CASSIS FLIGHT OPERATIONS USER MANUAL

Doc.No: EXM-CA-UMA-UBE-10001

Issue: 0

Revision: 4

Date: 11. May. 2015

Instrument name:	Colour and Stereo Surface Imaging System (CaSSIS)
Origin Name:	Physikalisches Institut, Universität Bern
WBS code:	N/A
Package code:	N/A
Restrictions:	N/A

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DOCUMENT CHANGE RECORD

Issue	Revision	Date	Pages, Tables, Figures affected	Modification	Initials
0	1	31 Jan 2015	All	First Issue	NT
0	2	16 Mar 2015	Sec 3.3	New Section: Take Test Image Command	RZ
			Sec 3.4	Section 3.4 (Set parameter value) added source table reference	RZ
0	3	14 April 2015	Sec 2.0	TC definition description updated due to conclusions from telecon 20.03.2015 with M. Sweeny and Rudy Ciarletta	RZ
			Sec 3.0	Updated command description table with all TCs updated and clarified (conclusions from telecon 20.03.2015 with M. Sweeny and Rudy Ciarletta)	RZ
			Sec 3.1	Now: Move motor to realtive position command	RZ
			Sec 3.2	Now: Move motor to absolute position command	RZ
			Sec 3.3	Updated due to conclusions from telecon 20.03.2015 with M. Sweeny and Rudy Ciarletta	RZ
			Sec 3.5	Updated due to conclusions from telecon 20.03.2015 with M. Sweeny and Rudy Ciarletta	RZ
			Sec 3.6	New section: create parameter table	RZ
			Sec 3.8	Formerly: get parameter table values → DELETED	RZ
			Sec 3.9	Update flight software → updated	RZ
			Sec 3.91 – 3.9.3	New subsections describing FSW update options	RZ
			Sec 3.10	Set temperatures → updated	RZ
			Sec 3.15	New section: modify configuration parameter	RZ
			Sec 4.0	Updated due to conclusions from telecon 20.03.2015 with M. Sweeny and Rudy Ciarletta	RZ
			Sec 4.1	Updated due to conclusions from telecon 20.03.2015 with M. Sweeny and Rudy Ciarletta	RZ
			Sec 4.2	New section: HK frame types	RZ
			Sec 4.2.1 – 4.2.7	New sections, describing HK frame types and content	RZ
			Sec 5	New section: CRC generation	RZ
			Sec 6	New section: CaSSIS time code	RZ
0	4	11 May 2015	Sec 2	Added TLV explanation	RZ
			Sec 3	Added TC table description Changes in table	RZ
			Sec 3.1	Removed description of absolute position	RZ

Issue	Revision	Date	Pages, Tables, Figures affected	Modification	Initials
			3.5	Renamed to “Set imaging parameter value”	RZ
			3.6	Renamed to “Create imaging parameter value”	RZ
			3.7	Renamed to “Set imaging parameter table”	RZ
			3.14	Renamed to “Enter operation mode” Added description	RZ
			4	Updated description	RZ
			4.2	Minor changes to HK frame tables	RZ
			4.3	Minor changes to table	RZ

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List of documents

Applicable documents		
AD 01	EXM-PL-IRD-ESA-00003 Issue 2 Rev 0 TGO E-IRD (JCCB - Signed)	Experiment Interface Requirements Document

Normative References		
NR1	EXM-CA-RSD-UBE-00003	Top Level System Requirement Document Iss 1, Rev 0
NR2	EXM-CA-RSD-UBE-10000	Science Requirements Document Iss 1, Rev 1
NR3	EXM-CA-TNO-UBE-10001	CaSSIS Functional Design Description-Document Iss 0, Rev 3
NR4	EXM-CA-DRW-UBE-20001	CaSSIS MICDs Iss 0, Rev 1
NR5	EXM-CA-ICD-UBE-20000	Telescope MICD Iss 0, Rev 1
NR6	EXM-CA-TNO-UBE-00001	CaSSIS Interface Data Sheet Iss 1, Rev 8
NR10	EXM-CA-ANA-UBE-00002	CaSSIS FDIR Analysis Iss 0, Rev 3
NR11	EXM-CA-PLN-UBE-00020	CaSSIS Cleanliness and Contamination Control Plan Iss 0, Rev 3
NR12	EXM-CA-ANA-UBE-00008	CaSSIS Pointing Analysis Iss 1, Rev 0

Informative References		
IR01	EXM-CA-LIS-UBE-00001	List of Acronyms Iss 1 Rev 0
IR02	EXM-CA-PLN-UBE-00024	CaSSIS Experiment Operations Plan Iss 0, Rev 4

Scope of the Document

CaSSIS is a four colour stereo camera located on the Exomars 2016 Trace Gas Orbiter Spacecraft.
The flight operations of the CaSSIS instrument is described in this document.

1 EXPERIMENT GENERAL DESCRIPTION

1.1 Mission and Instrument Overview

The ESA ExoMars program consist of two stages: an orbiter (called Trace Gas Orbiter, TGO) to be launched in 2016 and a rover to be launched in 2018. The program will demonstrate key flight and in situ enabling technologies by searching for signs of past and present life on Mars, investigate the water/geochemical environment and atmospheric trace gases and their sources. The TGO will carry a camera called CaSSIS (Colour and Stereo Surface Imaging System) developed by the University of Bern, which will take high resolution stereo images in 4 colours of the Martian surface. Figure 1 illustrated the imaging concept. This imager will characterize sites which have been identified as potential sources of trace gases and investigate dynamic surface processes and thus certify potential future landing sites. CaSSIS will observe a 8 km wide swath thereby providing the best colour imaging acquired from Mars, so far.

CaSSIS is made out of two major units: Camera Rotation Unit (CRU) and Electronics Unit (ELU). The CRU comprises of the telescope (incl. focal plane and associated electronics), the rotation system, cable management system and some structure to support all of the above and mount the CRU to the spacecraft. The ELU contains the boards with the electronics required to operate the camera (see Figure 2).

