SESAME Flight Software FM-3

Telecommand and Telemetry Formats

Prepared by

Hans-Herbert Fischer
MUSC, DLR, Cologne

Document History

Issue	Rev.	Date	Description of Change
Draft/0		5. August 2009	First draft (chapters 1 to 4.3)
Draft	0	7. August 2009	First complete draft
Draft	1	7. Sept. 2009	Corrected a couple of typos (mainly in the CASSE chapters); added execution durations of telecommands and infos on the generated data volume
		11 Feb. 2011	4.3.13: DIM Error Code table extended
		16 Aug 2011	*Explanation Slope factor in TC table removed. Zu WPENZ Beispiele einfügen!*
		25 May 2012	*PP Kapitel überarbeitet und an WS gesendet*
		26 Jun 2012	*DIM Kapitel leicht überarbeitet und an HK gesendet*

Table of Contents

Referenced / Applicable Documents

ID	Title	Code	Issue / Version	Date
RD1	Housekeeping Procedure	RO-LSE-TN-3402	2 / 5	4. May 2004
RD2	Cruise Phase Report: Flyby at Asteroid (2867) Steins	RO-LSE-RP-3102	SFB / 1.1	15. Dec. 2008
RD3	CASSE FM PCB User Guide	RO-LSE-UG-3821	1.2	6. Nov. 2002
RD4	Interaction of SESAME with other Lander Units	RO-LSE-TN-3403	4.1	24. Jul. 2006
RD5	DIM Software Description	RO-LSE-SP-3440	4.0	25. Jan. 2001
	Clarification of DIM Software User Requirements – Addendum to RO-LSE-SP-3440	-	4.0	24. July 2007
	ROSETTA Lander Common DPU (FM), User's Manual	RO-LCO-PR-3304	-	July 2000
	ROSETTA List of Acronyms	RO-LSE-LI-3003	7.1	5. Jan. 2002
	Software FM-3 User Requirements	RO-LSE-RD-3402	1.0	15. Aug. 2008
	PP Software Description	RO-LSE-SP-3460	2a	8. Sep. 2004
	PP Basic Algorithms and Software Test	RO-LSE-TR-3460	1.0	26. July 2007
	Flight Software User Manual, Issue 1: Software version FM-1.0	RO-LSE-UG-3401	1.2	10. Aug. 2001

1 Scope

The SESAME telecommands available with SESAME flight software FM-3 and the expected telemetry (TM) are described. Some hints are given for the use of the telecommands and the interpretation of TM. The document complements the SESAME software user manual (FM-3 version), which shall illustrate the higher level aspects of SESAME operation.

2 Data Types and Special Data

2.1 Data Types

The used data types and their designation in the telecommand and telemetry tables are listed in table 2.1. Bit positions are counted starting from zero, with bit 0 being the least significant bit (LSB).

Name	Meaning	Remarks
2N	two nibbles (4 bit each) in one byte.	
BitP	bit pattern	
CB	custom byte (bits 0 to 6: absolute value, bit 7 is sign: bit 7 set means negative value)	e.g. CASSE ADC raw format; data range -127 to +127
CW	custom word (bit 0 to 11: absolute value, bit 14 = sign bit: bit 14 set means negative value)	used for HK analogue values. data range -4095 to +4095
DB	Data block	format specified separately
N	Nibble (4 bit)	data range 0 to 15
UB	unsigned byte	data range 0 to 255
UW	unsigned word	data range 0 to 65535
W	Word	

Table 2.1: Data Types

2.2 Time Stamps

Two kinds of time stamps are used in telemetry. Both are based on CDMS RTIM messages and an RTX2010 timer value and consist of a low and a high word. **SESAME Local Time** contains the least significant 32 bits of the Lander LOBT and provides thus a resolution of 1/32 seconds. The most significant 5 bits of the LOBT can be read from the system status table in the "SESAME Ready Message". **SESAME High Resolution Time** has a resolution of 1/1024 seconds and is used in CASSE telemetry only. The ground software must extract the higher bits of the on-board time from the SESAME Local Time given in the preceding SESAME Science Data Measurement Header and from the "SESAME Ready Message". The high bits change rarely, but the ground software shall be prepared for that case, which - without correction - shows up as a time jump to the past in a series of SESAME time stamps.

Figure 2.1 shows the relationship between CDMS time information and the two SESAME time formats.

Note on High Resolution time

For obtaining a resolution of 1/1024 seconds on-board, the value 4883 is stored into the RTX timer1 preload register. With the given processor frequency (5 MHz) a timer1 interrupt is thus released each 4883/5000 ms = 0.9766 ms. The timer interrupts ("ticks") are counted and are processed as if they were generated each 1/1024 s. This is not exactly true (0.9766 ms = 1/1023.961 s), but no significant deviation occurs when time stamps are determined between two CDMS RTIM messages, which will be received at one second intervals. The timer value is also used to calculate the value of HK parameter TIBO (time [s] since boot). The accuracy of this value is slightly affected by the deviation of the interrupt frequency from 1024 per second. E.g. after 1 hour 3686259 interrupts are generated (1023.96 * 60 * 60) and not 3686400 (1024*60*60), which, if not corrected on ground, results in an inaccuracy of TIBO of (3686259 – 3686400) / 1024 = -0.14 s.

The Forth variable used for counting the timer ticks (“tick variable”) is set to zero after boot and is continuously incremented afterwards. It is a Forth 2VARIABLE (32 bit data width) and can thus cover approximately 2^32 / (1024 1/s) = 1165 hours before the data range is exceeded. The value of the tick variable is stored each time a CDMS RTIM message arrives as well as the LOBT coming with the data words of the RTIM message.

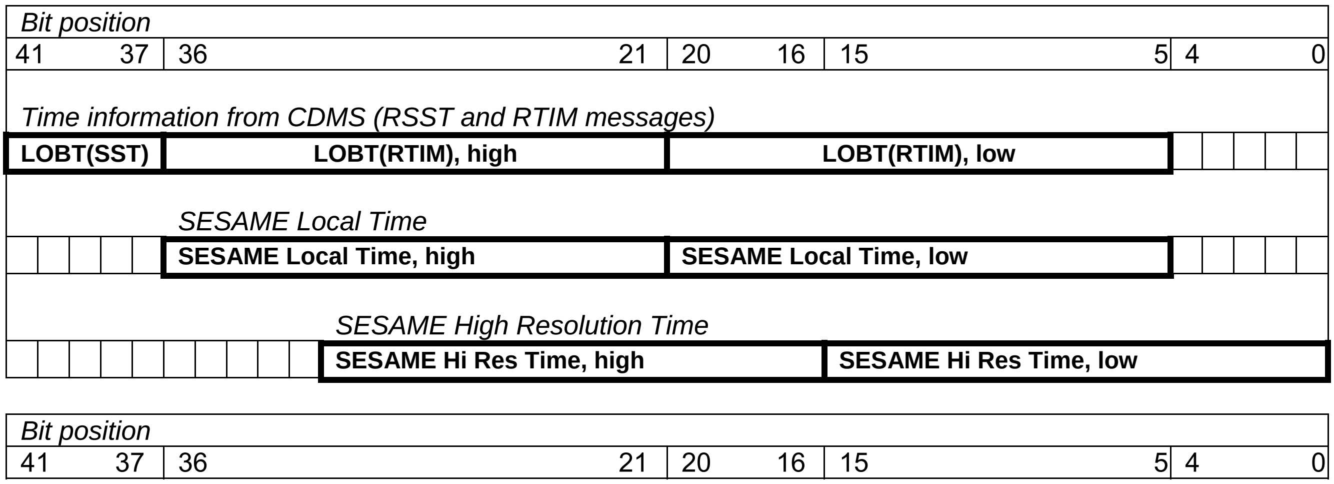

Figure 2.1: Relationship between CDMS time information available on-board and the derived SESAME time stamps

2.3 Temperature Measurements

Temperature measurements have been revised during cruise concerning (a) the introduction of a new measuring method, which provides an extended measuring range, (b) the investigation of the temperature dependence of the measuring circuit itself. The set of calibration data was completed during Rosetta thermal characterization 2 (February 2009), the in-depth data evaluation and set-up of calibration functions is still missing. Flight software FM-3 provides different kinds of temperature raw data depending on the measuring context (SESAME HC, CASSE TM, Housekeeping).

The temperatures of the CASSE sensors in the six Philae soles and the CASSE PCB temperature are measured by flight software in several ways:

- With the “old” method (the only method available until PC8). The measuring method yields the output of the CASSE temperature measuring circuit after standard AD conversion using the ADC of the C-DPU. The measuring circuit itself shows a temperature dependency (confirmed during Rosetta THC2). This affects not only the measuring values obtained in space, but more drastically the calibration curve obtained during “preliminary FM temperature calibration” before launch (when this effect was camouflaged, because PCB and external temperature sensors were always at the same temperature level). The lower measuring limit (-106 °C according to the preliminary, but now obsolete, calibration) deviates from the desired value (-150 °C) due to H/W problems. The corrected temperature calibration is TBD.

- With the “new” method (uploaded firstly with flight software FM-2), which was implemented to extend the measuring range to lower temperatures. An intermediate voltage value is measured when switching from a temperature channel to known reference voltages (+5 V (C-DPU) and +28 V power supply lines). The results of the new method are as well affected by the temperature dependence of the measuring circuit. Each execution of the new method delivers a couple of measuring values: intermediate voltages when switching to the two reference voltages [U(T, r=+5V), U(T, r=28V)], the two reference voltages, and the raw temperature value obtained with the old method. Depending on the context in which the method was invoked, the single values or the mean of the two intermediate voltages are included in telemetry.

3 Housekeeping Telemetry

SESAME housekeeping parameters and the assignment to the CDMS format count are listed in table 3.1. The scaling of analogue parameters is given for FM hardware and generally applies as well for Philae GRM hardware. The structure and meaning of parameters SUPS, TIBO, and ERRF is described separately in the present chapter. A description of the HK procedure with former flight software versions and a compilation of transfer functions for EQM and (older) lab electronics are compiled in the HK technical note (RD1).

Note that compared to flight software version FM-2, the HK parameters and their order are unchanged. There are a few differences concerning the contents of parameters: The value of CEID is 0xC5E5 with flight software FM-3 and temperature values are measured with a new measured and must be calibrated in a different, still TBD, way than previously.

Table 3.1: Housekeeping Parameters

CDMS Format Count	HK Name (used starting with FM-2)	previous HK Name	Meaning	Scaling / Comments
0	UFPG	CA-U1	Voltage 3.3V (FPGA)	0.002 V/mV
1	UD+5	DI-U1	Voltage +5V (DIM)	0.002 V/mV
2	UD-5	DI-U2	Voltage -5V (DIM)	0.002 V/mV
3	UP+5	PP-U1	Voltage +5V (PP)	0.002 V/mV (***)
4	U+05	CE-U1	Voltage +5V (CE)	0.01 V/mV
5	U-05	CE-U2	Voltage -5V (CE)	0.01 V/mV
6	U+12	CE-U3	Voltage +12V (CE)	0.01 V/mV
7	U-12	CE-U4	Voltage -12V (CE)	0.01 V/mV
8	U+28	CE-U5	Voltage +28V (CE)	0.01 V/mV
9	UCDP	CE-U6	Voltage +5V (C-DPU)	0.002 V/mV
10	URAD	CA-U2	Total Dose (RadFET)	0.002 V/mV
11	I+05	CE-I1	Current +5V (CE)	0.5 mA/mV
12	I-05	CE-I2	Current –5V (CE)	0.05 mA/mV
13	I+12	CE-I3	Current +12V (CE)	0.25 mA/mV
14	I-12	CE-I4	Current -12V (CE)	0.05 mA/mV
15	I+28	CE-I5	Current +28V (CE)	0.025 mA/mV
16	CEID	CE-ID	0xC5E5	n/a
17	TPCB	CA-T7	CASSE Board Temperature	T(x) °C/V (*)
18	CLTC	CE-C1	Last Telecommand received	n/a
19	CBTC	CE-C2	Last but one Telecommand	n/a
20	LMID	n/a	SESAME Local Time (midth word)	n/a (**)
21	LLOW	n/a	SESAME Local Time (low word)	n/a (**)
22	TT-Y	CA-T1	Foot –Y / TRM Temperature	T(x) °C/V (*)
23	TA-Y	CA-T2	Foot –Y / ACC Temperature	T(x) °C/V (*)
24	TT+X	CA-T3	Foot +X / TRM Temperature	T(x) °C/V (*)
25	TA+X	CA-T4	Foot +X / ACC Temperature	T(x) °C/V (*)
26	TT+Y	CA-T5	Foot +Y / TRM Temperature	T(x) °C/V (*)
27	TA+Y	CA-T6	Foot +Y / ACC Temperature	T(x) °C/V (*)
28	PPD	PP-D	Electron Density	n/a
29	SUPS	CE-F1 (different contents)	SRAM Usage / Power Status	see separate description
30	TIBO	CE-F2 (diff. contents)	Time since Boot [seconds]	see separate description
31	ERRF	CE-F3 (diff. contents)	Error Flags	see separate description

Notes:

(*) The temperature raw values are the mean of the two intermediate voltage values $U_{new}(T) = [U(T, r=5V)+U(T, r=28V)] / 2$, generated by the new measuring method. As usually, the data format of the voltage is CW (bit 0 to 11: absolute value, bit 14 = sign). The calibration is TBD and will be devised probably in 2009. For the time being, $U_{new}(T)$ can be converted to the voltage values, which would have been measured with the old method, using the linear part of the transfer function obtained after Steins Flyby (RD2):

$U_{old}(T) = 1.008 * U_{new}(T) - 0.205* U_{new}(TPCB) -1377$

$U_{old}(T)$ can then be converted to temperatures with the known transfer function of the old method. This preliminary procedure yields temperature data, which are calculated consistently with the temperatures obtained so far during cruise.

(**) SESAME Local Time is derived from the Lander Onboard Time (LOBT), which is received with a CDMS RTIM message. If no RTIM message has arrived (flag TI in ERRF), parameters with format count 20, 21 contain the time since boot.

(***) HK parameters U+05 and UP+5 can be used to determine the current consumption of the PP digital electronics. The difference between UP+5 and the incoming +5 V supply voltage (i.e. the value of U+05) is the voltage drop caused by the current through a 11.1 Ohm resistor; the current can thus be calculated as IP+5 = (U+05 - UP+5) / 11.1.

