the science data that most users seek. The DREAMS bundle will consist of several data collections, one for each processing level (raw, partially processed, etc.). Within each data level, a further division is by mission phase. Within each mission phase, a further division is by instrument subunit, i.e. by sensor in the case of DREAMS.
- A document collection that includes at least the Experiment to Archive Interface Control Document and likely calibration reports, etc.
- An XML schema collection containing all XML schema files included in or referenced by XML labels in the bundle along with any Schematron files created for validation purposes.

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