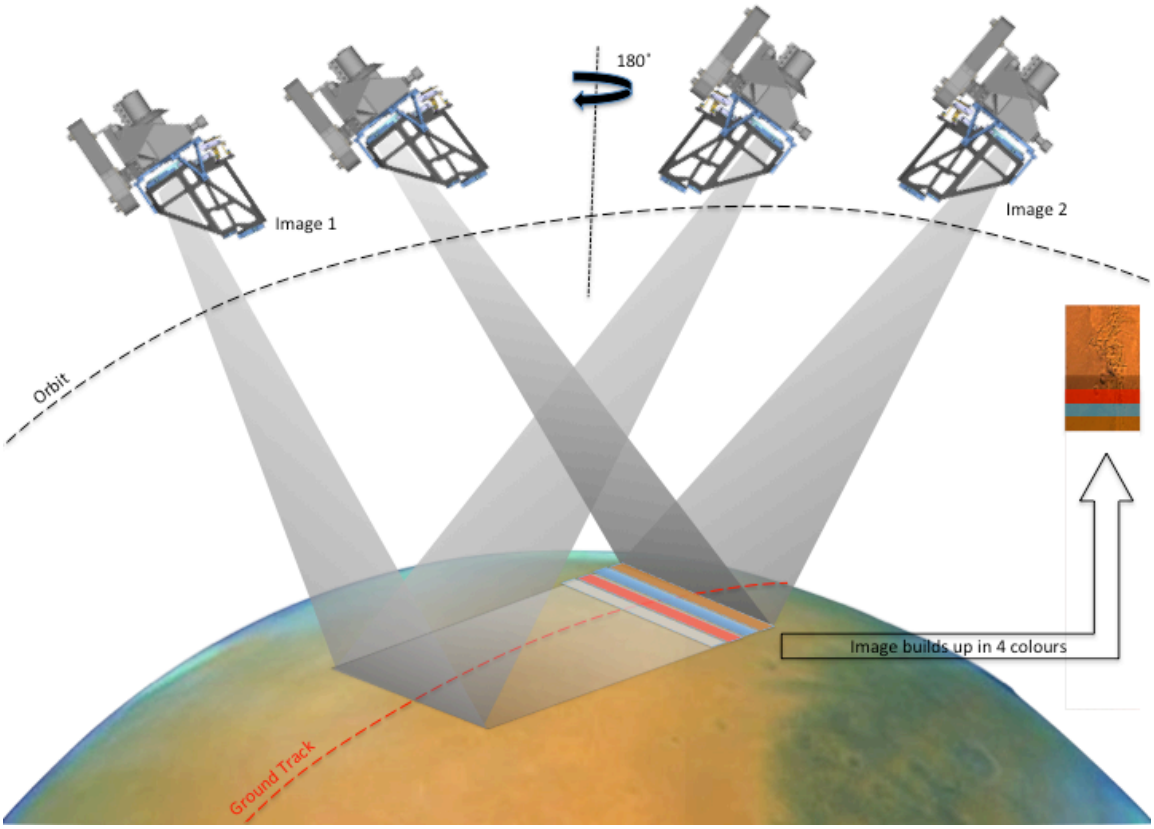

Figure 1: CaSSIS Stereo Image Acquisition

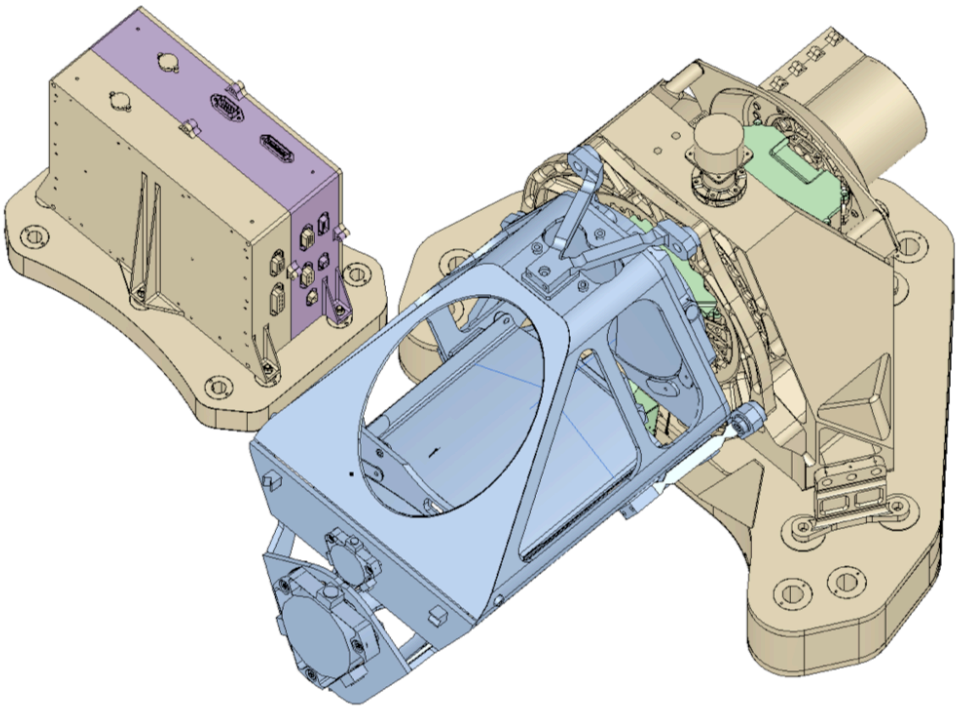

Figure 2: CaSSIS Instrumen view from top (right: CRU, left: ELU)

1.2 Scientific Objectives

The scientific objectives are summarized in the CaSSIS Science Requirements [NR1] Document and the System Requirements Document [NR2].This document is the formal starting point from which other CaSSIS requirements have been derived and layed down, i.e., the telescope requirements or software requirements. The top level science requirements are repeated below.

Image and analyze surface features possibly related to trace gas sources and sinks in order to better understand the broad range of processes that might be related to trace gases.
The science team will compile and prioritize a list of observation targets needed to test specific hypotheses concerning active surface processes on Mars. We will begin to address this objective early in the mission, prior to new trace-gas discoveries from EMTGO. Un-usual or changing colors indicate active processes, perhaps linked to methane formation or release.

Map regions of trace gas origination as determined by other experiments to test hypotheses.
EMTGO experiments are designed to dis-cover trace gases and study atmospheric dynamics to trace the gases back to their source regions (perhaps to tens of km). Once these discoveries are made (if that goal is realized), CaSSIS will place top priority on imaging these regions to formulate and test specific hypo-theses for the origin and/or release of trace gases.

Search for and help certify the safety of new candidate landing sites driven by *EMTGO* discoveries.
The discovery of methane has helped stimulate exploration plans in Europe and the U.S. A portion of NE Syrtis Major has recently been approved for priority *MRO* coverage as a candidate landing site for the Mars Science Laboratory; this site is at the margin of the Syrtis Major methane plume identified by Mumma et al. (2009). It is likely that the pair of NASA/ESA landers in 2019 will also con- sider methane areas for landing sites. At the workshop 'Habitability and Landing Sites' held in the UK (Cockell et al., 2009) the surfaces associated with methane plumes were identified as high priority exploration targets. However, the best locations will presumably be found by *EMTGO,* and *MRO/HiRISE* may or may not be able to certify new landing sites post 2017. CaSSIS cannot identify meter-scale hazards, but it can provide the 5 m scale slope information needed to complete certification of thousands of locations imaged by HiRISE, but not in stereo.

2 TC DEFINITION

All MIL TC frame contains CaSSIS_FSW command container and a 2 byte CRC. A CaSSIS_FSW command container contains CaSSIS_FSW commands in TLV structure. TLV is a triple containing 1 byte tag 1 byte length and as many byte data as the value of the length byte.
For every TC frame the command id of the frame (*cid* – 1 byte value at offset 2) defines the number of parameters along with its offset (byte position of the beginning of the parameter from the beginning of the TC) and length.

TC structure

0	**1**	**2 … (1 + len)**	**2 + len**	**3 + len**
0xf0	len	command	CRC-h	CRC-l

Command structure

cid offset			**prm1 value offset**		**prm2 value offset**	
2	3	4..5	6			
cid	clen	prm1 prefix	prm1 value	prm2 prefix	prm2 value	…

- All CaSSIS_FSW command is actually a TLV structure – but with pre-fixed position and length.
  - T: 1*Byte Tag – the id of the command
  - L: 1*Byte Length – the length of the V field in Bytes
  - V: L*Byte Value – the value field of the command
- Each Value field of a command contains TLV structures describing the parameters of the command. The wrapper around each parameter is only used by the on-board TC parser state machine.
  - T: 1*Byte Tag – the id of the command parameter
  - L: 1*Byte Length – the length of the parameter value filed
  - V: L*Byte Value – the value field of the parameter (the content of the parameter V field is determined by the Tag – usually a 1, 2 or 4 Byte length numerical value)
- Every MIL TC frame (64 byte) contains one command. Every command contains a pre defined number of parameters (defined by the command id). The list of parameter values along with its offset – from TC frame beginning – and length are fixed and defined by the command id (see command table for more details).
- 2 byte CRC is presented after the command in each TC.

Every telecommand received on MIL bus by CaSSIS instrument contains exactly 1 command. A command contains a command id (*cid*) and parameters. The structure of the contained parameters are defined by the *cid*. Every parameter contains a 2 byte parameter prefix – which is used internally by the CaSSIS instrument on-board software to parse the command structure – and a varying length parameter value filed. The actual length a parameter value field is depends on the *cid* and the index of the parameter.

2.1 Special considerations with TCs

CaSSIS FSW maintains an internal command table for commands with specific execution time (timestamp parameter is set). The table is able to contain up to 100 TCs maximum. The scheduling of the command transfer from S/C to CaSSIS has to ensure that the CaSSIS FSW does not receive more than 100 delayed TCs.

3 COMMANDS

The commands received from S/C over MIL are placed in a command container TLV structure. The tag of the command container is 0xf0. The 2 byte CRC used to check the MIL TC frame is not part of the command container and should be placed right after the end of the command container in raw format (not wrapped by TLV structure).

The following table contains the possible command ids and the parameter set of each CaSSIS command. The table specifies the following values for each command:

- **Command** – name of the command
- **Parameter** – the name of each parameter (command id is placed as the first parameter for every command)
- **Offset** – the beginning byte position of the parameter (or command id) from the 0. byte of the TC frame
- **Length** – the length of the parameter in bytes
- **Data type** – the type (encoding type) of the parameter. CaSSIS FSW handles the following data types for TC command parameters:
  - **byte** – 1 byte unsigned decimal value.
  - **unsinged decimal** – unsigned decimal value. CaSSIS FSW uses big-endian (MSB at lower byte position) byte order for decimal encoding. The possible length of the decimal values are:
    - 2 bytes
    - 4 bytes
    - 8 bytes
  - **byte array** – n byte octet string

The following table contains the description of the CaSSIS instrument telecommands. Every TC has the following structure:

- 0. byte: 0xf0 – TC frame
- 1. byte: overall length of the TC frame (depends on command id – *cid*)
- 2. byte: command id – cid. The value of this filed determines the followings:
  - Overall length of the TC frame
  - Number and sequence of parameters, the offset of each parameter value
- 6. byte: the first byte of the firs command parameter value
- subsequent bytes are depends on the value of *cid*

The table table columns are the following:

- Command: the name of the command
- Parameter: the name of the command parameter (for every command the first row of the parameter column contains the *cid* value)
- Offset: the offset of the beginning of the parameter value field (or *cid* value) from the beginning of the TC frame. Note that every parameter has a 2 byte prefix which is not part of the parameter value filed

(the prefix is used internally by the flight software for TC parsing)

- Length: the length of the parameter value filed (the 2 byte parameter prefix excluded)
- Data type: the type of contained data. CaSSIS on-board flight software uses unsigned decimal values encoded in big endian (higher bytes at lower positions) format. The decimal values are stored on 1, 2, 4 or 8 bytes. Longer than 8 byte values are stored as octet string (byte array)
- Description: the short description of the command or the parameter