Parameter SUPS: Instruments Power Status and SRAM Usage

Housekeeping Parameter Word SUPS															
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
o	**data page no**				**P2**	**P1**	**P0**	**-**	**D2**	**D1**	**D0**	**C3**	**C2**	**C1**	**C0**
SRAM usage					**PP-PWR**				**DIM-PWR**			**CASSE-PWR**			

CASSE-PWR: Contents of CASSE power register
- C0: ±5 V supply voltage (RAM, analogue circuits) ON (1), OFF (0)
- C1: +28 V supply voltage ACC -Y ON (1), OFF (0)
- C2: +28 V supply voltage ACC +X ON (1), OFF (0)
- C3: +28 V supply voltage ACC +Y ON (1), OFF (0)

(cf. “CASSE FM PCB User Guide” RO-LSE-UG-3821)

DIM_PWR: DIM power settings
- D0: ±5 V supply voltage via DIM select line ON (1), OFF (0)
- D1: /PWR_AMP in DIM control1 register; power supply to log amplifier, segment switches and average circuit; power on (0), power off (1) [sic!]
- D2: /PWR_BURST in DIM control1 register; power supply to threshold circuit, event comparator and offset-circuit of peak detector; power on (0), power off (1) [sic!]

Note: D1 and D2 denote the last register adjustments by flight software, after DIM was switched on for the first time. As long as DIM is turned off via the DIM select line (D0 = 0), they do not represent the actual DIM power status.

PP_PWR: Contents of PP power register
- P0: ±12 V for transmitter ON (1), OFF (0)
- P1: ±5 V for receiver ON (1), OFF (0)
- P2: ±5 V for Langmuir Probe ON (1), OFF (0)

Note: P0 to P2 denote the last register adjustments by flight software. As PP can be operated with automatic power-off, the flags can - for a certain time period - represent a different than the actual power status.

SRAM Usage

Data page no: Currently used SESAME SRAM data page for science data (0: less than one SD packet is waiting for transfer to CDMS)

o = 1: Memory overflow; SESAME SRAM currently exhausted by science data and temporary data

Parameter TIBO: Time since Boot

Time since boot of SESAME flight software (full seconds elapsed). Increases monotonously after boot (covers some 18 hours max.). See chapter 2.2 “Time stamps” for more information on that parameter.

Parameter ERRF: Error flags

Deviating from all other HK parameters, ERRF does not provide a snapshot of the situation at a particular point in time but collects information about the status of the CDMS-SESAME software interface during a time period (namely between two successive HK measurements). A set flag (bit value = 1) shows, that at least one error of the kind indicated by the bit position occurred between the time-stamps of the previous and the current HK parameter set.

Housekeeping Parameter Word ERRF															
SESAME Error Code									***CDMS Error Code***						
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
ME	**SD**	**BB**	**TC**	**TR**	**AD**	**TI**	**RQ**	**IN**	**-**	**UO**	**SV**	**MF**	**RU**	**IP**	**IR**

SESAME Error Code

Selected accumulated SESAME errors occurred since preceding HK measurement:

- IN: Invalid action code received or address was not SESAME or BROADCAST
- RQ: Cannot submit request to CDMS or request not fulfilled by CDMS within 2 minutes
- TI: No RTIM message received (yet)
- AD: Error during ADC
- TR: Error during send/receive trigger
- TC: Error during TC / STC processing
- BB: Error during read/write Backup RAM buffer
- SD: Error during science data processing
- ME: Memory (data pages) exhausted

CDMS Error Code

Accumulated CDMS error codes received via the CDMS RERC (Receive Error Code Word) message (cf. CDMS Subsystem Specification RO-LCD-SP-3101).

- IR: Illegal Request Code
- IP: Illegal pointer, offset, number (TCMO, TBUF)
- RU: Request undue (can not be accepted in this phase)
- MF: Mass-memory full
- SV: Science data volume exhausted
- UO: Destination unit off

4 Telecommands and Science Data Telemetry Formats

4.1 Common Telemetry Data Structures

4.1.1 Science Data Packet Header

The first word in each SESAME science data telemetry packet is reserved for the SESAME Science Data Packet Header, leaving 127 words for measurement data in the TM packet. The SD packet header word is used to indicate the transmission status (to CDMS) of the *preceding* SD telemetry packet. Its content is usually fixed to the pattern 0xEEFF. Any deviation from that pattern indicates an unexpected (not necessarily fatal) communication problem with the CDMS. Some bit positions have a special meaning:

Science Data Packet Header: Bit Structure															
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
1	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**S2**	**S1**	**CH**

CH = S1 = S2 = 1:	No error during transmission of the preceding SD packet to CDMS recognised.
CH cleared:	Checksums calculated by SESAME and by CDMS differ for the preceding science data packet.
S1 cleared:	Sync-error CDMS-SESAME; an RSCS action code was received from CDMS, but less than 128 SD words were sent by SESAME to CDMS.
S2 cleared:	Sync-error CDMS-SESAME; no RSCS action code was received from CDMS, but a complete SD packet (128 words) was sent to CDMS.

Notes:

(1) A cleared bit in the SD packet header indicates a communication problem with CDMS, but not in any case corrupted data. E.g. for some reason the arrival of a RSCS-message (“Receive Science Data Checksum”) from CDMS can be delayed by more than the expected maximum period of time (two seconds).

(2) In case science data are lost during transfer to or processing by CDMS, the Science Data Packet Header can be dislocated (it is then probably not the first word in the packet).

(3) There is no SD packet header in telemetry packets generated by the Common DPU Debug Monitor.

4.1.2 Science Data Measurement Header

Each data section in science data telemetry generated by SESAME software (thus not the C-DPU Debug Monitor messages) starts with a header containing meta-information about type and origin of data, total length and a time stamp:

Table 4.1 Science Data Measurement Header

Item No.	Byte No.	Data Type	Meaning	Value	Remarks
1	0 to 1	BitP	Sync	0xBCDE	Value indicates flight software version > FM-1.
2	2 to 3	BitP	Sync	0xBCDE	
3	4 to 5	UW	Measurement ID		= 0: “SESAME Ready Message” (boot message) = 0x7F00: error message Any other value is the command word of a TC; science data result from the execution of that TC.
4	6		*spare*		
5	7	UB	Length of data (high byte)		Data length includes the Science Data Header, but not the Science Data Packet Header(s)
6	8 to 9	UW	Length of data (low word)		
7	10 to 11	UW	SESAME local time (high word)		Point in time, when data were generated or execution of the TC started
8	12 to 13	UW	SESAME local time (low word)		

4.2 CASSE Telecommanding and Telemetry

4.2.1 Table of Telecommands

Table 4.2: CASSE: Defined Telecommands

IDENT	Command Word	Parameter Words			Description
		No	Meaning	Valid Range	
CAS_HC	1000	n/a	n/a	n/a	CASSE Health Check
CAS_MES	1100	n/a	n/a	n/a	CASSE measurement controlled by JOB_MES jobcard.
CAS_RJC	1310	16 parameter words, which contain a CASSE jobcard (see text for further details).			CASSE Receive Jobcard. Overrides default JOB_MES jobcard with the jobcard given in the parameter words. Valid until the next CAS_RJC command arrives or SESAME is switched off. No SD are generated.
CAS_PWRSW	1501	1	Power Setting	0 to 15	CASSE power switching. The value of the parameter word is written to the power hardware register. No SD are generated.
CAS_TEST	1A03	1	Mode	= 0: Dump base statistical values	CASSE software and instrument debug mode. Used during hardware and software tests only.
				=1: Perform time stamp test	
		2	Gap (seconds) between time stamps (mode = 1)	0 (mode=0) or 1 to 255 (mode=1)	
		3	Number of time stamps (mode=1)	0 (mode=0) or 1 to 30 (mode=1)	

4.2.2 Jobcard Format

CASSE health-check, CAS_MES and CAS_RJC make use of a set of measurement control and instrument parameters, called a jobcard. Table 4.3 is a synopsis of the jobcard formats used with flight software FM-3 and with previous software versions. The different formats can be identified using parameter JobVersion. Note that FM-3 software works correctly with all jobcard versions, while the compatibility of the new format with older flight software versions must be checked carefully for each individual jobcard.

The FM-3 jobcard parameters in detail:

Item 1: Jobcard Identifier (JobID)
The parameter is not used consistently and it is not evaluated by flight software.

Item 2: Jobcard Version (JobVersion)
The parameter contains the version of the Jobcard. With JobVersion = 0 all parameters will be interpreted in the same way as previous software versions did. JobVersion = 0x0B enables the different time units.

Item 3: StartCond
The parameter is not used.

Item 4: nMeas_Stack (number of measurements / stacking)
Bits 0 to 6 contain the number of measurements to be executed; bit7 set indicates that time series shall be stacked on-board.

Item 5: SndFreq (sounding frequency)
Nominal sounding frequency in Hz.

Item 6: SndDura / TrgTimeout
Sounding mode:
Duration of the ping. If JobVersion = 0x0B, bits 0 to 14 contain the numerical value and bit 15 indicates the physical unit [0.1 ms (bit 15 = 0) or 0.1 s (bit 15 = 1)]. Maximal value is 2000 s. If JobVersion = 0, the old format applies.
Triggered Mode:
Parameter contains the trigger time-out in seconds.

Item 7: SampFreq (sampling frequency)
Nominal channel sampling frequency (= (instrument sampling frequency) / nChan)

Item 8: TX_STATUS (active transmitters)
Selection of transmitters to be used in Sounding Mode. If TX_cycle is set, after a measurement the transmitter selection is (cyclically) shifted by one position up to yield the transmitters to be used for the next measurement. If Tx_reverse is additionally set, the selection of active transmitters is shifted one position downwards instead.

```
 7        0  bit
|xxxx|xxxx|
 ||||  |||
 ||||  |||+-- TRM -Y on
 ||||  ||+--- TRM +X on
 ||||  |+---- TRM +Y on
 ||||  +-----
 |||+------- Tx_cycle
 ||+-------- Tx_reverse
 |+---------
 +----------
```

Item 9: AGC (gain control)
Value to be written to the Amplifier Gain Control register of CASSE electronics. Value ranges from 0 (maximal gain) to 15 (minimal gain). Note (a) the gain is not a monotone function of the AGC value (cf. RD3), (b) the actually adjusted gain can deviate, if automatic gain setting (AGS) is enabled.

Item 10: TRG_SRC (trigger source)
The set bit positions indicate the subset of active sensor channels which shall be used as trigger sources. The meaning of bits 0 to 11 correspond to that of bits 0 to 11 of RX_STATUS (item 15). The remaining bits are not used.

Item 11: TrgDelay (trigger delay)
Determines the time range before (negative value) or after (positive value) a trigger event, which shall be included in the time series. Absolute value of TrgDelay must be less or equal LisDura.

Item 12: TrgLevPos (positive trigger level)
Value to be written to the UTT hardware register, which fixes the upper (always positive) trigger threshold. Note that the actually adjusted value can be different, if automatic trigger level setting is enabled.

Item 13: TrgLevNeg (negative trigger level)
Value to be written to the LTT hardware register, which fixes the lower (always negative) trigger threshold. Note that the actually adjusted value can be different, if automatic trigger level setting is enabled.

Item 14: LisDura (listening duration)
If JobVersion = 0x0B, bits 0 to 14 contain the numerical value and bit 15 indicates the physical unit [0.1 ms (bit 15 = 0) or 0.1 s (bit 15 = 1)]. Maximal value is 2000 s. If JobVersion = 0, the old format applies.

Item 15: RX_STATUS (active sensor channels)
Selection of sensor channels to be used. If cycle is set, after a measurement the receiver selection is (cyclically) shifted by one position (in the same direction as the transmitters, as indicated in TX_STATUS (item 8)). If the reversed flag is additionally set, the receiver cycling shall take place in the opposite direction as the transmitter cycling.

```
15      8 7      0 bit
|xxxx|xxxx|xxxx|xxxx|
 |||| |||| |||| ||||
 |||| |||| |||| |||+-- ACC -Y, x-axis
 |||| |||| |||| ||+--- ACC -Y, y-axis
 |||| |||| |||| |+---- ACC -Y, z-axis
 |||| |||| |||| +----- ACC +X, x-axis
 |||| |||| |||+------- ACC +X, y-axis
 |||| |||| ||+-------- ACC +X, z-axis
 |||| |||| |+--------- ACC +Y, x-axis
 |||| |||| +---------- ACC +Y, y-axis
 |||| |||+------------ ACC +Y, z-axis
 |||| ||+------------- TRM -Y
 |||| |+-------------- TRM +X
 |||| +--------------- TRM +Y
 |||+----------------- cycle (1: on, direction as TX_STATUS)
 ||+------------------ not used
 |+------------------- (reversed (0: normal, 1: rev. order))
 +-------------------- not used
```

Item 16: Options

Bit Position	Name	Meaning	Remarks
Bit 0	GGen	= 1: Prepare data for automatic gain adjustment	
Bits 1 to 2	GComp	= 0: Do not calculate optimized gain = 1: Optimize for lower 1/3 of channels = 2: Optimize for lower 2/3 of channels = 3: Optimize for strongest channel	
Bit 3	Spare		
Bit 4	TLGen	= 1: Prepare data for automatic trigger level adjustment	
Bit 5	TLComp	=1: Adjust optimized trigger levels	
Bit 6	Stats	=1: Include channels statistics for each measurement	
Bit 7	SkipTS	=1: Do not include time series into telemetry (ignored in Stacking Mode)	

Item 17: GTarval
Target value for automatic gain adjustment (linearized ADC units). In combination with the value of GComp (item 16) gain is adjusted such, that the absolute values of the samples of 1/3, 2/3 or all channels are close to, but below, GTarval.

Item 18: TLFactor
Value [*10 %] is used if TLComp is set. Distance of trigger level from mean of time series (of selected trigger channels) relative to the distance between mean and the extreme sample values; TLFactor = 10 (=100 %) means that trigger level are set equal to the maximum deviation from mean during the pre-measurement. A TLFactor value less than or equal 10 would have caused a trigger signal during the pre-measurement. For each sensor channel marked as trigger channel, flight software calculates preliminary trigger levels based on statistical values (Max, Min, Mean) of a pre-measurement with

trglevneg = (Min – Mean) * TLFactor / 10 + Mean
trglevpos = (Max – Mean) * TLFactor / 10 + Mean

The smallest value of the trglevneg obtained this way is adjusted as negative trigger level (TrgLevNeg), and the highest trglevpos as positive trigger level (TrgLevPos), possibly after correcting for different gain settings during the pre-measurement and the Triggered Mode measurement.