Command	Parameter	Offset	Length	Data type	Description
Move motor to relative position	**0x01**	0x02	0x01	byte	**This command moves the rotation mechanism to the specified position**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Direction	0x0c	0x01	byte	The direction of the movement – 0: clockwise, 1: anti-clockwise. Any other value will result in execution error.
	Relative displacement	0x0f	0x04	unsigned decimal / big endian	The relative displacement (number of steps) of the rotation on 4 byte unsigned integer.
	Timestamp	0x15	0x08	unsinged decimal / big endian	The timestamp of the starting of the movement in mission time – mandatory parameter
	CRC	0x1d	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Move motor to absolute position	**0x02**	0x02	0x01	byte	**This command moves the rotation mechanism to the specified position**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Absolute position	0x0c	0x04	unsigned decimal / big endian	The absolute position of the rotation mechanism. The FSW calculates the displacement by this value and the actual position. Optional value: if value not defined the mechanism moves to zero position
	Timestamp	0x12	0x08	unsigned decimal / big endian	The timestamp of the starting of the movement in mission time – mandatory parameter
	CRC	0x1a	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Take image	**0x03**	0x02	0x01	byte	**Take a new image.**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Timestamp	0x0c	0x08	unsigned	The timestamp of the starting of the take

				decimal / big endian	image command – the accurate time of the first exposure of the image – mandatory
	Parameter table reference	0x16	0x01	byte	The reference to the parameter table to use. Optional parameter, default: 0
	CRC	0x17	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Take test image	**0x04**	0x02	0x01	byte	**Take a test image.**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Timestamp	0x0c	0x08	unsigned decimal / big endian	The timestamp of the starting of the take image command – the accurate time of the first exposure of the image – mandatory
	Test image	0x16	0x01	byte	Take a test image. If parameter has been set in the command and value not 0 than the FSW will prepare a test image.
	CRC	0x17	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Set imaging parameter value	**0x06**	0x02	0x01	byte	**Set a imaging parameter value in the parameter table. If the referenced table does not exists the FSW tries to create it if there are available free memory.**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Table reference	0x0c	0x01	byte	Reference to the parameter table. Optional parameter, default: 0
	Source table reference	0x10	0x01	byte	The reference to a source table. If parameter has been set in the command the FSW will clone the first parameter table and then apply the changes.
	parameter id	0x13	0x01	byte	The id of the parameter to update
	parameter value	0x16	0x08	unsigned decimal / big endian	The new value for the parameter
	CRC	0x1e	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Create imaging parameter table	**0x16**	0x02	0x01	byte	**Create a new imaging parameter table with the specified id. If the referenced table does not exist the FSW tries to create it if there is available free memory. If the referenced table exists the FSW will overwrite its**

					content with values from the source parameter table.
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Table reference	0x0c	0x01	byte	Reference to the parameter table. Optional parameter, default: 0
	Source table reference	0x10	0x01	byte	The reference to a source table. The FSW will read the values from this table. If the table does not exist FSW will use the default table.
	CRC	0x1e	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Set imaging parameter table	**0x07**	0x02	0x01	byte	**Set the value of an imaging parameter table. All the parameter values inside the table are extracted from the 0x74 parameter. If the referenced table does not exist the FSW tries to create it if there is available free memory.**
	Table reference – trg-src	0x06	0x01	byte	The reference to the parameter table to use. Optional parameter, default: 0. The reference to a source table. If parameter has been set in the command the FSW will clone the first parameter table and then apply the changes.
	parameter table	0x09	0x35	byte array	The values for the parameter table are mandatory. The parameter contains the byte aligned values of the parameter table (53 bytes in current status)
	CRC	0x3e	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Reboot FSW	**0xff**	0x02	0x01	byte	**Reboot the FSW in the specific state and mode**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Timestamp	0x0c	0x08	unsigned decimal / big endian	The timestamp of the starting of the command. Optional parameter. Default: reboot immediately
	reset type	0x16	0x01	byte	0: warm reset (motor position, command table, etc.. are kept and no power cycle performed), 1: hard reset (motor is rotated to 0 position, command table dropped, power cycle performed)
	boot target	0x19	0x01	byte	0: default FSW ROM MRAM0 read only, 1: update FSW from MRAM1 rw

	CRC	0x1a	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Initiate FSW update	**0xf0**	0x02	0x01	byte	**Initiate the flight software update process.**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the update process. The following upload FSW image commands and the perform update should contain the same unique id.
	Number of image frames	0x0c	0x02	unsigned decimal / big endian	The number of software image frames.
	Update type	0x10	0x01	byte	The type of the update. • 0: absolute update • 1: differential update based on MRAM0 • 2: differential update based on MRAM1
	Number of image bytes	0x13	0x04	unsigned decimal / big endian	The precise length of the update image in bytes.
	CRC	0x0e	0x02	unsigned decimal / big endian	
Upload FSW image	**0xf1**	0x02	0x01	byte	The unique id of the update process. The following upload FSW image commands and the perform update should contain the same unique id. A previous Initiate FSW update with the same unique id is mandatory!
	Unique id	0x06	0x04	unsigned decimal / big endian	The same unique id as the Initiate FSW update command contains
	Frame count	0x0c	0x02	unsigned decimal / big endian	The sequence number of current frame
	Image data	0x10	0x2e	byte array	The image data part.
	CRC	0x3e	0x02	unsigned decimal / big endian	
Perform FSW Update	**0xf2**	0x02	0x01	byte	**Performs the FSW update.**
	Unique id	0x06	0x04	unsigned decimal / big endian	
	Image hash	0x0c	0x10	byte array	MD5 – 128 bit – hash form uploaded image.
	CRC	0x1c	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**

Set temperatures	**0x09**	0x02	0x01	byte	**Set the temperatures of specific zones**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	zone1 mod enable	0x0c	0x01	byte	Enable the modification of zone 1 temperature. 0: do not modify zone 1 temperature (zone 1 temperature from TC will be omitted). 1: modify zone 1 temperature by setting new value from TC.
	zone1 temperature min/max	0x0f	0x04	unsigned decimal / big endian	The minimal and maximal target temperature in Zone1 (higher 2 bytes minimal lower 2 bytes maximal)
	zone2 mod enable	0x15	0x01		Enable the modification of zone 2 temperature. 0: do not modify zone 2 temperature (zone 2 temperature from TC will be omitted). 1: modify zone 2 temp buy set new value from TC.
	zone2 temperature min/max	0x18	0x04	unsigned decimal / big endian	The minimal and maximal target temperature in Zone2 (higher 2 bytes minimal lower 2 bytes maximal)
	zone3 mod enable	0x1e	0x01		Enable the modification of zone 3 temperature. 0: do not modify zone 3 temperature (zone 3 temperature from TC will be omitted). 1: modify zone 3 temp buy set new value from TC.
	zone3 temperature min/max	0x21	0x04	unsigned decimal / big endian	The minimal and maximal target temperature in Zone3 (higher 2 bytes minimal lower 2 bytes maximal)
	zone4 mod enable	0x27	0x01		Enable the modification of zone 4 temperature. 0: do not modify zone 4 temperature (zone 4 temperature from TC will be omitted). 1: modify zone 4 temp buy set new value from TC.
	zone4 temperature min/max	0x2a	0x04	unsigned decimal / big endian	The minimal and maximal target temperature in Zone4 (higher 2 bytes minimal lower 2 bytes maximal)
	zone5 mod enable	0x30	0x01		Enable the modification of zone 5 temperature. 0: do not modify zone 5 temperature (zone 5 temperature from TC will be omitted). 1: modify zone 5 temp buy set new value from TC.
	zone5 temperature min/max	0x33	0x04	unsigned decimal / big endian	The minimal and maximal target temperature in Zone5 (higher 2 bytes minimal lower 2 bytes maximal)
	CRC	0x39	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Set GPIO state	**0x0a**	0x02	0x01	byte	**Set a specific GPIO state**

	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	GPIO id	0x0c	0x01	byte	the id of the GPIO pin
	GPIO value	0x0f	0x01	byte	the value of the GPIO (0: low, 1: high)
	CRC	0x10	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Dump	**0x0b**	0x02	0x01	byte	**Dumps a specified memory area and sends as TM science data (over SpW)**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	dump type	0x0c	0x01	byte	0: RAM area dump, 1: MRAM area dump, 2: parameter table dump
	Traget reference	0x0f	0x01	byte	in case of 0 type dump: RAM0/RAM1, in case of 1 type dump: MRAM0/MRAM1, in case of 2 type dump: reference of parameter table
	offset	0x12	0x04	unsigned decimal / big endian	offset of start in Bytes
	length	0x18	0x04	unsigned decimal / big endian	length of dump in Bytes
	CRC	0x2c	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Set TM rate	**0x0c**	0x02	0x01	byte	**Set the TM rate**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	TM rate	0x0c	0x01	byte	0: slow TM (0.1sample/s), 1: normal (1sample/s), 2: debug (10sample/s)
	CRC	0x0d	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Enter operation mode	**0xa3**	0x02	0x01	byte	**Forces the running FSW into safe mode**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	Mode	0x0c	0x04	unsigned decimal / big endian	A well known pattern for the corresponding mode to enter. • 0x5a00a500 – for normal mode • 0x0fa55a00 – for safe mode

	CRC	0x10	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Update HK parameter	**0x0e**	0x02	0x01	byte	**Update the value of a writeable HK parameter**
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	parameter id	0x0c	0x01	byte	
	Parameter value	0x0f	0x08	unsigned decimal / big endian	
	CRC	0x17	0x02	unsigned decimal / big endian	
Command	**Parameter**	**Offset**	**Length**	**Data type**	**Description**
Modify configuration Parameter	0xe5	0x02	0x01	byte	**Modify FSW configuration parameters** (configuration parameters are stored in non-volatile writeable memory)
	Unique id	0x06	0x04	unsigned decimal / big endian	The unique id of the command – optional field but recommended in order to provide accurate command execution report in HK
	parameter id	0x0c	0x02	unsigned decimal / big endian	The id of the configuration parameter. In case when the update configuration parameter process requires multiple frames for the same parameter the lower byte of the id field contains the frame sequence counter.
	Parameter value	0x10	0x2e	byte array	Octet stream containing the value for the specific parameter
	CRC	0x3e	0x02	unsigned decimal / big endian	

3.1 Move motor to relative position command

The move motor to position command instructs the CaSSIS experiment to rotate the telescope into a specific position. The position may be given either in absolute format or in relative to the current position. The command contains a timestamp with the exact time of the movement initiating. The specified timestamp is considered as the starting of the movement.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.