Item 19: Spare
Not used.

Item 20: Amplifier Setup Time (AmpSetUp)
Duration [*0.1 s] after start of time series recording used for amplifier setup (to yield constant base lines). A value of 10 (= 1 s) should normally be used, because it enables the correct identification of sensor channels for all possible sampling frequencies (no wrap-around of FIFO buffer). In case the jobcard version (JobVersion) is not 0x0B, AmpSetUp = 10 (i.e. one second amplifier setup time) is used. In any case the product of the instrument sampling frequency and the duration of the amplifier setup shall not be greater than 128k.

Item 21: FIFO_Lag
In all modes but Triggered Mode, parameter FIFO_Lag can be used to shift (increment or decrement) the address of the first sample in CASSE FIFO, which will be included into telemetry. Flight software calculates

FIFOFirstDat = AmpSetUp * SR – (AmpSetUp * SR modulo nChan) + FIFO_Lag,

with SR the instrument sampling frequency and nChan the number of active sensor channels.

With FIFO_LAG = 0, FIFOFirstDat contains a sample, which was measured shortly before or after AmpSetup has elapsed and the sample belongs to the first channel in the sensor lookup table. With FIFO_Lag it is possible to shift the timing relative to AmpSetUp (which is equal to the start of the ping in sounding mode). Alignment of samples to sensor channels can generally only be achieved if FIFO_Lag is a multiple (0, 1, 2, ..) of the number of channels nChan.

In Triggered Mode, FIFOFirstDat is calculated relative to FIFOTrigger applying the commanded trigger delay and FIFO_Lag is not evaluated.

Item 22: FootTemp (active foot temperature channels)
The Temperature and Radiation Dose Data Block will be generated by flight software, if at least one foot temperature channel is selected in FootTemp. It will additionally be included at the end of a measuring sequence, if the “Additional after job” flag is set.

```
 7       0  bit
|xxxx|xxxx|
 ||||  |||
 ||||  ||+-- Temperature –Y, TRM
 ||||  |+--- Temperature –Y, ACC
 ||||  +---- Temperature +X, TRM
 |||+------- Temperature +X, ACC
 ||+-------- Temperature +Y, TRM
 |+--------- Temperature +Y, ACC
 |+--------- Addit. ‘after-job’ temperatures
 +---------- not used
```

Item 23: AddDelay
Additional delay [s] between measurements of a measurement sequence

Flight Software FM-3							*FM 1 and FM 2*				
No	***Off-set***	***Data type***	***Name***	***Description***	**Range/ Unit**	**Comment**	***No***	***Off-set.***	***Data type***	***Name***	***Description***
1	0	UB	JobID	JobCard identifier	Not evaluated by flight software.	Jobcard will be always included into TM.	***1***	0	UB	Job_ID	Job ID; bit 6 set: include full jobcard into telemetry full
2	1	UB	JobVersion	JobCard version	= 0: FM-1 and FM-2 format. = 0xB: FM-3 format.		***2***	1	UB	Sub_ID	Job_ID extension
3	2	UB	StartCond	Start condition for measurement	Not evaluated by flight software.	Not used.	***3***	2	UB	Start_Cond	Start condition for measurement
4	3	BitP	nMeas_Stack	Number of measurements; bit 7 set: stack measurements	Bit 0 to 6: nMeas = 1 to 127 Bit 7: 0/1	Unchanged compared to FM-1 / FM-2.	***4***	3	UB	nMeas (aka "Rep_avrg")	Number of measurements; bit 7 set: stack measurements
5	4	UW	SndFreq	Transmitter sound frequency	10 to 10000 [Hz]	Unchanged compared to FM-1 / FM-2.	***5***	4	UW	Snd_freq	Transmitter sound frequency
6	6	UW	SndDura	Ping duration Bit 0 to bit 14: value; bit 15: phys. Unit; max.: 2000 s	If JobVersion = 0xB: Bits 0 to 14: 0 to 32767 (but <= 2000 s) bit 15=0: *0.1 ms; bit 15=1: *0.1 s	If JobVersion=0, FM-1 / FM-2 format applies.	***6***	6	UW	Snd_duration [*0.1 ms] (1 to 65535)	Sound duration (0.1 ms to 6.55 s)
			TrgTimeout	Time-out when waiting for trigger signal	0 to 32767 [s]	Variant used in Triggered Mode. Unchanged compared to FM-1 / FM-2.				Trg_Timeout	Time-out when waiting for trigger signal
7	8	UW	SampFreq	Channel sampling frequency [80 Hz to 100 kHz]	8 to 10000 [*10 Hz]	Unchanged compared to FM-1 / FM-2.	***7***	8	UW	Samp_freq	Channel sampling frequency
8	10	BitP	TX_STATUS	Selection of transmitter(s); cycling	Bit 0: -Y Bit 1: +X Bit 2: +Y Bit 4: cycle Bit 5: reverse	Unchanged compared to FM-1 / FM-2.	***8***	10	UB	TX_status	Selection of transmitter(s); cycling
9	11	UB	AGC	Amplifier gain control;	0 to 15.	Can be overwritten by AGS.	***9***	11	UB	AGC_sel	Amplifier gain control

Flight Software FM-3							FM 1 and FM 2				
No	***Off-set***	***Data type***	***Name***	***Description***	**Range/ Unit**	**Comment**	***No***	***Off-set.***	***Data type***	***Name***	***Description***
10	12	BitP	TRG_SRC	Trigger source. Selection of channels which can generate a trigger signal		Same bit setting as in item 15: “RX_STATUS”; Unchanged compared to FM-1 / FM-2.	***10***	12	UW	Trg_source	Trigger source. Selection of channels which can generate a trigger signal
11	14	W	TrgDelay	Trigger delay. Determines the time period before or after a trigger event to be included into telemetry.	[0.1 ms], signed; abs(TrgDelay) must be <= LisDura;	Unchanged compared to FM-1 / FM-2.	***11***	14	W	Trg_delay	Trigger delay.
12	16	CB	TrgLevPos	Positive trigger level	Bits 0 to 6: trigger level (ADC units) Bit 7: 0	Unchanged compared to FM-1 / FM-2.	***12***	16	UB	Trg_lev_pos	Positive trigger level
13	17	CB	TrgLevNeg	Negative trigger level	Bits 0 to 6: absolute value of trigger level (ADC units) Bit 7: 1	Unchanged compared to FM-1 / FM-2.	***13***	17	UB	Trg_lev_neg	Negative trigger level
14	18	UW	LisDura	Listening duration Max: 2000 s.	If JobVersion = 0xB: Bits 0 to 14: 0 to 32767 (but <= 2000 s) bit 15=0: *0.1 ms; bit 15=1: *0.1 s	If JobVersion=0, FM-1/FM-2 format applies	***14***	18	UW	Msr_duration	Measurement duration. Does not include Snd_duration.
15	20	BitP	RX_STATUS	Receiver status: selection of sensor channels.		Unchanged compared to FM-1 / FM-2.	***15***	20	UW	Rcv_status	Receiver status: selection of sensor channels.
16	22	BitP	Options	Bit0: GGen Bit1 to 2: GComp Bit3: spare Bit4: TIGen Bit5: TIComp Bit6: Statistics Bit7: SkipTS			***16***	22	UW	GPW1	Not used.
17	23	UB	GTarVal	Absolute target value for AGS.	linearized ADC units; 1 to 255						

Flight Software FM-3							FM 1 and FM 2				
No	***Off-set***	***Data type***	***Name***	***Description***	**Range/ Unit**	**Comment**	***No***	***Off-set.***	***Data type***	***Name***	***Description***
18	24	UB	TLFactor	Factor for calculating trigger levels [10 to 2550 %].	1 to 255 [*10 %]		***17***	24	UW	GPW2	Not used.
19	25	UB	Spare	N/A		Not used.					
20	26	UB	AmpSetup	Amplifier setup time; in sounding mode, the ping will start at t(Burst_on) + AmpSetup.	0 to 255 [*0.1 s]	Should usually be 10 (= 1 s)	***18***	26	UW	GPW3	Not used.
21	27	CB	FIFOLag	Optional corrective offset of the address of the first sample to be transferred.	-127 to +127	Value should be a multiple of nChan (usually = 0), else the identification of channels might be wrong.					
21	28	BitP	FootTemp	Foot temperature channels	See text.	Unchanged compared to FM-1/FM-2	***19***	28	UB	Ft_temp_ch	Foot temperature channels
22	29	UB	AddDelay	Additional delay between measurements of a measurement sequence	0 to 255 [s].		***20***	29	UB	Outbuff_pg	Not used.
23	30	UW		Not used.			***21***	30	UW	Outbuff_adr	Not used.

Table 4.3: Jobcard Formats (FM-3 and previous software versions)

4.2.3 CASSE Health-Check (CAS_HC)

CASSE health-check provides a standard measurement sequence to check the status of the electronics and of all CASSE transmitters and receivers. A ping (1000 Hz, duration 5 ms) is successively transmitted by the transmitters at each foot and simultaneously the accelerometer on the same foot (x, y, z axes; total listening duration per foot: 40 ms, sampling rate per channel: 16 kHz) is listening ("intra-foot sounding"). Amplifier gain is set to 53.79. The measurements are repeated once. Flight software performs a statistical evaluation of channel data for each measurement.

Notes

The operational difference when commanding CASSE health-check compared to the regular measurements is that CAS_HC measuring parameters are fixed in a jobcard in the software code. It is neither necessary to upload a jobcard prior to a CASSE health-check nor is it possible to modify the health-check measuring parameters with a telecommand.

CAS_HC telemetry data is formatted (and can be decommutated) according to the generic format of any CASSE measurement (cf. next chapter) except the measurement ID in the measurement header (which is 0x1000 and not 0x1100).

Expected Science Data Volume

Expected net science data volume is 11988 byte, yielding 48 science data packets including SESAME telemetry packet headers and filling-up of the final packet.

Expected Execution Time

The expected execution time (without data transfer to CDMS) is 11 seconds, if power settings are adjusted before with the CAS_PWRSW command, else 71 seconds.

4.2.4 CASSE Measurement (CAS_MES)

4.2.4.1 Operation Modes

After the reception of a CAS_MES telecommand a previously received set of control and measuring parameters (a jobcard) is executed. The content of some jobcard parameters determines in which (virtual) CASSE operation mode the instrument is operated. The telemetry of the different operation modes consists generally of generic data blocks which do not depend – as far as possible - on the operation mode executed:

A measurement can be regarded as the execution of the **CASSE Listening Mode**, if no transmitter bit is set in the jobcard, no trigger channel is selected and the stacking bit is not set. The order of time series in telemetry corresponds to the order of selected receiver channels in the jobcard, possibly after applying the optional receiver cycling from measurement to measurement.

Triggered Mode is entered if at least one receiver channel is marked as a trigger channel in the jobcard. The telemetry of the Triggered Mode does generally not differ from the telemetry of Listening Mode. A major difference exists concerning the assignment of time series to physical sensor channels, as in Triggered Mode the first time series in telemetry does not necessarily belong to the first active sensor (but the order "channel – next channel" is kept in any case). It is the task of the ground software to determine the assignment of time series to physical sensor channels.

The **Sounding Mode** is characterized by the fact, that at least one transmitter bit is set in the jobcard. The duration of one measurement is calculated as the sum of the ping duration and the subsequent listening duration. The order of time series in telemetry corresponds to the order of selected (“active”) receiver channels in the jobcard, possibly after applying the optional receiver cycling from measurement to measurement.

If the stacked bit is set in the jobcard **CASSE Stacked Mode** is executed. Deviating from all other modes, the time series samples have 16-bit data width to keep the improved resolution due to the on-board stacking of up to 127 measurements. Cycling of receiver channels must not be enabled in stacking mode and the order of time series in telemetry corresponds to the order of active receiver channels in the jobcard.

In any mode, the (optional) channel statistics (in the Channel Statistics data block) are sorted corresponding to the order of time series.

4.2.4.2 Assignment of Time Series to Physical Sensor Channels

In all modes but Triggered Mode the physical channel, to which a time series belongs, can be straight forward inferred from the order of channels in the corresponding jobcard parameter RX_STATUS (considering a possibly commanded cycling of sensor channels between measurements). Time series of Triggered Mode must be assigned using the formula shown in the present chapter.

The telemetry of each measurement contains the FIFO address, from which the first sample of the first time series was read (FIFOFirstDat in the Meta Data Block). In Triggered Mode, the trigger can occur at any time in the time-out interval, and the 128 kB large FIFO RAM might have been filled several times (say: n_{FIFO} times) before the event. Thus actually, the first sample is not the FIFOFirstDatth sample measured, but the (FIFOFirstDat + n_{FIFO}*128k)th sample measured. The FIFO overflow count n_{FIFO} can be computed by exploiting some more information from the Meta Data Block and the Jobcard Block :

$$n_{FIFO} = \mathrm{INT}((\mathrm{TimBurstOff} - \mathrm{TimBurstOn} - \mathrm{LisDura}) * \mathrm{SR} / 2^{17})$$

LisDura is the listening duration (a jobcard parameter). The instrument sampling frequency SR can be calculated from the frequency increment x (parameter no 5 in the Meta Data Block)

$$\mathrm{SR} = x * (\text{processor instruction frequency}) / 2^{16} = x * 76.294$$

We know now, that the first sample of the first time series of a measurement in telemetry is the nth sample measured. It belongs to the (n modulo nChan)th active sensor channel in RX_STATUS, with nChan = number of active sensor channels. Of course all other samples of the first time series belong to the same sensor channel. The subsequent time series in telemetry was generated by the next active sensor in RX_STATUS and so on.

Putting the single formulas together, the position p in RX_STATUS of the active sensor channel belonging to the first time series in the telemetry of Triggered Mode data can be calculated with

$$p = (\mathrm{FIFOFirstDat} + \mathrm{INT}((\mathrm{TIMBurstOff} - \mathrm{TimBurstOn} - \mathrm{LisDura}) * x * 76.294 / 2^{17}) * 2^{17}) \text{ modulo nChan} \quad (4.1)$$

Note that the position is counted starting from 0, i.e. the first channel has position 0.

Example: (GRM test of WOL-3 for PC10, 6th Triggered Mode measurement)
RX_STATUS (from JobCard): 0000000111111111b.
Listening duration (from JobCard): 1.5 s
Burst Off (Meta Data Block): 2366:13:27:24.069 LOBT
Burst On (Meta Data Block): 2366:13:25:09.792 LOBT
FIFOFirstDat (Meta Data Block): 89531
x (Meta Data Block): 177
nChan (Meta Data Block): 9

$$p = (89531 + \text{INT}((134.277 - 1.5) * 177 * 76.294 / 2^{17}) * 2^{17}) \text{ modulo } 9 = 1$$

The first time series of the measurement is generated by the 2nd active channel (position 1) in RX_STATUS. This is channel -Y,y. The assignments of all channels is consequently

```
1 -Y,y
2 -Y,z
3 +X,x
4 +X,y
5 +X,z
6 +Y,x
7 +Y,y
8 +Y,z
9 -Y,x
```

Note that position p refers to the *active* channels in RX_STATUS. If RX_STATUS was e.g. 0000001111111110b (sensor channel –Y,x not active, but –Y,trm), the channel assignment would be (starting again with the second *active* channel)

```
1 -Y,z
2 +X,x
3 +X,y
4 +X,z
5 +Y,x
6 +Y,y
7 +Y,z
8 -Y,trm
9 -Y,y
```

4.2.4.3 Start Times of Times Series

The problem of determining the time axes of all time series of a measurement can be reduced to the determination of the measuring time of the very first sample. Subsequent samples of the same time series are measured at intervals of nChan/SR, with nChan the number of active channels and SR the instrument sampling frequency. The start times of subsequent time series are shifted by 1/SR each.

Because the on-board determination of FIFO RAM addresses and of SESAME High Resolution time involves some latencies and time information includes some inaccuracy itself (in the order of a few milliseconds), redundant information is given in telemetry (Meta Data Block), which can be used to cross-check the data and to evaluate more reliable time stamps by averaging.

Absolute time information is given in telemetry with

(a) TimBurstOn
TimBurstOn is determined just before the CASSE instrument is commanded to start recording of time series. At that point in time CASSE FIFO address is 0. It is assumed that the state of CASSE electronics is settled AmpSetUp (jobcard parameter) after TimBurstOn. In Sounding Mode, the transmitter signal is emitted at (TimBurstOn + AmpSetUp).

(b) TimBurstOff
TimBurstOff is determined just after the CASSE instrument is commanded to stop recording of time series. At that point in time the CASSE FIFO address is FIFOBurstOff.

(c) TimTrigger (only in Triggered Mode)
TimTrigger is measured after a trigger event was recognized by the CASSE hardware and the corresponding interrupt signal was received by flight software. At that point in time the CASSE FIFO address has the value FIFOTrigger.

Time-stamp of the first sample of a measurement
In all modes but Triggered Mode, the first time series in telemetry starts close to (TimBurstOn + AmpSetUp). "Close" means, that flight software determines the start of the first time series by considering that the first sample should come from the first active sensor channel. A commanded FIFO_Lag must be observed additionally. *Flight software* calculates

FIFOFirstDat = AmpSetup * SR – ((AmpSetup * SR) modulo nChan) + FIFO_Lag.

The measuring time of the first sample t_0 can be calculated *on-ground* by (all modes but Triggered Mode)

$$t_0 = \text{TimBurstOn} + \text{FIFOFirstDat} / \text{SR} \quad (4.2)$$
$$t_0 = \text{TimBurstOff} - (\text{FIFOBurstOff} - \text{FIFOFirstDat}) / \text{SR}. \quad (4.3)$$

The results of equations 4.2 and 4.3 should not differ by more than a few milliseconds (TBC). The mean shall be used as *the* start time of the first time series and as reference for all sample measuring times.

In Triggered Mode *flight software* calculates FIFOFirstDat simply from the current FIFO address at the time, when the trigger occurred, or – without trigger event – from the final address in FIFO RAM after stopping the measurement. No adjustment concerning the channel assignment of the start sample is made. FIFO_Lag is ignored.

On ground, an equation similar to 4.2 can be used to determine the start time with reference to TIMBurstOn. But it has to be taken into account, that FIFOFirstDat is the current address in the FIFO only and the FIFO could have been filled several times before. The reference to TIMBurstOff is equal to 4.3 and another equation (4.6) can be used to exploit the third time stamp (which is available if a trigger event occurred, i.e. not with a "time out" error). The results of equations 4.4 to 4.6 should not differ by more than a few milliseconds. The mean shall be used as *the* start time of the first time series.

Triggered Mode:

$$t_0 = \text{TimBurstOn} + (\text{FIFOFirstDat} + n_{\text{FIFO}} * 2^{17}) / \text{SR} \quad (4.4)$$
$$t_0 = \text{TimBurstOff} - (\text{FIFOBurstOff} - \text{FIFOFirstDat}) / \text{SR} \quad (4.5)$$
$$t_0 = \text{TimTrigger} - (\text{FIFOTrigger} - \text{FIFOFirstDat}) / \text{SR} \quad (4.6)$$

Note that a possible FIFO overflow must be corrected when subtracting FIFO addresses (add 2^{17} if the subtractions in 4.5 to 4.6 yield negative results).

4.2.4.4 Conversion of Sample Values to Acceleration

Transfer functions are known for the accelerometer channels only. Transmitters are rarely used as receivers and currently only for qualitative measurements. It is TBD, whether transmitters can be calibrated.

Several steps are necessary to calculate acceleration from a time series sample value:

(1a) All modes but Stacking Mode

Convert the sample's CB format to the number representation of the computer/programming language which is used on ground. That yields the ADC output value adc.

Linearize the sample value adc by inverting the inbuilt flattening of the ADC characteristics (cf. RD3) and convert the results to voltage at ADC (mV), e.g. by using

```
if (adc > 96) mV = 51.562 * adc - 3300.;
else if (adc > 64) mV = 25.781 * adc - 825.;
else if (adc < -96) mV = 51.563 * adc + 3300.;
else if (adc < -64) mV = 25.781 * adc + 825.;
else mV = 12.89 * adc;
```

(1b) Only Stacking Mode

Divide the sample, which is actually the sum of linearized samples from several measurements, by the number of measurements nMeas and perform voltage conversion

mV = 12.89 * sampleValue / nMeas.

In fact it is expected that some ("nFail") of the nMeas measurements fail and deliver constant signal values only, because the instrument sometimes gets stucked. This can be detected with the channel statistics of the single measurements (min = max = mean). SampleValue must then be corrected. To this end, subtract the constant value(s) from sampleValue to yield sampleValue and calculate mV by dividing by the number of successful measurements

mV = 12.89 * sampleValue* / (nMeas – nFail).

(2) Convert the voltage at the ADC (mV) to the output voltage of sensors by considering the adjusted instrument gain.

U_{out}[mV] = mV / gain.

The gain is related to the adjusted AGC value (parameter in the Meta Data Block) and the nominal gain can be calculated according to (cf. RD3)

```
float calcGain(unsigned short AGCvalue) {
  float rtnVal = 1.0;
  if (!(AGCvalue&0x01)) rtnVal *= 3.13;
  if (!(AGCvalue&0x02)) rtnVal *= 2.13;
  if (!(AGCvalue&0x04)) rtnVal *= 4.55;
  if (!(AGCvalue&0x08)) rtnVal *= 5.55;
return (rtnVal);
}
```

(3) Convert the output voltage of accelerometer channels to acceleration. The sensitivity of the accelerometers (at 159.2 Hz) is 10 mV/(ms^{-2}). The (nominal) transfer function is

$$a[ms^{-2}] = f(sensor, T) * U_{out}[mV]/10.$$

with f(sensor, T) a factor close to 1 for all sensors, which varies only little with the sensor temperature T.

4.2.4.5 Telemetry Data Blocks

Previously (FM-1, FM-2) and now (FM-3) used telemetry block headers in CASSE measurement data (CAS_MES, CAS_HC):

CASSE Block Headers			
Name	**Value**	**Meaning**	**Comment**
BH_JOBCARD	0x0707	Jobcard parameters	
BH_ERRCODE	0x8888	Error code	
BH_TEMP_DOSE	0x1515	Temperature&Dose data	Generated only with S/W version >= FM-3.0
BH_BURSTMES3	0x7171	Burst data (listening or sounding mode)	
BH_TRIGMES3	0x7272	Triggered Mode data	
BH_STACKED	0x7373	Stacking Mode data	
BH_FIFO_CHAN3	0x7777	Sensor channel time series (ADC sample format)	
BH_FIFO_STACKED	0x7878	Sensor channel time series (stacked linearized sample data)	
BH_STATS	0x9999	Channel statistics	
BH_FOOT_TEMP	0x1414	Foot temperatures	Generated only with S/W version < FM-3.0
BH_BURSTMES	0x2121	Burst data (listening or sounding mode)	
BH_TRIGMES	0x2222	Triggered Mode data	
BH_FIFO_CHAN	0x6666	Sensor channel time series	

Note: The Meta Data Block does not have a block header.

JOBCARD DATA BLOCK						
Item No.	**Byte No.**	**Length [Byte]**	**Data Type**	**Name**	**Value**	**Remarks**
1	0 to 1	2	UW	Block Header	0x0707	Block Header
2	2	1	UB	JobID		
3	3	1	UB	JobVersion	0 or 0x0B	
4	4	1	UB	StartCondition		Not used
5	5	1	UB	nMeas_stacked		Number of measurements nMeas=(nMeas_stacked AND 0x7F); stacked = (nMeas_stacked AND 0x80) > 0;
6	6 to 7	2	UW	Sound frequency [Hz]		
7	8 to 9	2	UW	Sound duration (SndDura) or trigger time-out		In Sounding Mode: sound duration; in Triggered Mode: time-out.
8	10 to 11	2	UW	Channel sampling frequency [10 Hz]		
9	12	1	BitP	Transmitter channels		Selected transmitter channels

JOBCARD DATA BLOCK						
						(input to TC register)
10	13	1	UB	Value of CASSE Amplifier Gain Control (AGC) register		Nominal AGC value; a different gain can be adjusted by automatic gain setting.
11	14 to 15	2	BitP	Trigger channels		Bit pattern (input to TS1 and TS2 registers) indicating the sensor channels able to generate trigger signals.
12	16 to 17	2	W	Trigger delay (TrgDelay) [0.1 ms]		Time period before / after a trigger event to be included in telemetry.
13	18	1	CB	Negative trigger level		Inputs to CASSE trigger threshold registers; values can be modified by flight software (see item 17 “Options”).
14	19	1	CB	Positive trigger level		
15	20 to 21	2	UW	Listening duration (LisDura)		
16	22 to 23	2	BitP	Receiver channels		Receiver channel(s) to be activated. See text.
17	24	1	BitP	Options		See text
18	25	1	UB	GTarVal		Target value used for automatic gain control.
19	26	1	UB	TLFac [10%]		Sensitivity factor used for automatic trigger level setting.
20	27	1	n/a	Spare		
21	28	1	UB	AmpSetUp [0.1 s]		Amplifier setup time
22	29	1	CB	FIFO_LAG		See text.
23	30	1	BitP	Selected foot temperature channels.		See text.
24	31	1	UB	Additional Delay [s]		Additional delay between measurements of a measurement sequence.
25	32 to 33	2	n/a	Not used.		

META DATA BLOCK						
Item No.	**Byte No.**	**#byte**	**Data Type**	**Name**	**Value**	**Remarks**
1	0	1	2N	Power register setting / mode		Bits 0 to 3: value of power control register Bits 4 to 7 = 0: power set during measurement initialization Bits 4 to 7 = 1: power set by previous CAS_PWRSW command:
2	1	1	UB	AGC register value	0 to 15	Value of amplifier gain control register.
3	2	1	UB	SLTLA	0 to 11	Value of sensor lookup table length and address register (number of sensor channels nChan = SLTLA + 1)
4	3	1	UB	Frequency divider	1 to 15	Value of transmitter frequency control register
5	4 to 5	2	UW	Frequency increment	1 to 1312	Value of sampling rate control registers

META DATA BLOCK						
6	6	1	CB	Negative trigger level		Value of lower trigger threshold register
7	7	1	CB	Positive trigger level		Value of lower trigger threshold register
8	8 to 9	2	BitP	Trigger Status		Contents of trigger status register indicating the channel(s) which triggered.
9	10 to 11	2	UW	TimBurstOn (high)		SESAME High Resolution Time at start of recording
10	12 to 13	2	UW	TimBurstOn (low)		
11	14 to 15	2	UW	TimTrigger (high)		SESAME High Resolution Time when trigger occurred (in Triggered Mode, else TimTrigger=0)
12	16 to 17	2	UW	TimTrigger (high)		
13	18 to 19	2	UW	TimBurstOff (high		SESAME High Resolution Time, when recording was stopped.
14	20 to 21	2	UW	TIMBurstOff(low)		
15	22 to 23	2	UW	FIFOTrigger (high)		FIFO address when trigger occurred.
16	24 to 25	2	UW	FIFOTrigger (low)		
17	26 to 27	2	UW	FIFOBurstOff (high)		FIFO address of the final sample after recording stopped.
18	28 to 29	2	UW	FIFOBurstOff (low)		
19	30 to 31	2	UW	FIFOFirstDat(high)		FIFO address of the first sample included in telemetry.
20	32 to 33	2	UW	FIFOFirstDat(low)		
20	34 to 35	2	UW	nSamp (high)		nSamp = number of samples per channel in telemetry.
21	36 to 37	2	UW	nSamp (low)		

Notes
(1) After "burst on", the recording of sensor signals starts and the first sample of the first sensor channel in the sensor lookup table is stored in FIFO address 0 (FIFOBurstOn = 0).
(2) The giving of high resolution time stamps and FIFO addresses provides some redundancy, as both magnitudes are related via the sampling frequency. TimBurstOn and TimBurstOff are determined just before (TimBurstOn) or shortly after (TimBurstOff) the respective action takes place, while TimTrigger is measured after the instrument signalled a trigger event. FIFOBurstOff and FIFOFirstDat are exact, but FIFOTrigger is read from the instrument after the trigger signal was received by flight software while recording is in progress. Depending on the sampling frequency and the latency of instrument-software communication, FIFOTrigger is somewhat higher (a few samples) than the actual value.
(3) In Triggered Mode, the address FIFOFirstDat does not necessarily contain a sample of the first channel in the sensor lookup table.