- Timestamp – the exact time to start the telescope rotation.
- Relative position – specify the number of steps to move the telescope.
- Direction – the direction of the movement. 0: clockwise, 1: anti-clockwise. Any other value of the direction parameter will result in execution error.
- Relative displacement – specify the relative displacement of the telescope after the movement.

3.2 Move motor to absolute position

The move motor to position command instructs the CaSSIS experiment to rotate the telescope into a specific position. The position may be given either in absolute format or in relative to the current position. The command contains a timestamp with the exact time of the movement initiating. The specified timestamp is considered as the starting of the movement.

Parameters:

- Unique id – used by the CaSSIS instrument for report generation.
- Timestamp – the exact time to start the telescope rotation.
- Absolute position – specify the absolute position of the telescope after the movement.

3.3 Take image command

The take image command makes the CaSSIS instrument to create an image of the surface at the specific time. The image contains as many exposures as specified by the command. The image is sent to the spacecraft in compressed format as science data over spacewire connection.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.
- Timestamp – the exact time to start the imaging procedure (the taking of the first exposure)
- Parameter table reference – contains the id of the parameter table to be used for the take image sequence.
-

3.4 Take Test Image Command

The take test image command makes the CaSSIS instrument to create a test image at the specific time.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.
- Timestamp – the exact time to start the imaging procedure (the taking of the first exposure)
- Test image – type of the test image. (In case more than one test image is foreseen...)

3.5 Set imaging parameter value

The set imaging parameter value command will update the value of a specific parameter in the referenced parameter table.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.
- Table reference – the id of the table in which the parameter value should be updated.
    - If the referenced table does not exists the CaSSIS FSW tries to create it (in case of sufficient amount of memory is available). The new parameter table is filled up with values of the referenced source table. The parameters specified in the command will override the default value or the referenced values in the new table.
- Source table reference – if target table (referenced by *Table reference* parameter) does not exist then target table is created and filled up with parameters from the source table (if referenced source table does not exist then the default table will be used). If the target table exists this value is omitted.
- Parameter id – The id of the parameter to update.
- Parameter value – the value of the parameter

The following table contains the parameters of a parameter table:

Parameter id	name	description
0x00	T_exp	integration time of the detector in us (0.001ms)
0x01	Num_exp	the number of exposures in the image
0x02	Step_exp	time between each exposure in us (0.001ms)
0x03	RIOC_Freq	the RIOC clock frequency id (0: 1.25MHz, 1: 2.5MHz, 2: 5MHz)
0x04	Num_win	The number of windows used
0x05	Bin_win1	The binning factor for window 1
0x06	Bin_win2	The binning factor for window 2
0x07	Bin_win3	The binning factor for window 3
0x08	Bin_win4	The binning factor for window 4
0x09	Bin_win5	The binning factor for window 5
0x0a	Bin_win6	The binning factor for window 6
0x0b	Win1_str	Start of the window 1 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x0c	Win1_end	End of the window 1 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x0d	Win2_str	Start of the window 2 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x0e	Win2_end	End of the window 2 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x0f	Win3_str	Start of the window 3 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x10	Win3_end	End of the window 3 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x11	Win4_str	Start of the window 4 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x12	Win4_end	End of the window 4 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x13	Win5_str	Start of the window 5 (4 byte value: upper 2 byte for column lower 2 byte for row)

0x14	Win5_end	End of the window 5 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x15	Win6_str	Start of the window 6 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x16	Win6_end	End of the window 6 (4 byte value: upper 2 byte for column lower 2 byte for row)
0x17	PE_test	PE test mode enable (0: disable, 1: enable)
0x18	Win1_CompR	Compression ratio for Window 1
0x19	Win2_CompR	Compression ratio for Window 2
0x1a	Win3_CompR	Compression ratio for Window 3
0x1b	Win4_CompR	Compression ratio for Window 4
0x1c	Win5_CompR	Compression ratio for Window 5
0x1d	Win6_CompR	Compression ratio for Window 6
0x1e	TEC_start	TEC start status

3.6 Create imaging parameter table

Creates a new imaging parameter table or overwrites an existing one. The new table will contain the values from the referenced table or the default in case if the referenced one does not exist.

Parameters:

- Unique id – used by the CaSSIS instrument for report generation.
- Table reference – the id of the table to create. In case the table already exists the FSW will overwrite its entire content from the source table. If there is not sufficient memory available for the new parameter table the command execution will terminate with error.
- Source table reference – if target table (referenced by Table reference parameter) does not exist target table is created and filled up with parameters from the source table (if referenced source table does not exist then the default table will be used). If the target table exists this value is omitted.

3.7 Set imaging parameter table

The set imaging parameter table either updates an entire parameter table or creates it in case if it does not exist. Set parameter table command is a convenient way to send an entire parameter table in one command.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.
- Table reference – FSW updates the parameters in the referenced table. If the referenced table does not exist the CaSSIS FSW tries to create it (in case of sufficient amount of memory is available).
- Packed parameters – required.
- Source table reference – the target table is filled up with parameters from the source table (if referenced source table does not exist than the default table will be used).
    - NOTE: if this parameter is defined and the parameter table referenced by Table reference parameter already exists the command will override the whole table with values from source.

The following table contains the packed parameter table structure:

offset	parameters	name	description	Length (byte)
0x00	0x00	T_exp	integration time of the detector in us (0.001ms)	0x02
0x02	0x01	Num_exp	the number of exposures in the image	0x01
0x03	0x02	Step_exp	time between each exposure in us (0.001ms)	0x04
0x07	0x03	RIOC_Freq	the RIOC clock frequency id (0: 1.25MHz, 1: 2.5MHz, 2: 5MHz)	0x01
0x08	0x04	Num_win	The number of windows used	0x01
0x09	0x05, 0x06, 0x07, 0x08, 0x09, 0x0a	Bin	The binning factor for windows. Every window has 4 bit (bit alignment: 111122223333444455556666)	0x03
0x0c	0x0b, 0x0c	Win_1	Start and end coordinates for Window 1 (bit alignment: 11111111111x22222222222x33333333333x44444444444x)	0x06
0x12	0x0d, 0x0e	Win_2	Start and end coordinates for Window 2 (bit alignment: 11111111111x22222222222x33333333333x44444444444x)	0x06
0x18	0x0f, 0x10	Win_3	Start and end coordinates for Window 3 (bit alignment: 11111111111x22222222222x33333333333x44444444444x)	0x06
0x1e	0x11, 0x12	Win_4	Start and end coordinates for Window 4 (bit alignment: 11111111111x22222222222x33333333333x44444444444x)	0x06
0x24	0x13, 0x14	Win_5	Start and end coordinates for Window 5 (bit alignment: 11111111111x22222222222x33333333333x44444444444x)	0x06
0x2a	0x15, 0x16	Win_6	Start and end coordinates for Window 6 (bit alignment: 11111111111x22222222222x33333333333x44444444444x)	0x06
0x30	0x17	PE_test	PE test mode enable (0: disable, 1: enable)	0x01
0x31	0x18, 0x19, 0x1a, 0x1b, 0x1c, 0x1d	CompR	Compression ratio for Windows (bit alignment 111122223333444455556666)	0x03
0x34	0x1e	TEC_start	TEC start status	0x01

3.8 Reboot system

The reboot system command forces the CaSSIS flight software to reboot. The reboot type and the target mode can be specified.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.
- Timestamp – the exact time to start the reboot process.
- Reset type – The reset type specifies the reboot process:
  - 0: warm reset. The command table, motor position, etc. are kept and no power cycle performed.
  - 1: hard reset. Motor is rotated to zero position, command table dropped and memory is cleaned up entirely. Reset power cycle is performed.
- Boot target – required parameter. Specifies which FSW image should be booted:

- 0: Default FSW from MRAM0
- 1: update FSW from MRAM1

3.9 Update flight software

The flight software update process provides the opportunity to upload newer software versions during the mission. The upload process contains 3 different commands:

- Initiate update command initiates the update process by commanding the running FSW into update state and setting up the FSW image upload task.
- Upload FSW image command is used to upload a part of the new software image into the instrument.
- Perform update command forces the on-board running FSW to check the previously uploaded image consistency and perform the update task.