REGULAR (non-stacked) CHANNEL DATA BLOCK						
Item No.	**Byte No.**	**Length [Byte]**	**Data Type**	**Name**	**Value**	**Remarks**
1	0 to 1	2	UW	Block Header	0x7777	
For each channel in measurement (nChan times)						
For each sample in channel (nSamp times)						
2	+1	1	CB	Time series sample	-127 to +127	Sample value in ADC output format (inbuilt ADC characteristics not inverted)

The values for nChan and nSamp must be taken from the Meta Data block.

STACKED CHANNEL DATA BLOCK						
Item No.	**Byte No.**	**Length [Byte]**	**Data Type**	**Name**	**Value**	**Remarks**
1	0 to 1	2	UW	Block Header	0x7878	
For each channel in measurement (nChan times)						
For each sample in channel (nSamp times)						
2	+1 to +2	2	W	Time series sample	-32004 to +32004	Linearized sample values (inbuilt ADC characteristics inverted) summed over all measurements

The values for nChan and nSamp must be taken from the Meta Data block.

CHANNEL STATISTICS BLOCK						
Item No.	**Byte No.**	**Length [Byte]**	**Data Type**	**Name**	**Value**	**Remarks**
1	0 to 1	2	UW	Block Header	0x9999	
For each channel in measurement (nChan times)						
2	+1	1	CB	Minimal channel sample value	-127 to +127	Sample value in ADC output format (inbuilt ADC characteristics not inverted)
3	+2	1	CB	Maximal channel sample value	-127 to +127	Sample value in ADC output format (inbuilt ADC characteristics not inverted)
4	+3 to +4	2	W	10 * Mean of channel sample values	-2520 to +2520	Mean of linearized sample values times ten.

The value for nChan must be taken from the Meta Data block. Note that the order of channels corresponds to the order of time series.

TEMPERATURE & RADIATION DOSE BLOCK						
Item No.	**Byte No.**	**Length [Byte]**	**Data Type**	**Name**	**Value**	**Remarks**
1	0 to 1	2	UW	Block Header	0x1515	.
2	2 to 3	2	W	Temperature Foot –Y, TRM		Voltage in mV; Calibration TBD (see text for a preliminary solution to allow testing).
3	4 to 5	2	W	Temperature Foot –Y, ACC		
4	6 to 7	2	W	Temperature Foot +X, TRM		
5	8 to 9	2	W	Temperature Foot +X, ACC		
6	10 to 11	2	W	Temperature Foot +Y, TRM		
7	12 to 13	2	W	Temperature Foot +Y, ACC		
8	14 to 15	2	W	CASSE PCB temperature		
9	16 to 17	2	W	RadFET voltage		0.002 V/mV

ERROR CODE BLOCK						
Item No.	**Byte No.**	**Length [Byte]**	**Data Type**	**Name**	**Value**	**Remarks**
1	0 to 1	2	UW	Block Header	0x8888	
2	2 to 3	2	BitP	Error Code		See list of CASSE error flags, which are combined in the error code.

4.2.4.6 Error Flags

Error codes are composed of the following bit settings, e.g. error Code 0x03 = (EB_FREQ | EB_DIVRAT) indicates a non fatal error during adjustment of sounding and sampling frequency.

CASSE Error Flags		
Value (hex)	**Name**	**Meaning**
0001	EB_FREQ	Invalid frequency increment (adjustment of sampling frequency); default (= 1312) used.
0002	EB_DIVRAT	Invalid frequency divider (adjustment of sounding frequency); default (= 1) used.
0004	EB_CDPU_ADC	Error during temperature A/D conversion.
0010	EB_TIMEO	Time-out during triggered mode.
4008	EB_NCHAN	Always fatal: Invalid number of sensor channels
4020	EB_NOSTRT	Always fatal: Measurement start condition not fulfilled.
0080	EB_NSAMP	Calculated number of samples/measurement > 128kB
0100	EB_DURA	Sounding or listening duration invalid.
0200	EB_AUTO	No base value for automatic gain or trigger level adjustment.
0400	EB_MATH	Numerical exception; check command parameters
8040	EB_RAMOVR	Fatal: Allocated SESAME SRAM space exhausted.
4000	EB_FATAL_MES	Fatal error or time-out; current measurement will be aborted.
8000	EB_FATAL_SEQ	Fatal error; entire sequence of measurements (controlled by one jobcard) will be aborted.

4.2.4.7 Proposed Decommutation Program Flow

0. Read SESAME Science Data Measurement Header
If Measurement ID equal 0x1000 or 0x1100 -> CASSE measurement data.

1.1 Read block header
Block header must be BH_JOBCARD = 0x0707, else error “No Jobcard telemetry block”.
With software version FM-3, the jobcard is always included in telemetry. Earlier software versions used a flag in the jobcard which determined whether the full or only a part of the jobcard shall be included in telemetry (however, for flight operations and GRM tests this flag was always set to “Include full jobcard”).

1.2 Read Jobcard telemetry block
The interpretation of jobcard parameters is not a necessary prerequisite for a successful decommutation of CASSE telemetry, but it helps to check the proper application of jobcard parameters by the flight software.

2. Read block header.
Possible cases:
SWITCH (header)
CASE 0x1414: Read Foot Temperature Block, FM-1 / FM-2 calibration applies.
Read Error Code Block (errors during initialization)
ENDCASE
CASE 0x1515: Read Temperature&Radiation Dose Block, FM-3 calibration applies.

Read Error Code Block (errors during initialization)
ENDCASE
CASE 0x8888: Read Error Code Block (errors during initialization)
ENDCASE
ENDSWITCH

Temperature/RadFET data are expected if at least one foot temperature measurement is commanded in the jobcard.
If a fatal error is indicated in the error code word proceed with step 6.

3.1 Read block header
3.2 Proceed depending on block header value:
SWITCH (header)
CASE 0x2121: Burst Mode data (FM-1 or FM-2 software); proceed with known FM-1 / FM-2 decommutation
ENDCASE
CASE 0x2222: Triggered Mode data (FM-1 or FM-2 software); proceed with known FM-1 / FM-2 decommutation
ENDCASE
CASE 0x7171: Burst Mode data (FM-3 software); proceed with next step
ENDCASE
CASE 0x7272: Triggered Mode data (FM-3 software); proceed with next step
ENDCASE
CASE 0x7373: Stacking Mode data (FM-3 software); proceed with next step
ENDCASE
ENDSWITCH

4. Read Meta Data Block
At least the number of channels (=SLTLA+1) and the number of samples per channel read from the Meta Data Block are used later to read the time series. Time stamps and FIFO addresses are used later to determine the start time of time series.

5. Read block header
Possible cases:
SWITCH(header)
CASE 0x7777: Read Channel data block (Burst Mode or Triggered Mode; “regular” format”)
Read Error Code Block (errors during measurement)
ENDCASE
CASE 0x7878: Read Stacked Channel data block
Read Error Code Block (errors during measurement)
ENDCASE
CASE 0x8888: Read Error Code Block (errors during measurement)
ENDCASE
ENDSWITCH

Channel data are expected for a measurement

- In Stacking Mode (but only once in the measurement loop)
- In Triggered Mode only, if no time out occurred or it is the final measurement and all preceding measurements ended with time outs.
- In Burst Mode (Listening or Sounding) only if the “SkipTS” flag is not set in the jobcard.

6. Read block header
SWITCH(header)
CASE 0x1515: Read Temperature & Radiation Dose Block
STOP
ENDCASE
CASE 0x9999: Read Channel Statistics block
Proceed with step 2.0 (read error code after initialization of next measurement)

until all measurements of the measuring sequence are processed.
ENDCASE
Default: If (EB_FATAL_SEQ is set in Error Code) STOP
Else
Proceed with step 2 (read error code after initialization of next measurement) until all measurements of the measuring sequence are processed.
ENDSWITCH

4.2.4.8 Data Volume and Execution time

Data Block	Length [byte]	Number of Data Blocks per Measurement Sequence
Science Data Measurement Header	14	1
Jobcard Data Block	34	1
Meta Data Block	38	= 1, if in Stacking Mode, else = nMeas.
Regular Channel Data Block	2 + nChan * nSamp Can be estimated with 2 + SR * (LisDura+SndDura)	= 0, if in Stacking Mode or option SkipTS is set, else = nMeas
Stacked Channel Data Block	2 + 2 * nChan * nSamp Can be estimated with 2 + 2 * SR * (LisDura+SndDura)	= 0, if not in Stacking Mode, else = 1
Channel Statistics Block	2 + nChan *4	= 0, if option Statistics not chosen and not in Stacking Mode, else = nMeas
Temperature / Radiation Dose Block	18	= 0 (no temperature channel selected) = 1 (at least one channel selected, but flag “Additional after job” not set) = 2 (at least one channel selected, and flag “Additional after job” set)
Error Code Block	4	= 2 * nMeas, if not in Stacking Mode, else = 2

Total data volume: TBD
Execution time: TBD

4.2.5 CASSE Receive Jobcard (CAS_RJC)

The telecommand is used to upload a jobcard, which is contained in the parameter words. Subsequent CASSE measurements invoked by telecommand CAS_MES are controlled by the uploaded jobcard. The jobcard is valid until another CAS_RJC command arrives or until SESAME is switched off.

No science data are generated. The execution of the telecommand takes less than one second.

4.2.6 CASSE Power Switch (CAS_PWRSW)

The CASSE power switch command (CAS_PWRSW, 0x1501) fixes the CASSE power settings for all subsequent CASSE measurements (invoked by CAS_MES or CAS_HC) of a procedure (until a further CAS_PWRSW command or SESAME is switched off). The data word of the CASSE power switch command is the nominal value of the CASSE power register (cf. RD3). It is thus possible to switch CASSE power circuits individually (not just "all circuits on or off" as with previous software versions). A waiting period of at least one minute shall be applied after sending CAS_PWRSW and before executing a measurement, because the power status of the accelerometers changes slowly only.

In case no CAS_PWRSW is received the standard measurement settings (all CASSE circuits on, one minute waiting period before the actual measurement starts) will be applied.

No science data are generated. The execution of the telecommand takes less than one second.

4.2.7 CASSE Test/Debug (CAS_TEST)

The operations executed upon a CAS_TEST command are used for dedicated test and debug purposes. They are not part of the regular CASSE measurement suite and it is probably not necessary to include the telemetry in the Planetary Science Archive (TBC).

The first TC parameter ("mode") determines which operation is executed. Upon mode = 0, base statistical data of a preceding CASSE measurement (CAS_MES or CAS_HC) are dumped to telemetry. Flight software normally uses these data for the calculation of gain and trigger levels when automatic gain or trigger level adjustment is in effect. The values of TC data words 2 and 3 are ignored by flight software in this mode, but the data words must exist.

With mode = 1, the two kinds of time stamps (SESAME Local and High Resolution Time) are generated and included in telemetry. The remaining TC data words contain the time period between time stamps and the number of time stamps to be generated.

Expected SD output for CAS_TEST command

No.	Byte No	Data Type	Meaning	Typical value	Remarks
1	0 to 13	DB	Science Data Header		ID = 0x1A03
2		DB	Data Block "CASTEST-M1" or "CASTEST-M2"		

Data Block CASTEST-M1

No.	Byte No	Data Type	Meaning	Typical value	Remarks
1	0 to 1	BitP	Block Header	0xA0A0	0xA0A0 corresponds to TC parameter mode = 0
2	2 to 3	UW	nChan	0 to 12	Number of active channels in preceding measurement
3	4 to 5	UW	GAIN.GAIN	100 to 16836	Adjusted gain (*100) when base data for AGS where determined.
4	6 to 7	UW	TL.GAIN	100 to 16836	Adjusted gain (*100) when base data for ATL where determined.
5	8 to 9	UW	CURR.GAIN	100 to	Last adjusted gain (*100).

				16836	
6	10 to 33	12* UW	12 * GAIN.SABS(channel)	0 to 255 each	Maximal absolute, linearized, sample values of all channels (sorted)
7	34 to 57	12* W	12 * TL.SMIN(channel)	-252 to +252 each	Minimal, linearized, sample values of all channels
8	58 to 71	12* W	12 * TL.SMAX(channel)	-252 to +252 each	Maximal, linearized, sample values of all channels
9	72 to 95	12* W	12 * TL.SMEAN*10(channel)	-2520 to +2520 each	Mean (*10) of linearized sample values of all channels
10	96 to 119	12* UW	12 * IsTriggerChannel(channel)	True: 0xFFFF False: 0x0000	Indicates whether a channel is regarded as trigger channel or not.

Note: AGS = Automatic Gain Setting
ATL = Automatic Trigger Level Setting

Data Block CASTEST-M2					
No.	**Byte No**	**Data Type**	**Meaning**	**Typical value**	**Remarks**
1	0 to 1	BitP	Block Header	0xA1A1	0xA1A1 corresponds to TC parameter mode = 1
2	2 to 3	UW	Delta [s]	1 to 255	Time gap between time stamps.
3	4 to 5	UW	nStamps	1 to 30	Number of time stamps generated.
nStamps times					
4	+1 to +2	UW	SESAME Local Time (high)		
5	+3 to +4	UW	SESAME Local Time (low)		
6	+5 to +6	UW	SESAME HiRes Time (high)		
7	+7 to +8	UW	SESAME HiRes Time (low)		

4.2.8 Overview of new/modified CASSE Features with Flight Software FM-3

CASSE Power Switching

The CASSE power switch command (CAS_PWRSW, 0x1501) now fixes the CASSE power settings for all subsequent measurements of a procedure (until SESAME is switched off). In case no CAS_PWRSW is received the standard measurement settings (all CASSE circuits on, one minute waiting period before the actual measurement starts) will be applied. The parameter of the CASSE power switch command now is the nominal value of the CASSE power register. It is thus possible to switch CASSE power circuits individually (not just “all circuits on or off” as previously).

Identification of Sensor Channels

A new measuring strategy shall ensure that channel data in telemetry can be unambiguously assigned to the physical sensor channels. That is essentially achieved by combining the blind measurement for amplifier setup and the actual sample recording into a single measurement to avoid a reset problem in the CASSE FPGA program.

In all modes but Triggered Mode the order of time series in telemetry corresponds to the order of channels in the CASSE Sensor Lookup Table. In Triggered Mode, the value of FIFOFirstDat in telemetry can be used to determine on ground the channel assignment of a time series using the algorithm described in chapter 4.2.4.2.