The above 3 commands are used to upload a new FSW image and replace the old one in on-board non-volatile memory. The full update sequence should contain an explicit FSW reboot to start the previously updated software version. The full update process should contain the following steps:

- Enter safe mode command – forces the running FSW to enter safe mode and become ready for update.
- Update flight software – initiate update, send FSW image data and perform update.
- Reboot system – forces the running FSW to reboot (reboots the updated flight software version.)

3.9.1 Initiate FSW update

Initiate FSW update command is processed by the FSW only in safe mode. This command tells the running FSW to enter in FSW update state. The initiate update command contains the number of subsequent upload FSW image TCs and a unique id. The running software prepare the reception of the defined number of upload FSW image command and a perform update command both with the same unique id as the initiate FSW update command. Any violation of this sequence will result in the rollback of the update process.

Parameters

- Unique id – used by the CaSSIS instrument for report generation and to merge the subsequent update related commands.
- Number of image frames – tells the running software the number of FSW image upload TC frames following the initiate FSW update command.
- Update type – the type of the update process. The CaSSIS FSW supports the following update processes:
  - Absolute update: an entire image is uploaded. Upon update the received image should overwrite the stored image in MRAM1.

- Differential update: a differential image is received. Upon update the running FSW should create the update image by the source image and the received differential commands.

3.9.2 Upload FSW image

Update flight software can be used to upload and install a new version of the FSW. As an FSW image is far bigger than a MIL TC frame an FSW update command is received in more TC frames. To support the multi frame reception the update flight software command contains parameters describing the total number of frames and the current frame index. Upon FSW update the running FSW receives the update TCs stores it at a predefined location. If all the frames received the running FSW checks the consistency of the received image (CRC checking). If the whole image is received the FSW performs the update process. In other cases the running FSW rejects the command and reports the error in HK. The running FSW receives update command only in safe mode. In operation mode the FSW rejects all update related commands.

Parameters

- Unique id – used by the CaSSIS instrument for report generation and to merge the update related commands. Should be the same as the previous Initiate FSW update commands unique id.
- Frame count – the index of the current FWS image frame. Multiple upload FSW image commands with same unique id and frame count will result in that the later one overwrites the earlier ones.
- Image data – contains the actual part of the FSW image data. As the image data parameter has a fixed size (46 bytes) the FSW will pack the resulting image by inserting the received data from 0 + (46 * *Frame count*) into the buffer containing the reconstructed FSW image.

3.9.3 Perform FSW update

Perform FSW update command finalizes an update process. If the FSW has already received all the FSW image data parts in earlier upload FSW image commands it checks the integrity of the uploaded image:

- MD5 hash will be calculated to the received buffer
- The calculated checksum is validated by the received one – extracted from the perform FSW update command.

If the uploaded image integrity is verified the uploaded image will replace the existing FSW image in non-volatile memory.

Parameters

- Unique id – used by the CaSSIS instrument for report generation and to merge the update related commands. Should be the same as the previous Initiate FSW update commands unique id.
- Image hash – MD5 hash calculated for the uploaded image on Earth.

3.10 Set temperatures

Set temperatures command sets the target temperatures in the three different zones of the CaSSIS instrument.

Parameters

- Unique id – used by the CaSSIS instrument for report generation
- Zone1 mod enable – enables the modification of the zone1 temperature. If the value is 1 than the software reads zone1 temperature from TC and sets it as new target temperature. On any other cases the software omits the zone1 temperature parameter in TC.
- Zone1 temperature min/max – target temperature range for zone 1. Higher 2 byte contains the minimal temperature (in big-endian format) while lower 2 bytes of the parameter contains the maximal temperature (in big-endian format).
- Zone2 mod enable – enables the modification of the zone2 temperature. If the value is 1 than the software reads zone2 temperature from TC and sets it as new target temperature. On any other cases the software omits the zone2 temperature parameter in TC.
- Zone2 temperature min/max – target temperature range for zone 2. Higher 2 byte contains the minimal temperature (in big-endian format) while lower 2 bytes of the parameter contains the maximal temperature (in big-endian format).
- Zone3 mod enable – enables the modification of the zone3 temperature. If the value is 1 than the software reads zone3 temperature from TC and sets it as new target temperature. On any other cases the software omits the zone3 temperature parameter in TC.
- Zone3 temperature min/max – target temperature range for zone 3. Higher 2 byte contains the minimal temperature (in big-endian format) while lower 2 bytes of the parameter contains the maximal temperature (in big-endian format).
- Zone4 mod enable – enables the modification of the zone4 temperature. If the value is 1 than the software reads zone4 temperature from TC and sets it as new target temperature. On any other cases the software omits the zone4 temperature parameter in TC.
- Zone4 temperature min/max – target temperature range for zone 4. Higher 2 byte contains the minimal temperature (in big-endian format) while lower 2 bytes of the parameter contains the maximal temperature (in big-endian format).
- Zone5 mod enable – enables the modification of the zone5 temperature. If the value is 1 than the software reads zone5 temperature from TC and sets it as new target temperature. On any other cases the software omits the zone5 temperature parameter in TC.
- Zone5 temperature min/max – target temperature range for zone 5. Higher 2 byte contains the minimal temperature (in big-endian format) while lower 2 bytes of the parameter contains the maximal temperature (in big-endian format).

3.11 Set GPIO state

Set GPIO state command sets a specific GPIO pin state to the specified value. The GPIO pin can be selected from a predefined set of GPIOs.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.
- GPIO id – the id of the GPIO pin to manipulate
- GPIO value – the new value of the selected GPIO pin (0 or 1).

3.12 Dump

The Dump command forces the FSW to prepare a specific dump data set and send it over spacewire link to the spacecraft.

Parameters

- Unique id – used by the CaSSIS instrument for report generation.
- Dump type – type of the dump. The CaSSIS FSW supports the following dump types:
  - 0: RAM area dump. Dump a specific area of the RAM
  - 1: MRAM area dump
  - 2: parameter table dump
- Target reference – depends on the Dump type:
  - In case of Dump type 0:
    - RAM0 or RAM1 can be selected
  - In case of Dump type 1:
    - MRAM0 or MRAM1 can be selected
  - In case of Dump type 2:
    - The reference of the parameter table to dump

3.13 Set TM rate

The Set TM rate command sets the telemetry rate.

Parameters

- Unique id – optional parameter used by the CaSSIS instrument for report generation.
- TM rate – the target rate for TM generating
  - 0: Slow TM rate (10s / TM frame)
  - 1: Normal TM rate (1s / TM frame)

- 2: debug TM rate (0.1s / TM frame)

3.14 Enter operation mode

Enter safe mode command forces the FSW to enter to safe mode.

Parameters

- Unique id – optional parameter used by the CaSSIS instrument for report generation.
- Mode – A pattern for the corresponding mode to enter.
  - 0x5a00a500 – for normal mode
  - 0x0fa55a00 – for safe mode

3.15 Modify configuration parameter

The CaSSIS instrument flight software contains a number of configuration parameters stored in writeable non-volatile memory. These configuration options provide the opportunity to modify/configure some internal characteristics of the software without full software update process.

4 TM DEFINITION

A HK telemetry frame sent by the CaSSIS instrument to the spacecraft over MIL bus contains a HK container structure and 2 byte CRC. The HK container contains the HK frame type and parameters at fixed position based on the type of the frame.
The HK parameters sent to S/C over MIL are placed a telemetry container inside the MIL HK frame. The telemetry container has a fixed 0xf5 at byte position 0. The 2 byte CRC used to check the MIL TC frame integrity is not part of the telemetry container and it is placed right after the end of the telemetry container. The length of the telemetry container is implicitly defined by the telemetry frame type byte at byte position 1.

Header		**Data**	**Tail**	
0x00	0x01	0x02...(0x02 + TM container length)		
0xf5	type_byte	Data	CRC-h	CRC-l

4.1 MIL TM – HK parameters

Every CaSSIS HK parameter is unsigned decimal value stored on 1, 2, 4 or 8 bytes. Every HK parameter is in big endian byte order.

List of currently foreseen HK parameters:

Tag	Length	Name	HK frame type	Description	r/w from S/C
0x01	0x02	FSW_VERSION	0x10	Firmware version	r
0x02	0x08	FSW_LUPDATE	0x10	Last update	r
0x03	0x01	FSW_MODE	0x10	Current FSW mode	r
0x04	0x02	IMEM_USED	0x10	Used image memory blocks	r
0x05	0x02	IMEM_FREE	0x10	Available free image memory blocks	r
0x06	0x02	IMEM_COMP	0x10	number of compressed blocks	r
0x07	0x02	IMEM_OFLW_CNT	0x10	memory overflow counter	r
0x08	0x02	IMEM_STATE	0x10	memory usage state...	r
0x09	0x08	SC_LSENT_ITAG	0x10	last sent image tag (4 byte: UID/random | window cnt | sequence cnt)	r
0x0a	0x08	SC_LCOMP_ITAG	0x10	last compressed image tag (4 byte: UID/random | window cnt | sequence cnt)	r
0x0b	0x08	FSW_UPTIME	0x10	FSW up time since last boot – in sec	
Tag	**Length**	**Name**	**HK frame type**	**Description**	**r/w from S/C**
0x10	0x04	FSW_LAST_ISSUE	0x11	Last issued command unique id	r
0x11	0x04	FSW_LAST_EXEC	0x11	Last executed command unique id	r
0x12	0x04	FSW_LAST_RCV	0x11	Last received command unique id	r
0x13	0x04	FSW_LAST_FAILED	0x11	Last failed command unique id	r

0x14	0x01	FSW_LAST_ECODE	0x11	Last error code	r
0x15	0x01	FSW_CMEM_FREE	0x11	Available command slots	r
0x16	0x08	FSW_STATUS_0	0x11	Process status word. Every main running process (max 8) of the CaSSIS FSW has 8 bit status field.	r
0x17	0x04	TSENS_H_STAT	0x11	Temperature sensors health status. The 32 bit word contains the helath status bit for every temperature sensor. 0: sensor failed, 1: sensor OK.	r/w
0x18	0x01	HEATER_H_STAT	0x11	Heather health status. The 16 bit word contains the health status bit for each heather. 0: heater failed, 1: heater OK.	r/w
0x19	0x01	HEATER_STAT	0x11	Heater status. There are 2*5 heaters handled by CaSSIS FSW: 5 heaters both main/red. HEATER_STAT contains 0 for switched off heaters and 1 for switched on heaters	r/w
Tag	**Length**	**Name**	**HK frame type**	**Description**	**r/w from S/C**
0x20	0x02	Z1_CALC_TEMP	0x01	Zone 1 temperature	r
0x21	0x02	Z2_CALC_TEMP	0x01	Zone 2 temperature	r
0x22	0x02	Z3_CALC_TEMP	0x01	Zone 3 temperature	r
0x23	0x02	Z4_CALC_TEMP	0x01	Zone 4 temperature	r
0x24	0x02	Z5_CALC_TEMP	0x01	Zone 5 temperature	r
0x25	0x02	Z1_MIN_TEMP	0x01	Zone 1 target temperature min	r
0x26	0x02	Z2_MIN_TEMP	0x01	Zone 2 target temperature min	r
0x27	0x02	Z3_MIN_TEMP	0x01	Zone 3 target temperature min	r
0x28	0x02	Z4_MIN_TEMP	0x01	Zone 4 target temperature min	r
0x29	0x02	Z5_MIN_TEMP	0x01	Zone 5 target temperature min	r
0x2a	0x02	Z1_MAX_TEMP	0x01	Zone 1 target temperature max	r
0x2b	0x02	Z2_MAX_TEMP	0x01	Zone 2 target temperature max	r
0x2c	0x02	Z3_MAX_TEMP	0x01	Zone 3 target temperature max	r
0x2d	0x02	Z4_MAX_TEMP	0x01	Zone 4 target temperature max	r
0x2e	0x02	Z5_MAX_TEMP	0x01	Zone 5 target temperature max	r
Tag	**Length**	**Name**	**HK frame type**	**Description**	**r/w from S/C**
0x30	0x02	PT_DPM	0x00	PT1000 DPM Board	r
0x31	0x02	PT_PE_2	0x00	PT1000 on PE (No. 2)	r
0x32	0x02	PT_PE_1	0x00	PT1000 on PE (No. 1)	r
0x33	0x02	PT_FPA_1	0x00	PT1000 FPA (No. 1)	r
0x34	0x02	PT_FPA_2	0x00	PT1000 FPA (No. 2)	r
0x35	0x02	PT_TEL_M1_1	0x00	PT1000 Telescope Mirror 1 (No.1)	r
0x36	0x02	PT_TEL_M1_2	0x00	PT1000 Telescope Mirror 1 (No.2)	r
0x37	0x02	PT_TEL_RB_1	0x00	PT1000 Telescope Rear Baffle (No.1)	r
0x38	0x02	PT_TEL_RB_2	0x00	PT1000 Telescope Rear Baffle (No.2)	r
0x39	0x02	PT_TEL_M2	0x00	PT1000 Telescope Mirror 2	r
0x3a	0x02	PT_TEL_FB	0x00	PT1000 Telescope Front Baffle	r

0x3b	0x02	PT_PCM_5V	0x00	PT1000 PCM Board near 5V DC/DC	r
0x3c	0x02	PT_PCM_PE	0x00	PT1000 PCM Board near PE DC/DC	r
0x3e	0x02	PT_RCM	0x00	PT1000 RCM Board	r
0x3f	0x02	PT_PCM_MOT	0x00	PT1000 PCM Board near Motor DC/DC	r
0x40	0x02	PT_MOT_1	0x00	PT1000 Step Motor No. 1	r
0x41	0x02	PT_MOT_2	0x00	PT1000 Step Motor No. 2	r
Tag	**Length**	**Name**	**HK frame type**	**Description**	**r/w from S/C**
0x50	0x02	0V5_REF	0x02	0.5V Reference Voltage for PT OpAmps	r
0x51	0x02	I_3V3	0x02	Current on 3.3V DPM Supply	r
0x52	0x02	3V3	0x02	3.3V of DPM	r
0x53	0x02	I_1V8	0x02	Current of 1.8V Processor Supply	r
0x54	0x02	1V8	0x02	1.8V Processor Core Voltage	r
0x55	0x02	5V_OP	0x02	5V Operating Voltage	r
0x56	0x02	5V_ANA	0x02	5V Analogue Voltage	r
0x57	0x02	I_5V_ANA	0x02	Current of 5V Analogue Voltage	r
0x58	0x02	I_3V3_FPGA	0x02	Current of 3.3V FPGA Voltage	r
0x59	0x02	3V3_FPGA	0x02	3.3V FPGA Voltage	r
0x5a	0x02	I_1V2_FPGA	0x02	Current of 1.2V FPGA Voltage	r
0x5b	0x02	1V2_FPGA	0x02	1.2V FPGA Voltage	r
0x5c	0x02	24V_MOT_1	0x02	24V Motor DC/DC No. 1 Voltage	r
0x5d	0x02	24V_MOT_2	0x02	24V Motor DC/DC No. 2 Voltage	r
0x5e	0x02	U_3V3	0x02	PE Digital 3.3V Voltage	r
0x5f	0x02	I_3V3	0x02	PE Digital 3.3V Current	r
0x60	0x02	U_8.5V	0x02	PE Detector Positive +8.5V Voltage	r
0x61	0x02	I_8V5	0x02	PE Detector Positive +8.5V Current	r
0x62	0x02	U-8V5	0x02	PE Detector Negative -8.5V Voltage	r
0x63	0x02	I-8V5	0x02	PE Detector Negative -8.5V Current	r
0x64	0x02	U_25V	0x02	PE Detector Bias +25V Voltage	r
0x65	0x02	I_25V	0x02	PE Detector Bias +25V Current	r
Tag	**Length**	**Name**	**HK frame type**	**Description**	**r/w from S/C**
0x70	0x01	PE_HK_STAT	0x03	PE HK status word (PE HK 29)	r
0x71	0x01	PE_HK_LASTVENT	0x03	PE HK Last event (PE HK 30)	r
0x72	0x02	PE_HK_ADDRRW	0x03	PE HK Address read/writen (PE HK 42 | PE HK 41)	
0x73	0x02	PE_HK_ADDRRW_CONT	0x03	PE HK Address read/writen content (PE HK 44 | PE HK 43)	
0x74	0x02	PE_HK_TEMP_FPA1	0x03	PE HK FPA temperature 1 (PE HK 46 | PE HK 45)	
0x75	0x02	PE_HK_TEMP_FPA2	0x03	PE HK FPA temperature 2 (PE HK 48 | PE HK 47)	
0x76	0x02	PE_HK_TEMP_PE	0x03	PE HK PE temperature (PE HK 50 | PE HK 49)	
0x77	0x02	PE_HK_TEMP_CH1	0x03	PE HK channel 1 temperature (PE HK 52 | PE HK 51)	

0x78	0x02	PE_HK_TEMP_CH2	0x03	PE HK channel 2 temperature (PE HK 54 | PE HK 53)	
0x79	0x02	PE_HK_33V	0x03	PE HK measure of 3.3 voltage (PE HK 56 | PE HK 55)	
0x7a	0x02	PE_HK_PROTFLAG	0x03	PE HK protection flags (PE HK 58 | PE HK 57)	
0x71	0x02	PE_ROIC_REQ	0x03	PE ROIC frequency	
Tag	**Length**	**Name**	**HK frame type**	**Description**	**r/w from S/C**
	0x04	TSCP_ACTUAL_POS	0x01	Current telescope position	r
	0x04	TSCP_TARGET_POS	0x01	Last requested telescope position	r
	0x01	TSCP_ROT_STAT	0x01	Rotation status	r
	0x01	TSCP_ROT_SWHEALTH	0x01	End switch health status	r/w
	0x01	FPGA_COMM_STAT	0x01	FPGA communication status (0: failure, 1: OK)	r

4.2 HK frame types

There are a number of different HK frames. The frames are distinguished by the frame type id. The 1 byte frame type id is placed at byte position 1 in every HK frame (every HK frame contains 0xf5 at byte position 0). The CaSSIS uses the following frame types:

Frame id	Frame name	TM container length (bytes)
0x00	Temperature frame 1	60
0x01	Temperature frame 2	60
0x02	Currents and voltages frame	60
0x03	PE HK frame	60
0x10	FSW internal status frame 1	60
0x11	FSW internal status frame 2	60
0x20	Imaging frame	60
0xa0	For later use	n.a.
0xa1	For later use	n.a.
0xa2	For later use	n.a.