Stacking Mode

In order to increase the signal to noise ratio of sounding measurements, a stacking mode has been implemented. The time series of up to 127 measurements can be summed-up on-board after linearization (i.e. inversion of the in-built “quasi-logarithmic” characteristics of the CASSE ADC) of each sample value. In order to keep the improved resolution, the stacked sample values are transferred to ground with 16 bit data width.

CASSE Health-Check

The CASSE health-check measuring sequence has been changed. Major differences refer to the sounding frequency (now 1000 Hz) and that all measurements are executed twice.

Triggered Mode

The triggered mode will always return at least one set of time series, even if all measurements of a sequence ended with a time-out (no trigger signal received). Consequently, a time-out is now indicated in the error code word with two different bit settings:

error code = 0x4010 (time-out and fatal flag set): time-out during triggered mode, no time-series data included in telemetry

error code = 0x0010 (time-out flag set): time-out during triggered mode, time-series data (the final nSamp values before the time-out occurred) are included in telemetry.

Automatic Gain and Trigger Level Adjustment

The automatic calculation and adjustment of the gain and trigger level settings is a two-step process. Firstly a (at least one) measurement must be executed to obtain information about the signal strength with the given instrument settings. This measurement stores statistical data of the time series in SESAME RAM, which are (second step) used to adjust optimal values of instrument settings considering user defined target values.

The first step, the *generation* and saving of base statistical data for later adjustment of gain and trigger levels, is invoked by setting one or both “Gen” flags (GGen, TLGen) in the jobcard. The base data are available unless overwritten by another measurement with “Gen”-flags set and SESAME is not power-cycled. Later measurements with a “Comp”-flag (GComp or TLComp) not equal to zero use the base data and user supplied target values to *compute* optimized instrument settings.

The control of automatic gain and trigger level adjustment by individual flags in the jobcard provides optimal flexibility, but it must rely on a reasonable commanding from ground. The ground software (command generator) and the operations planning shall particularly consider:

- Base data for automatic trigger level adjustment (TLGen = 1) can not be generated in Triggered Mode. They must be determined with a Listening Mode measurement (or, if this is considered to be reasonable, in Sounding Mode).
- At least two listening measurements shall be executed when determining base data for optimal gain adjustment *and trigger level simultaneously*, because after the first measurement trigger level data are based on a possibly not optimal gain setting.
- Preferentially, Triggered Mode measurements shall be executed with a similar gain than the previous measurement which determined the base data.
- Generally, it does not make sense to execute a measurement with the “Comp”-flags set without a preceding measurement, which generated the base data. But it is possible to combine step one and two of the automatic adjustment by setting “Gen” and “Comp”-flags simultaneously. This enables the optimization of the base values in an iterative way by executing a measurement sequence.
- The computation of optimal gain and / or trigger level settings requires the presence of reasonable target values in the jobcard.
- The GGen flag shall not be set for a Stacking Mode measurement.
- TLGen shall not be set in Triggered Mode.
- Cycling of receiver channels shall not be commanded in Triggered Mode.
- In Stacking Mode, the cycling of transmitter or receiver channels shall not be commanded.

Time Series in Telemetry
Depending on a flag in the jobcard (“options”), time series data are included in telemetry or not. The flag is not evaluated in Stacking Mode (in this mode, the time series of single measurements are never and the stacked time series are always included).

Statistics
Depending on a flag in the jobcard, minimum, maximum and mean of the time series samples of each sensor channel are included in telemetry or not.

Extended Time Ranges
With jobcard version = 0xB, longer sounding and listening time periods can be commanded than with version = 0.

Temperature Measurements, new “Temperature&Radiation Dose” Data Block
Temperature measurements are now performed with a new method. Consequently, the raw (voltage) values have to be converted into temperatures with a different calibration than those obtained with previous software versions.
The new calibration (TBD) depends on two reference voltage values, which do not change rapidly. They can be taken from housekeeping. Additionally, the results of the new method depend on the PCB-temperature (as the values obtained with the old method do). The voltage in the CASSE PCB temperature channel was thus added to the temperature block.

The CASSE RadFET voltage is now included in the block. The rationale for that is, that CASSE measurements usually take place at least one minute after CASSE analogue power is switched on, thus sufficient setup duration for the RadFET readout is automatically given. We can therefore reduce the duration of the SESAME HC, which was prolonged just for this purpose. Temperature and RadFET measurements can be handled coherently in flight software, because voltages measurements of only differing CASSE MUX channels are performed. The block header changed from 0x1414 (FM-1 and FM-2 software) to 0x1515.

If additional temperature measurements are commanded in the jobcard, they will not be performed after each single measurement, but only once after the entire measurement sequence.

HiRes-Time
The SESAME High Resolution Time is used for some time-stamps.

4.3 DIM Telecommanding and Telemetry

4.3.1 Table of Telecommands

DIM: Defined Telecommands					
IDENT	Command Word	Parameter Words			Description
		No	Meaning	Valid Range	
DIM_PC	3000	n/a	n/a	n/a	DIM Power Check
DIM_NT	3100	n/a	n/a	n/a	DIM Noise Test
DIM_ST	3202	1	Margin [dB]	0, 10, 20, .. 70	DIM Sensor Test
		2	Direction (sensor face)	=0: X, =1: Y, =2: Z	
DIM_CA	3302	1	Margin (low level calibration) [dB]	0, 10, 20, .. 70	DIM Calibration
		2	Margin (high level calibration) [dB]	0, 10, 20, .. 70	
DIM_AV	3404	1	Direction (sensor face)	=0: X, =1: Y, =2: Z	DIM Average Continuous Measurement
		2	Energy control	not evaluated by flight software.	
		3	Sampling interval [s]	> 2 << measuring time	
		4	Measuring time [s]	> 0	
DIM_PWRSW	3501	1	Power Mode	= 0: power off = 1: power on	Power switching via DIM select line (no TM is generated)
DIM_BC	3606	1	Direction (sensor face)	=0: X, =1: Y, =2: Z	DIM Burst Continuous Measurement (storage of measured values in (U,T) matrix)
		2	Margin [dB]	0, 10, 20, .. 70	
		3	Energy control	not evaluated by flight software.	
		4	Sensor signal decay time [ms]	0 < t < 255 ACHTUNG SW: 2 bis 100 TBC	
		5	Sampling interval [s]	=0: no sampling >0: sampling	
		6	Measuring time [s]	>0	
DIM_HC	3A03	1	Margin (low level calibration) [dB]	0, 10, 20, .. 70	DIM Health Check
		2	Margin (high level calibration) [dB]	0, 10, 20, .. 70	
		3	Margin (Sensor Test) [dB]	0, 10, 20, .. 70	
DIM_MES	3F02	1	Sensor signal decay time [ms]	1 < t < 255 ACHTUNG SW: 2 bis 100 TBC	DIM Autonomous Measuring Mode
		2	Nominal total execution time [s]	> 120; for significant Burst Continuous measurements: > 300	

DIM: Defined Telecommands					
DIM_BCTEST2	3E06	1.	Direction (sensor face)	=0: X, =1: Y, =2: Z	DIM Burst Continuous Test Mode (includes time stamps for each dust impact event); version 2 for flight software version FM-3
		2.	Margin [dB]	0, 10, 20, .. 70	
		3.	Energy control	not evaluated by flight software	
		4.	Signal decay time [ms]	0 < t < 255 ACHTUNG SW: 2 bis 100 TBC	
		5.	Sampling interval [s]	not evaluated by flight software	
		6.	Measuring time [s]	> 0	
DIM_SPEC	3D02		two data words		Used for flight software debugging on-ground only (“undocumented feature”).

4.3.2 DIM Impact Measuring Values

Depending on DIM measuring mode, the instrument delivers up to three measuring parameters.

4.3.2.1 Impact duration

The impact duration (half contact time) of a single dust impact corresponds to the first “half-sine” of the signal. Flight software reads the number of ticks (TC) of a 20 MHz clock from two DIM hardware registers (low byte / high byte). The impact duration in physical units is t_c [μs] = TC / 20.

Either the counter value TC or the logarithmically scaled value T_c is included into telemetry:

$$T_c[\mathrm{dB}] = 20 * \log10(2 * TC) = 20 * \log10(40 * t_c\,[\mu s]).$$

The actual algorithm in flight software applies a function “*1000*LG10*()”, which returns an approximation of the common logarithm multiplied by 1000 and it considers rounded division to yield the integer result:

$$T_c[\mathrm{dB}] = \mathrm{INTEGER}((1000{*}LG10(TC)+25)/50) + 6 \qquad \text{(DIM.1)}$$

The measuring range is limited by the clock frequency (20 MHz corresponding to a resolution of 50 ns) and the low frequency limit of the log-amplifier (which is approximately 10 kHz yielding an upper limit of 25 μs for t_c). Thus the following instrument limits have been specified: $t_{c,\,min}$ = 100 ns and $t_{c,\,max}$ = 25 μs, which corresponds to TC_{min} = 2, TC_{max} = 500, or $T_{c,\,min}$ = 12 dB and $T_{c,\,max}$ = 60 dB.

Depending on impact duration, flight software identifies “false” and “long” events using the algorithms specified in RD1 (procedures Single_burst() and Burst_Continuous()). The numbers of discarded events are included into burst-mode telemetry. Flight software scales the remaining “true” events according to equation DIM.1. The resulting T_c values are restricted to [10 dB, 70 dB]. Impacts with T_c <= 10 dB are counted as impacts with 10 dB, impacts with T_c >= 70 dB are counted as impacts with 70 dB (if any).

4.3.2.2 Peak Voltage

The instrument provides the peak voltage U_{out} of a single dust impact after peak detection and logarithmic amplification. Setting the appropriate C-DPU and CASSE multiplexer channels, U_{out} is determined using the ADC of the C-DPU. The maximum value is $U_{out,\ max}$ = 3000 mV. The transfer characteristic of the DIM log-amplifier is slightly different for the FM and GRM and can vary with time (the calibration procedure checks that; cf. the transfer characteristics of FM and GRM according to ground calibration in RD2). For storage during Burst Continuous, flight software uses a fixed scaling:

$$U[dB] = INTEGER((U_{out}[mV] - 500 + 15) / 30). \qquad (DIM.2)$$

Thus U_{max}[dB] = 83. Potential negative results from equation DIM.2 are added to the U[dB] = 1 bin.

4.3.2.3 Average Signal Height

The DIM averaging circuit measures an analogous value for the average signal height. It is digitized using the ADC of the Common DPU, thus the maximum value is 3000 mV. For further on-board processing a scaled value A[dB] = (A[mV]+15) / 30 is computed (A_{max}[dB] = 100). The averaging time period T_AVER_SETTL is controlled by flight software. T_AVER_SETTL is 4 seconds in flight software versions FM-1 and FM-2 and T_AVER_SETTL = 2 seconds in flight software FM-3.

In order to be prepared for potential big differences of the average signal when switching from one sensor direction to another, in flight software FM-3 a dummy measurement of the average value is included prior to the first “real” measurement of the average signal (the results of the dummy measurement are discarded).

4.3.3 DIM Power Check (DIM_PC)

DIM Power Test verifies that DIM supply voltages are within predefined limits. Accepted ranges are (-5.0 ± 0.5) V on -5 V line and (+5.0 ± 0.5) V on +5 V line. Measured voltage values are included into telemetry. The error bit EB_BAD_HEALTH is set when at least one of the supply voltages are out of range.

Expected SD output for DIM Power Check				
Item No.	**Byte No.**	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
1	0 to 13	Science Data Measurement Header	BCDE BCDE 3000 0000 0018 tttt tttt	ID = 0x3000; length = 0x18 = 24 byte
2	14, 15	Block header: Power Check Data	6363	
3	16, 17	Voltage on +5V line	e.g. 1388	Voltage in HK format; e.g. 0x1388 => 5000 mV
4	18, 19	Voltage on -5V line	e.g. 5388	Voltage in HK format; e.g. 0x5388 => -5000 mV
5	20	Error Code	e.g. 00	EB_BAD_HEALTH if power out of limits
6	21, 22	Block delimiter: end of Power Check Data	9C9C	
7	23	Padding character	00	

If Power Check is invoked by telecommand DIM_PC, the generated data volume is one science data packet. If executed implicitly by commanding DIM_HC or DIM_MES, the net measurement length (24 byte) is used up.

The execution duration is less than 1 second (plus 10 s warm-up time if individually commanded and DIM not powered before).

4.3.4 DIM Noise Test (DIM_NT)

DIM Noise Test measures electronic noise on DIM amplifier. Starting with margin = 0, the lower detection threshold (margin) is increased in steps of 10 dB until no pulse is detected (with sensor disconnected). If events are detected even with maximum margin (70 dB), the error bit EB_NOISY_AMP is set. The determined margin (typically 30 to 40 dB with FM electronics) is stored for a possible later use on board and included into telemetry.

Expected SD output for DIM Noise Test

Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 13	Science Data Measurement Header	BCDE BCDE 3100 0000 0014 tttt tttt	ID = 0x3100; length = 0x14 = 20 byte
2	14, 15	Block header: Noise Test Data	1818	
3	16	Margin [dB], for which no amplifier noise was measured	e.g. 1E	Margin range is 0-70 dB. Lower margin means less noise on amplifier (typ. 20 to 40 dB).
4	17	Error Code	e.g. 00	
5	18, 19	Block delimiter: end of Noise Test data	E7E7	

If Noise Test is invoked by telecommand DIM_NT, the generated data volume is one science data packet. If executed implicitly by commanding DIM_HC or DIM_MES, the net measurement length (20 byte) is used up.

The technically possible upper limit for the execution duration is 7 s, but this would imply an “impossible” noise distribution with time. The expected duration is 1 to at most 2 seconds (plus 10 s warm-up time if individually commanded and DIM not powered before).

4.3.5 DIM Sensor Test (DIM_ST)

DIM Sensor Test is used to check one of the three sensing faces of the sensor. First a sample of the average signal height is compared with predefined limits. If limits are exceeded (which effectively means that the average signal height is too high for measuring single impacts), the error bit EB_NOISY_TEST is set and, after saving the average sample value, the sensor test is aborted. Else an electrical pulse (approximately 5 V for 10 µs) is applied to the sensing face, and the response of the sensing face is registered in the same way a dust impact would be measured. Telecommand parameters are margin, which determines the detection threshold of the measuring amplifier, and the direction (x, y, z in DIM coordinate system).

In case the response of the sensor face (peak voltage and impact duration) exceeds predefined limits, the error bit EB_BAD_TEST is set. Further error conditions can be indicated in the sensor test error flags, which are generated in the peak detection routine Single_Burst: EB_NO_PULSE or EB_LONG_T.

Because the measuring values include some variance and depend on environmental conditions (e.g. the sensor temperature), the ranges of accepted values for U and T_c are relative large.

Ranges of DIM Measuring Values			
	Lower limit	**Upper limit**	**Comments**
Flight software version FM-1			
Average signal height	AV_TEST_LO = 0	AV_TEST_HI = 20	Limits specify applicable range for single impact measurements.
Peak voltage	U_TEST_LO = 55	U_TEST_HI = 70	Peak voltage test passed if value within limits.
Impact duration	T_TEST_LO = 46	T_TEST_HI = 64	Impact duration test passed if value within limits.
Flight software versions FM-2 and FM-3			
Average signal height	AV_TEST_LO = 0	AV_TEST_HI = 20	Limits specify applicable range for single impact measurements.
Peak voltage	U_TEST_LO = 40	U_TEST_HI = 70	Peak voltage test passed if value within limits.
Impact duration	T_TEST_LO = 40	T_TEST_HI = 70	Impact duration test passed if value within limits.

Expected SD output for DIM Sensor Test				
Item No.	**Byte No.**	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
1	0 to 13	Science Data Measurement Header	BCDE BCDE 3202 0000 0020 tttt tttt	ID = 0x3202; length = 0x20 = 32 byte
2	14 to 15	Block header	3636	
3	16	Direction/Margin		Bits 7,6,5: Direction (100: x, 010: y, 001: z) Bits 2,1,0: Margin divided by ten
4	17	Error Code	00	
5	18 to 19	Data Block Header	7272	
6	20 to 21	Average signal [mV]	0 to 3000 decimal	
7	22 to 23	Signal peak voltage [mV]	0 to 3000 decimal	
8	24 to 25	Impact time [timer count TC]	2 to 500 decimal	tc [µs] = TC / 20
9	26	Average Sample [dB]	0 to 100 decimal	
10	27	Signal peak voltage [dB]	0 to 83 decimal	
11	28	Impact time [dB]	10 to 70 decimal	
12	29 to 30	Block delimiter: end of Sensor Test data	C9C9	
13	31	Padding character	00	

If Sensor Test is invoked by telecommand DIM_ST, the generated data volume is one science data packet. If executed implicitly by commanding DIM_HC or DIM_MES, the net measurement length (32 byte) is used up.

The expected duration (which is essentially the duration needed for determining the average signal value) is approximately 4 seconds (plus 10 s warm-up time if individually commanded and not powered before).

4.3.6 DIM Calibration (DIM_CA)

The results of the DIM Calibration procedure are used for the re-calibration of the transfer characteristic of the log-amplifier and for checking the time measuring (t_c) circuit. To this end, two test pulses (low level and high level) are applied to the log-amplifier. While the pulse amplitudes are fixed in DIM electronics, the pulse durations are controlled by flight software. Pulse height and duration are 1 mV, 8 µS for low-level and 100 mV, 20 µS for high-level. The results of the calibration procedure are used on ground to re-calibrate the measuring values and have no effect on the scaling of measured values by flight software.

If the measured peak voltage and impact duration values exceed predefined limits, the measuring process is repeated (up to a total of four trials per calibration level). In that case an appropriate error flag is set (EB_BAD_CAL_LO and/or EB_BAD_CAL_HI). Other possible error flags refer to the measuring process itself (EB_NO_PULSE, EB_LONG_T, EB_NO_AD_RDY). The calibration is successful, if there is one trial with error code = 0 for each calibration level.

Telecommand parameters are the margin values, which shall be adjusted by flight software for the low and high level calibration measurements.

Expected SD output for DIM Calibration

Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 13	Science Data Measurement Header	BCDE BCDE 3302 llll llll tttt tttt	ID = 0x3302; length variable
2	14 to 15	Block header	2727	
3	16	Low Margin	1E	
4	17	High Margin	32	
next data block (item 5 to 12) may occur up to eight times				
5	+1 to +2	Data Block Header	7272	
6	+3	Margin		
7	+4	Level		0x00 = Low, 0xFF = High
8	+5 to +6	Timer Count		
9	+7 to +8	Peak Voltage [mV]		
10	+9	Time [dB]		
11	+10	Peak Voltage [dB]		
12	+11	Error Code for one trial	00	
13	+1 to +2	Total error (summed over all trials)		
14	+3 to +4	Block delimiter: end of Calibration data	D8D8	
next item (# 15) occurs only if the total number of bytes so far (from items 1 to 14) is odd, i.e. the number of calibration trials (equals the number of blocks #5 to #12) is odd.				
15	+5	Padding character	00	

If Calibration is invoked by telecommand DIM_CA, the generated data volume is one science data packet. If executed implicitly by commanding DIM_HC or DIM_MES, the net measurement length (up to 118 byte) is used up. The maximal execution time is approximately 8*400 ms = 3.2 seconds (plus 10 s warm-up time if individually commanded and not powered before).

4.3.7 DIM Average Continuous (DIM_AV)

Samples of the average signal voltage of one sensor face are taken at specified time intervals. Telecommand parameters are the sensor face (x, y, z), the time interval between samples t_aver_interval and the total measuring time. A fourth parameter (energy control) is kept for compatibility, but is not evaluated by any flight software version. Note that the averaging time period T_AVER_SETTL is fixed in the software code. The telecommand parameter t_aver_interval does not affect the averaging period. The time period between samples taken is always MAX(t_aver_interval, T_AVER_SETTL).

Note that the average measuring process was changed in flight software version FM-3 by reducing T_AVER_SETTL from 4 to 2 seconds and discarding the very first sample.

Expected SD output for DIM Average Continuous Mode (DIM_AV)				
Item No.	**Byte No.**	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
1	0 to 13	Science Data Measurement Header	BCDE BCDE 3404 llll llll tttt tttt	ID = 0x3404; length depending on measuring and sampling time.
2	14, 15	Block header: Average Continuous	4545	
3	16	Direction (sensor face)	0 (x) or 1 (y) or 2 (z)	Echoed Command Parameter
4	17	Energy control	00 or 01 or 02	Echoed Command Parameter
5	18, 19	Sampling interval [s]		Echoed Command Parameter
6	20, 21	Measuring time [s]		Echoed Command Parameter
7	22, 23	Data Block header	7272	
8	24, 25	Sampling interval [s]		
9	26, 27	nSamp: Number of measured samples		
next data block (item 10) occurs nSamp times				
10	+1	Average sample [dB]		
11	+1 to +2	Time after final sampling (high word)		SESAME Local Time
12	+3 to +4	Time after final sampling (low word)		
13	+5	Error Code		
14	+6, +7	Block delimiter: Average Continuous data	BABA	
next item (# 15) occurs only if the total number of bytes so far (from items 1 to 14) is odd, i.e. the number of samples (item 9) is even.				
15	+8	Padding character	00	

The expected science data volume is 28 + 8 + (measuring time)/(sampling interval) byte, rounded-up to the next multiple of 256 byte. The execution duration is given with “measuring time” (TC parameter). Ten seconds must be added for DIM electronics warm-up if Average Continuous is individually invoked with DIM_AV (and it is not executed as part of Autonomous Mode).

4.3.8 Burst Continuous Mode (DIM_BC)

Single events on one sensor face are registered in Burst Continuous Mode. Measured values (peak amplitude U and impact duration T) are stored in a compressed way. First they are scaled to 1 <= U[dB] <= 83 dB and 10 <= T[dB] <= 70 according to equations DIM.1 and DIM.2. The counts for events with a particular (U[db], T[db]) combination are stored in memory cells of different sizes (one word (UW), one byte (UB), one nibble (N) = 4 bit), depending on the expected frequency of such events. The resulting matrix of packed counts has a fixed size of 3585 byte (independent of the actual number of events). Note: the ranges of U[dB] and T[dB] and thus the size of the (U, T_c)-matrix have been reduced starting with flight software version FM-2.

Additionally average samples can be measured. Note: The instrument is not sensitive for single impacts while averaging. Thus the sampling time should be chosen large enough (>> T_AVER_SETTL) to leave gaps for significant measurements of single impacts. Each Burst Continuous Mode starts with a 10 seconds instrument warm-up period, which is not included in the measuring time (the warm-up period is skipped when Burst Continuous is executed as part of the DIM Autonomous Mode).

Telecommand parameters are the designation of the sensor face (x, y, z), the total measuring time, the time interval between average samples, the sensor signal decay time and the margin to be adjusted by flight software. A further parameter (energy control) is kept for compatibility, but is not evaluated by any flight software version.

Area	Addressing (U, T in dB)	Memory Space [byte]	Range [dB]	Box Length
1	2 * [U–1 + 20*(T–10)]	440	U: 1 , 2, .., 20 T: 10, 11, .., 20	2 byte
2	440 + [U–1 + 20*(T–21)]	400	U: 1 , 2, .., 20 T: 21, 22, .., 40	1 byte
3	840 + [U–21 + 20*(T–10)]	620	U: 21, 22, .., 40 T: 10, 11, .., 40	1 byte
4	1460 + [0.5*(U–1) + 20*(T–41)]	600	U: 1, 2, .., 40 T: 41, 42, .., 70	0.5 byte (*)
5	2060 + [0.5*(U–41) + 25*(T–10)]	1525	U: 41, 42, .., 90 T: 10, 11, .., 70	0.5 byte (*)

(*) if U is even: high nibble, else low nibble

To allow faster memory access during a measurement, the matrix is temporarily stored in the code page (page 0) of SESAME SRAM and after the completion of the measurement transferred to the science data buffer (pages 1 to 7). The start address is DIMMAT_ADR (with flight software FM-2 and FM-3 equal to 0xC350). In case of trouble with SESAME science data transfer to CDMS the code page 0 can be dumped to CDMS using C-DPU Debug Monitor commands to obtain the DIM matrix (data will be valid until a further measurement is executed).

Expected SD output for DIM Burst Continuous Mode (DIM_BC)				
Item No.	**Byte No.**	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
1	0 to 13	Science Data Measurement Header	BCDE BCDE 3606 llll llll tttt tttt	ID = 0x3606; length variable
2	14, 15	Block header	5454	
3	16	Direction	00 (x) or 01 (y) or 02 (z)	Echoed Command Parameter
4	17	Margin		Echoed Command Parameter
5	18	Energy Control	00 or 01 or 02	Echoed Command Parameter; not used in S/W
6	19	Signal decay Time [ms]		Echoed Command Parameter
7	20, 21	Sampling Interval [s]		Echoed Command Parameter
8	22, 23	Measuring Time [s]		Echoed Command Parameter
9	24, 25	Data Block header	7272	
10	26, 27	Number of Events detected		
11	28, 29	Number of false Events		
12	30, 31	Number of long Events		
13	32, 33	nSamp: Number of Average Samples		
next data block (item 14) occurs nSamp times				
14	+1	Average Sample [dB]		
15	+1 to +2	Time at end of measuring period (high word)		SESAME Local Time
16	+3 to +4	Time at end of measuring period (low word)		
17	+5	Error Code	00	
18	+1 to +440	220 event counts for 0<U[db]<21 and 9<T[db]<21		Data size: one word; order of (U[db], T[db]) pairs: (1,10),(2,10),(3,10),..., (19,20),(20,20)
19	+441 to +840	400 event counts for 0<U[db]<21 and 20<T[db]<41		Data size: one byte; order of (U[db], T[db]) pairs: (1,21),(2,21),(3,21),..., (19,40),(20,40)
20	+841 to +1460	620 event counts for 20<U[db]<41 and 9<T[db]<41		Data size: one byte; order of (U[db], T[db]) pairs: (21,10),(22,10),(23,10), ...,(39,40),(40,40)
21	+1461 to +2060	1200 event counts for 0<U[db]<41 and		Data size: one nibble (4 bit); order of (U[db], T[db]) pairs:

Expected SD output for DIM Burst Continuous Mode (DIM_BC)				
Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
		40<T[db]<71		(1,41),(2,41),(3,41), ...,(39,70), (40,70); in a byte, the low nibble (bits 0..3) refers to the lower U[db] value.
22	+2061 to +3585	3050 event counts for 40<U[db]<91 and 9<T[db]<71; data length: one nibble		Data size: one nibble (4 bit): order of (U[db], T[db]) pairs: (41,10),(42,10),(43,10), ...,(89,70),(90,70); in a byte, the low nibble (bits 0..3) refers to the lower U[db] value.
23	+1, +2	Block delimiter: Burst Continuous data	ABAB	
next item (# 24) occurs only if the total number of bytes so far (from items 1 to 23) is odd, i.e. the number of average samples (item 13) is odd.				
24	+3	Padding character	00	

The expected science data volume is 15 science data packets, if the mode is invoked by telecommand DIM_BC and approximately 14.3 science data packets (the net data volume of 3636 byte plus Science Packet Headers), if Burst Continuous is executed as part of Autonomous Mode.

The execution duration is given with “measuring time” (TC parameter). Ten seconds must be added for DIM electronics warm-up if Burst Continuous is individually invoked with DIM_BC (and it is not executed as part of Autonomous Mode).

4.3.9 Burst Continuous Test Mode 2 (DIM_BCTEST2)

Additionally to the regular Burst Continuous Mode (which delivers the DIM (U, T_c)-matrix), a Burst Continuous Test Mode (DIM_BCTEST2) is implemented. DIM_BCTEST2 delivers for each single impact U[mV], U[dB], TC, T_c[dB] and – deviating from DIM_BCTEST of earlier flight software versions – additionally the Lander Onboard Time (LOBT), when the impact was registered. The LOBT is determined directly after the event was accepted as a real impact.

The number of events, which can be stored and included into telemetry, is limited in flight software versions FM-1 and FM-2 by the available free memory space (and the total measuring time). With flight software FM-3 a limit of 350 real events (impacts) is imposed. The resulting maximal telemetry volume (14 science data packets) equals approximately the memory consumption of a DIM_BC measurement.

Burst Continuous Test Mode 2 uses the same telecommand parameters as DIM_BC, but it does not measure average samples (ignoring the corresponding TC parameter).