Every HK frame contains a 0xf5 byte at byte position 0 and a frame type byte at byte position 1 followed by an 8 byte timestamp. The content of the HK frame after the timestamp is defined by the HK frame id. Subsequent sections contain the definitions of the currently used HK frames.

4.2.1 Temperature frame 1

Frame type	Offset	Content	Length (byte)	Param name
0x00	0x00	0xf5	0x01	HK frame header

0x00	0x01	0x00	0x01	HK frame type
0x00	0x02	timestamp	0x08	Timestamp
0x00	0x0a	PT_DPM	0x02	PT1000 DPM Board
0x00	0x0c	PT_PE_2	0x02	PT1000 on PE (No. 2)
0x00	0x0e	PT_PE_1	0x02	PT1000 on PE (No. 1)
0x00	0x10	PT_FPA_1	0x02	PT1000 FPA (No. 1)
0x00	0x12	PT_FPA_2	0x02	PT1000 FPA (No. 2)
0x00	0x14	PT_TEL_M1_1	0x02	PT1000 Telescope Mirror 1 (No.1)
0x00	0x16	PT_TEL_M1_2	0x02	PT1000 Telescope Mirror 1 (No.2)
0x00	0x18	PT_TEL_RB_1	0x02	PT1000 Telescope Rear Baffle (No.1)
0x00	0x1a	PT_TEL_RB_2	0x02	PT1000 Telescope Rear Baffle (No.2)
0x00	0x1c	PT_TEL_M2	0x02	PT1000 Telescope Mirror 2
0x00	0x1e	PT_TEL_FB	0x02	PT1000 Telescope Front Baffle
0x00	0x20	PT_PCM_5V	0x02	PT1000 PCM Board near 5V DC/DC
0x00	0x22	PT_PCM_PE	0x02	PT1000 PCM Board near PE DC/DC
0x00	0x24	PT_RCM	0x02	PT1000 RCM Board
0x00	0x26	PT_PCM_MOT	0x02	PT1000 PCM Board near Motor DC/DC
0x00	0x28	PT_MOT_1	0x02	PT1000 Step Motor No. 1
0x00	0x2a	PT_MOT_2	0x02	PT1000 Step Motor No. 2
0x03	0x2c	DMY1	0x02	
0x03	0x2e	DMY2	0x04	
0x03	0x32	DMY3	0x04	
0x03	0x36	DMY4	0x04	
0x03	0x3a	DMY5	0x04	
0x03	0x3e	CRC	0x02	CRC

4.2.2 Temperature frame 2

Frame type	Offset	Content	Length (byte)	Param name
0x01	0x00	0xf5	0x01	HK frame header
0x01	0x01	0x01	0x01	HK frame type
0x01	0x02	timestamp	0x08	Timestamp
0x01	0x0a	Z1_CALC_TEMP	0x02	Zone 1 temperature
0x01	0x0c	Z2_CALC_TEMP	0x02	Zone 2 temperature
0x01	0x0e	Z3_CALC_TEMP	0x02	Zone 3 temperature
0x01	0x10	Z4_CALC_TEMP	0x02	Zone 4 temperature
0x01	0x12	Z5_CALC_TEMP	0x02	Zone 5 temperature
0x01	0x14	Z1_MIN_TEMP	0x02	Zone 1 target temperature min
0x01	0x16	Z2_MIN_TEMP	0x02	Zone 2 target temperature min
0x01	0x18	Z3_MIN_TEMP	0x02	Zone 3 target temperature min
0x01	0x1a	Z4_MIN_TEMP	0x02	Zone 4 target temperature min

0x01	0x1c	Z5_MIN_TEMP	0x02	Zone 5 target temperature min
0x01	0x1e	Z1_MAX_TEMP	0x02	Zone 1 target temperature max
0x01	0x20	Z2_MAX_TEMP	0x02	Zone 2 target temperature max
0x01	0x22	Z3_MAX_TEMP	0x02	Zone 3 target temperature max
0x01	0x24	Z4_MAX_TEMP	0x02	Zone 4 target temperature max
0x01	0x26	Z5_MAX_TEMP	0x02	Zone 5 target temperature max
0x01	0x28	TSCP_ACTUAL_POS	0x04	Current telescope position
0x01	0x2c	TSCP_TARGET_POS	0x04	Last requested telescope position
0x01	0x30	TSCP_ROT_STAT	0x01	Rotation status
0x01	0x31	TSCP_ROT_SWHEALTH	0x01	End switch health status
0x01	0x32	FPGA_COMM_STAT	0x01	FPGA communication status (0: failure, 1: OK)
0x01	0x33	DMY1	0x01	Reserved
0x01	0x34	DMY2	0x02	Reserved
0x01	0x36	DMY3	0x04	Reserved
0x01	0x3a	DMY4	0x04	Reserved
0x01	0x3e	CRC	0x02	CRC

4.2.3 Currents and voltages frame

Frame type	Offset	Content	Length (byte)	Param name
0x02	0x00	0xf5	0x01	HK frame header
0x02	0x01	0x02	0x01	HK frame type
0x02	0x02	timestamp	0x08	Timestamp
0x02	0x0a	0V5_REF	0x02	0.5V Reference Voltage for PT OpAmps
0x02	0x0c	I_3V3	0x02	Current on 3.3V DPM Supply
0x02	0x0e	3V3	0x02	3.3V of DPM
0x02	0x10	I_1V8	0x02	Current of 1.8V Processor Supply
0x02	0x12	1V8	0x02	1.8V Processor Core Voltage
0x02	0x14	5V_OP	0x02	5V Operating Voltage
0x02	0x16	5V_ANA	0x02	5V Analogue Voltage
0x02	0x18	I_5V_ANA	0x02	Current of 5V Analogue Voltage
0x02	0x1a	I_3V3_FPGA	0x02	Current of 3.3V FPGA Voltage
0x02	0x1c	3V3_FPGA	0x02	3.3V FPGA Voltage
0x02	0x1e	I_1V2_FPGA	0x02	Current of 1.2V FPGA Voltage
0x02	0x20	1V2_FPGA	0x02	1.2V FPGA Voltage
0x02	0x22	24V_MOT_1	0x02	24V Motor DC/DC No. 1 Voltage
0x02	0x24	24V_MOT_2	0x02	24V Motor DC/DC No. 2 Voltage
0x02	0x26	U_3V3	0x02	PE Digital 3.3V Voltage
0x02	0x28	I_3V3	0x02	PE Digital 3.3V Current
0x02	0x2a	U_8.5V	0x02	PE Detector Positive +8.5V Voltage
0x02	0c2c	I_8V5	0x02	PE Detector Positive +8.5V Current

0x02	0x2e	U-8V5	0x02	PE Detector Negative -8.5V Voltage
0x02	0x30	I-8V5	0x02	PE Detector Negative -8.5V Current
0x02	0x32	U_25V	0x02	PE Detector Bias +25V Voltage
0x02	0x34	I_25V	0x02	PE Detector Bias +25V Current
0x02	0x36	DMY1	0x04	
0x02	0x3a	DMY2	0x04	
0x02	0x3e	CRC	0x02	CRC

4.2.4 PE HK frame

Frame type	Offset	Content	Length (byte)	Param name
0x03	0x00	0xf5	0x01	HK frame header
0x03	0x01	0x03	0x01	HK frame type
0x03	0x02	timestamp	0x08	Timestamp
0x03	0x0a	PE_HK_STAT	0x01	PE HK status word (PE HK 29)
0x03	0x0b	PE_HK_LASTVENT	0x01	PE HK Last event (PE HK 30)
0x03	0x0c	PE_HK_ADDRRW	0x02	PE HK Address read/writen (PE HK 42 | PE HK 41)
0x03	0x0e	PE_HK_ADDRRW_CONT	0x02	PE HK Address read/writen content (PE HK 44 | PE HK 43)
0x03	0x10	PE_HK_TEMP_FPA1	0x02	PE HK FPA temperature 1 (PE HK 46 | PE HK 45)
0x03	0x12	PE_HK_TEMP_FPA2	0x02	PE HK FPA temperature 2 (PE HK 48 | PE HK 47)
0x03	0x14	PE_HK_TEMP_PE	0x02	PE HK PE temperature (PE HK 50 | PE HK 49)
0x03	0x16	PE_HK_TEMP_CH1	0x02	PE HK channel 1 temperature (PE HK 52 | PE HK 51)
0x03	0x18	PE_HK_TEMP_CH2	0x02	PE HK channel 2 temperature (PE HK 54 | PE HK 53)
0x03	0x1a	PE_HK_33V	0x02	PE HK measure of 3.3 voltage (PE HK 56 | PE HK 55)
0x03	0x1c	PE_HK_PROTFLAG	0x02	PE HK protection flags (PE HK 58 | PE HK 57)
0x03	0x1e	PE_ROIC_REQ	0x02	PE ROIC frequency
0x03	0x20	DMY1	0x02	
0x03	0x22	DMY2	0x04	
0x03	0x26	DMY3	0x04	
0x03	0x2a	DMY4	0x04	
0x03	0x2e	DMY5	0x04	
0x03	0x32	DMY6	0x04	
0x03	0x36	DMY7	0x04	
0x03	0x3a	DMY8	0x04	
0x03	0x3e	CRC	0x02	CRC

4.2.5 FSW internal status frame 1

Frame type	Offset	Content	Length (byte)	Param name

0x10	0x00	0xf5	0x01	HK frame header
0x10	0x01	0x10	0x01	HK frame type
0x10	0x02	timestamp	0x08	Timestamp
0x10	0x0a	FSW_VERSION	0x02	Firmware version
0x10	0x0c	FSW_LUPDATE	0x08	Last update
0x10	0x14	FSW_MODE	0x01	Current FSW mode
0x10	0x15	IMEM_USED	0x02	Used image memory blocks
0x10	0x17	IMEM_FREE	0x02	Available free image memory blocks
0x10	0x19	IMEM_COMP	0x02	number of compressed blocks
0x10	0x1b	IMEM_OFLW_CNT	0x02	memory overflow counter
0x10	0x1d	IMEM_STATE	0x02	memory usage state...
0x10	0x1f	SC_LSENT_ITAG	0x08	last sent image tag (4 byte: UID/random | window cnt | sequence cnt)
0x10	0x23	SC_LCOMP_ITAG	0x08	last compressed image tag (4 byte: UID/random | window cnt | sequence cnt)
0x10	0x2b	FSW_UPTIME	0x08	FSW up time since last boot – in sec
0x10	0x33	DMY1	0x01	
0x10	0x34	DMY2	0x02	
0x10	0x36	DMY3	0x04	
0x10	0x3a	DMY4	0x04	
0x10	0x3e	CRC	0x02	CRC

4.2.6 FSW internal status frame 2

Frame type	Offset	Content	Length (byte)	Param name
0x11	0x00	0xf5	0x01	HK frame header
0x11	0x01	0x11	0x01	HK frame type
0x11	0x02	timestamp	0x08	Timestamp
0x11	0x0a	FSW_LAST_ISSUE	0x04	Last issued command unique id
0x11	0x0e	FSW_LAST_EXEC	0x04	Last executed command unique id
0x11	0x12	FSW_LAST_RCV	0x04	Last received command unique id
0x11	0x16	FSW_LAST_FAILED	0x04	Last failed command unique id
0x11	0x1a	FSW_LAST_ECODE	0x01	Last error code
0x11	0x1b	FSW_CMEM_FREE	0x01	Available command slots
0x11	0x1c	FSW_STATUS_0	0x08	Process status word. Every main running process (max 8) of the CaSSIS FSW has 8 bit status field.
0x11	0x24	TSENS_H_STAT	0x04	Temperature sensors health status. The 32 bit word contains the helath status bit for every temperature sensor. 0: sensor failed, 1: sensor OK.
0x11	0x28	HEATER_H_STAT	0x01	Heather health status. The 16 bit word contains the health status bit for every heather. 0: heater failed, 1: heater OK.

0x11	0x29	HEATER_STAT	0x01	Heater status. There ara 2*5 heaters handled by CaSSIS fsw: 5 heaters both main/red. HEATER_STAT contains 0 for switched off heaters and 1 for switchde on heaters
0x11	0x2a	DMY1	0x04	
0x11	0x2e	DMY2	0x04	
0x11	0x32	DMY3	0x04	
0x11	0x36	DMY4	0x04	
0x11	0x3a	DMY5	0x04	
0x11	0x3e	CRC	0x02	CRC

4.2.7 Imaging frame

Frame type	Offset	Content	Length (byte)	Param name
0x20	0x00	0xf5	0x01	HK frame header
0x20	0x01	0x02	0x01	HK frame type
0x20	0x02	timestamp	0x08	Timestamp
0x20	0x0a	0V5_REF	0x02	0.5V Reference Voltage for PT OpAmps
0x20	0x0c	I_3V3	0x02	Current on 3.3V DPM Supply
0x20	0x0e	3V3	0x02	3.3V of DPM
0x20	0x10	I_1V8	0x02	Current of 1.8V Processor Supply
0x20	0x12	1V8	0x02	1.8V Processor Core Voltage
0x20	0x14	5V_OP	0x02	5V Operating Voltage
0x20	0x16	5V_ANA	0x02	5V Analogue Voltage
0x20	0x18	I_5V_ANA	0x02	Current of 5V Analogue Voltage
0x20	0x1a	I_3V3_FPGA	0x02	Current of 3.3V FPGA Voltage
0x20	0x1c	3V3_FPGA	0x02	3.3V FPGA Voltage
0x20	0x1e	I_1V2_FPGA	0x02	Current of 1.2V FPGA Voltage
0x20	0x20	1V2_FPGA	0x02	1.2V FPGA Voltage
0x20	0x22	24V_MOT_1	0x02	24V Motor DC/DC No. 1 Voltage
0x20	0x24	24V_MOT_2	0x02	24V Motor DC/DC No. 2 Voltage
0x20	0x26	U_3V3	0x02	PE Digital 3.3V Voltage
0x20	0x28	I_3V3	0x02	PE Digital 3.3V Current
0x20	0x2a	U_8.5V	0x02	PE Detector Positive +8.5V Voltage
0x20	0c2c	I_8V5	0x02	PE Detector Positive +8.5V Current
0x20	0x2e	U-8V5	0x02	PE Detector Negative -8.5V Voltage
0x20	0x30	I-8V5	0x02	PE Detector Negative -8.5V Current
0x20	0x32	U_25V	0x02	PE Detector Bias +25V Voltage
0x20	0x34	I_25V	0x02	PE Detector Bias +25V Current
0x20	0x36	IMEM_FREE	0x02	Available free image memory blocks
0x20	0x38	IMEM_COMP	0x02	number of compressed blocks

0x20	0x3a	IMEM_OFLW_CNT	0x02	memory overflow counter
0x20	0x3c	DMY	0x02	
0x20	0x3e	CRC	0x02	CRC

Imaging HK frame is sent only during imaging process.

4.3 SpW TM science parameters

The CaSSIS science data has the same structure as the TM data frame. It contains a science data container in TLV format. The science data container contains the actual values of the science data parameters in TLV format. The following table contains the parameters inside a SpW TM science frame:

Tag	Length	Name	Description
0x01	0x00000008	Timestamp	Timestamp – on-board instrument time – when the appropriate window data was exactly read from PE
0x02	0x00000004	UID	UID / Random – the unique id of the appropriate take image command or a random number if it was not specified. Same and unique number for all the sub-exposures and exposures taken by the same take image command
0x03	0x00000001	Window counter	The number of the actual PE window (1-6) where the data was taken
0x04	0x00000001	Sequence counter	The sequence counter of the actual exposure (nominal value depends on the size of each image and the available image memory. The value is stored internally on16 bits)
0x05	0x00000001	Compression ratio	The id of the applied compression ratio (6 nominal values depends on compression algorithm) The id is stored on 16 bit integer. Nominal values for the compression rate depend on the compression algorithm.
0x06	0x00000004	Total data length	The number of bytes the actual compressed window data contains (to provide the possibility to cut the compressed window data into more SpW science packets). This value may aid the reconstruction of compressed window data.
0x07	0x00000004	Offset	The offset – inside the total data length area – where the actual data starts from
0x10	x	Data	The actual compressed window data / compressed window data part
0x08	0x00000001	Type	The type of the frame: 0: science, 1: memory dump, 2: parameter table dump, ...
0x50	0x00000040	PE-HK	The HK parameters received from PE
additional parameters			

All SpW TM science frame may contain any other parameter from HK table – especially PE HK parameters.

The science telemetry parameters sent to S/C over SpaceWire are placed into a science data container TLV structure. The tag of the science data container is 0xfa. The MD5 hash print used to check the science TM frame integrity is not part of the science data container and it is placed right after the end of the science data container in raw format (wrapped by dedicated TLV structure).

5 CRC GENERATION

CaSSIS instrument telecommand frames contain a 2 byte (16 bit) CRC value calculated for all the bytes of the TC frame up to CRC position. CRC is calculated to TC bytes from 0 to CRC offset. The CaSSIS flight software uses a fast lookup table based CRC16-CCITT CRC generation algorithm to calculate the CRC for both TC and TM frames.

6 CaSSIS TIME CODE

CaSSIS instrument software uses 8 byte time code. The time code is derived from the on board CCSDS CUC time format by omitting the first and last bytes of the CCSDS CUC time code.

The following table shows the applied segment of the standard CCSDS CUC time code:

Position	Content
0	P-field (b00101111)
1	$2^{31} - 2^{24}$
2	$2^{23} - 2^{16}$
3	$2^{15} - 2^{8}$
4	$2^{7} - 2^{0}$
5	$2^{-1} - 2^{-8}$
6	$2^{-9} - 2^{-16}$
7	$2^{-17} - 2^{-24}$

The real granularity of the CaSSIS internal time code is 0.1ms.