Expected SD output for DIM Burst Continuous Test Mode 2 (DIM_BCTEST2)				
Item No.	**Byte No.**	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
1	0 to 13	Science Data Measurement Header	BCDE BCDE 3E06 llll llll tttt tttt	ID = 3E06; length variable
2	14, 15	Block header	5454	
3	16	Direction	00 (x) or 01 (y) or 02 (z)	Echoed Command Parameter
4	17	Margin [dB]	eg 1E	Echoed Command Parameter
5	18	Energy Control	00 or 01 or 02	Echoed Command Parameter; not used.
6	19	Signal Decay Time [ms]	2 to 100 [ms]	Echoed Command Parameter
7	20, 21	Sampling Interval [s]		Echoed Command Parameter; not used.
8	22, 23	Measuring Time [s]	> 20 [s]	Echoed Command Parameter
9	24, 25	Data Block header	7272	
10	26, 27	nevent: Number of Events detected		
11	28, 29	Number of false Events		
12	29, 30	Number of long Events		
13	32, 33	Number of Average Samples	0000	
next data block (item 14 to 17) occurs MIN(nevent, 350) times				
14	+1, +2	Event time (high word)		SESAME Local Time
15	+3, +4	Event time (low word)		
16	+5, +6	Timer Count		
17	+7, +8	Peak Amplitude [mV]		
18	+9	Timer [dB]		
19	+10	Peak Amplitude [dB]		
20	+1 to +2	Time at end of measuring period (high word)		SESAME Local Time
21	+3 to +4	Time at end of measuring period (low word)		
22	+5	Error Code	00	
23	+6, +7	Block delimiter: end of Burst Continuous data	ABAB	

The maximal science data volume generated is 14 science packets. The execution duration is “measuring time” (TC parameter) plus ten seconds for DIM electronics warm-up.

4.3.10 DIM Power Switch (DIM_PWRSW)

Switching of DIM ±5 V power supply via the DIM select line. A simple interface circuit on DIM PCB is not affected; it is always powered if SESAME is powered.
No science data are generated. The execution of the TC takes less than 1 second.

4.3.11 DIM Health Check (DIM_HC)

DIM Health-check performs DIM Power Check and, if no error during Power Check occurred, subsequently the sequence DIM Noise Test, DIM Calibration, DIM Sensor Test (sensor face x), DIM Sensor Test (y), DIM Sensor Test (z). Science data generated are composed of the data of the single procedures.

4.3.12 DIM Autonomous Measuring Mode (DIM_MES)

DIM Autonomous Mode starts with a health check (DIM_HC). The results of the health check are used to determine which of the three sensor faces can be used and which measuring mode (Burst Continuous or Average Continuous) is applicable for each of the sensor faces. The margin (sensitivity of measurement) is adjusted according to the result of the noise test (part of DIM_HC). In case Burst Continuous measurements shall be performed the margin is additionally checked with a short (30 s) pre-measurement: If the pre-measurement reveals that the sum of long and false events exceeds the number of accepted (dust impact) events the margin is increased. The total measuring time is distributed among the single measurements for each working sensor face and the first and a concluding DIM Health-check.

Science data generated by DIM_MES comprise the science data of the single measurements mentioned above. No extra data are generated.

4.3.12.1 Autonomous Mode: Health Check

The margin values are fixed to 30 dB for low-level calibration, 50 dB for high-level calibration and 40 dB for the sensor tests. In case a fatal error is reported (power supply out of limits or persistent over-current interrupts), the complete Autonomous Mode measurement is aborted.
The result of the Noise Test is stored as the initial margin for Burst Continuous. The results of the sensor tests are stored for the following decision making.

4.3.12.2 Autonomous Mode: Decision making

According to the decision module, Average Continuous Mode will be executed, if the average signal height exceeds predefined limits. Burst Continuous will be executed, if all results of the sensor test (for the particular sensor face) are within the limits or only the average signal is within the specified range and the responses (U, T_c) of all three sensing faces to the electrical stimulus during sensor test were out of range. No measurement will be performed with the particular sensing face, if the averaged signal height is within limits, U and T are out of range and the response of at least one other sensing face to the electrical stimulus is as expected.

Derived Quantities: Measuring Time
The measuring time for dust impact measurements T_M (BC or AV) is derived from TM, taken into account the results of the Health Check; i.e. if one or two sensor faces are not operational, the measuring time for the remaining direction(s) is correspondingly extended.

The measuring time T_M is calculated in procedure Decision (after HC) similar to the algorithms given in RO-LSE-SP-3440, page 33:

$$T\_M(N) = (TM - 2^* T_{elapsed} + T_{warmup} - 30[s]^*B) / N \qquad (DIM.4)$$

where
$T_{elapsed}$ = time elapsed since start of DIM_MES when the decision module was invoked (i.e. after the first health check)

T_{warmup} = waiting period after switching the select line on (+- 5V on); *currently 10 s*
N = total number of measurements (A + B = 1 .. 3).
A = number of Average Continuous measurements (1 .. 3)
B = number of Burst Continuous measurements (1 .. 3)

Equation DIM.4 must be taken into account when choosing the TC parameter “total execution time” (TM). The two Health Checks already last ($2*T_{elapsed} – T_{warmup}$) ≈ 25 to 35 s (depending on the execution duration of the sub-procedures Noise Test and Calibration). In case three Burst Continuous measurements shall be executed (B=3), there will be three pre-BC-measurements, each 30 s long. Thus up to approximately 30 s plus 3*30 s = 120 s are consumed without any scientific measurement.

Derived Quantities: Sampling Time

The time period between two successive average sample measurements (Sampling Time) is
$T_{sampling}$ = 2 * Aver_Settling, if an Average Continuous Measurement is performed,
$T_{sampling}$ = Integer (T_M / 10), if a Burst Continuous Measurement is performed.

4.3.13 DIM Error Codes

Error codes are composed of the following bit settings, e.g. Error Code 0x30 = (EB_CAL_LO | EB_BAD_CAL_HI) indicates an error during low level and high level calibration.

DIM Error Flags			
Flag (hex.)	**Name**	**S (*)**	**Meaning**
01	EB_OVERCURR	W	Over-current interrupt detected.
02	EB_NOISY_AMP	W	DIM_NT: Noise level higher than limit (70 dB).
02	EB_NO_AD_RDY	W	Error using ADC of C-DPU. Delivered digital value is invalid.
04	EB_NO_PULSE	W	DIM_ST: No pulse detected but expected.
04	EB_BAD_HEALTH	F	DIM_PC: Voltage out of limits +- [4.5, 5.5] V; measurement aborted.
08	EB_LONG_T	W	Long pulse measured (DIM_CAL, DIM_ST, DIM_BC).
10	EB_BAD_CAL_LO	W	Calibration (low level) failed (U not in the range 33 to 49 dB or T not in the range 20 to 60 dB).
10	EB_NOISY_TEST	W	DIM_ST: Average sample exceeds limit (> 20 dB).
20	EB_BAD_CAL_HI	W	Calibration (high level) failed (U not in the range 71 to 83 dB or T not in the range 40 to 70 dB).
20	EB_BAD_TEST	W	DIM_ST: Peak voltage and signal length out of range (not in the range 40 to 70 dB).
40	EB_MEM_FULL	F	Allocated SESAME RAM memory space exhausted. Aborted.
80	EB_OC_PWROFF	F	Excessive INT4 (over-current) interrupts; DIM instrument switched off.

(*) Severity: W = info / warning; F = fatal error

4.3.14 New/modified DIM Features in Flight Software FM-3

DIM Autonomous Mode has been revised and tested. It can be safely commanded using FM-3 flight software. Note: The order of data words of telecommand DIM_MES is reversed compared to the documentation in the FM-2 user manual of the (then not released) DIM_MES command.

DIM Burst Continuous Mode 2 has been included, which registers single dust impacts and includes timestamps for each individual impact.

4.4 PP Telecommanding and Telemetry

4.4.1 Table of Telecommands

PP: Defined Telecommands

IDENT	Com-mand Word (hex.)	Parameter Words			Description
		No	Meaning	Valid Range	
PP_HC	5000	n/a	n/a	n/a	PP Health Check
PP_LM	5100	n/a	n/a	n/a	PP Langmuir Probe with different integration times
PP_AM2	6201	1	Electrode configuration: 0x0abi, with a=electrode for DAC output A, b=electrode for DAC output B, i=electrode used for current measurement (*).	a = 0, 1, 2 b = 0, 2, 3 (not equal to a) i = 0, 1, 2, ... ,7 with 1 = +X leg 2 = MUPUS PEN 3 = APX 5 to 7: see text 0 = return potential difference	PP Active Mode measurements with different transmitter frequencies and three output voltage amplitudes each (according to the PP Control Table); results of onboard data evaluation are transmitted to ground.
PP_AMTEST2	6B04	1	Electrode configuration: 0abi, with a=electrode for DAC output A, b=electrode for DAC output B, i=electrode used for current measurement (*).	a = 0, 1, 2 b = 0, 2, 3 (not equal to a) i = 0, 1, 2, ... ,7 with 1 = +X leg 2 = MUPUS PEN 3 = APX 5 to 7: see text 0 = return potential difference	One PP active measurement with raw data output and onboard data evaluation.
		2	nominal TX frequency	20 to 11000 [Hz] (0x0014 to 0x2AF8)	
		3	no. of waves	3, 5, 7, ...,125	
		4	TX amplitude damping	0= full amplitude 1= half amplitude 2= ¼ amplitude	
PP_AMTEST	5B03	1	Electrode configuration: 0abi, with a=electrode for DAC output A, b=electrode for DAC output B, i=electrode used for current measurement (*).	a = 0, 1, 2 b = 0, 2, 3 (not equal to a) i = 0, 1, 2, ... ,7 with 1 = +X leg 2 = MUPUS PEN 3 = APX 5 to 7: see text 0 = return potential difference)	One PP active measurement with raw data output and onboard data evaluation; PP_AMTEST is equivalent to the PP_AMTEST2 command with the same parameters 1 to 3 and full transmitter current amplitude. Note: Science data appear under the header of PP_AMTEST2.
		2	Nominal TX frequency	20 to 11000 [Hz] (0x0014 to 0x2AF8)	
		3	No. of waves	3, 5, 7, ...,125	

PP: Defined Telecommands					
IDENT	**Com-mand**	**Parameter Words**			**Description**
PP_PM2	6301	1	Spare (not used)		One PP passive measurement with on-board data evaluation. Note: The command parameter is currently not evaluated, but must be included (use e.g. 0xFFFF)
PP_PMTEST2	6C01	1	Exponent of two ***n*** such that the number of used samples ***ns*** is $ns = 2^n$ n = 10, 11, 12, 13 (0x0A to 0x0D)		One PP passive measurement with raw data output and on board data evaluation; the sampling frequency, the number of skipped samples and the number of frequency bins are read from the control table.
PP_PWRSW	5501	1	Power Mode	= 0: all circuits off = 1: all circuits on	PP power switching used for H/W test / debugging (no SD are generated).
PP_DA	5802	1	Address	0018 *or* 0019	PP direct register address
		2	Value		
PP_RCTL	591A	1 to 26	26 data words which contain a PP Control Table		PP Update Control Table (called “PP Receive Control Table” before hibernation)
PP_DCTL	5D03	1	Mode	1	PP Dump Control Table; dump contents of Control Table to one science TM packet; synonym for PP_SPEC with mode = 1.
		2	not evaluated	any value (1 word)	
		3	not evaluated	any value (1 word)	
PP_SPEC	5D03	1	Mode	= 0: write Forth stack to telemetry = 1: dump PP Control Table	Used for software tests.
		2	not evaluated	any value (1 word)	
		3	not evaluated	any value (1 word)	

(*) PP electrode configuration:
In Active Mode, PP uses 4 (of 5 available) electrodes for transmitting and receiving signals. The two receiver electrodes are mounted in the -Y and +Y landing gear feet. The connection of the receiver electrodes is fixed and thus there is no need to include their configuration neither in the TC nor in telemetry. Three electrodes are left: one is in the +X landing-gear foot, another one is mounted at the insertion end of the MUPUS hammering device PEN and the third electrode is mounted into the lid of the APX detector. Two of the electrodes can be selected for the insertion of a current into the cometary surface. To this end, one of these electrodes has to be connected to the TX A output of the PP central electronics, the other one to the TX B output. The TX A output is also called "direct output" or "DAC output A", the TX B output is also called "inverted output" or "DAC output B".

For current measurements, one of the three electrodes can be connected to the input of the receiver circuit in PP central electronics. For calibration and debug purposes, also other channels can be connected to the input.

Thus a number of combinations are possible, and one integer word is used to describe the electrode configuration (for TC and TM). Written as hex value 0x0abi, the first (most significant) digit of the word is always "0" and the next 3 digits describe the electrical configuration using indices of electrodes and channels.

a: electrode connected to the TX A output.
Possible values: 0 [none], 1 [+X leg], 2 [MUPUS PEN]

b: electrode connected to the TX B output.
Possible values: 0 [none], 2 [MUPUS PEN], 3 [APX]

i: input channel
Possible values:
0 [potential difference]
1 [current at +X leg]
2 [current at MUPUS PEN]
3 [current at APX]
4 [direct measurement at -Y foot]
5 [direct measurement at +Y foot]
6 [reference voltage -2.5 V]
7 [reference voltage +2.5 V]

Sub-parameter i can thus be any octal digit. This allows instrument descent calibration with code 0abi=0104 and 0abi=0105, which sends sinusoidal voltage variations between +X foot and lander ground and measures the response on the +Y-foot and -Y-foot, respectively. Values 6 and 7 would be reference voltages in case instabilities are suspected.

Example: electrode configuration is "0x0131": The first digit "0" means nothing but format is OK so far. The second digit "1" indicates TX A (=direct output=DAC output A) is connected to the +X foot electrode. The third digit "3" means TX B (=inverted output=DAC output B) is connected to the APX sensor. The fourth digit "1" means current measurement uses the +X foot electrode.

4.4.2 PP Control Table

Almost all measuring parameters, which determine an active or passive PP mode, are defined in a structure called PP Control Table. This data structure is part of the flight software code and can be altered using telecommand PP_RCTL. After a power-cycle, the default control table is active again.

Parameters in PP Control Table						
No	**Byte**	**Name**	**Meaning**	**Data Type**	**Range**	**Default Value(s)**
1	1	INTDIV	Clock divider for Langmuir Probe (LP)	UB	0 .. 15	15
2	2	LMREP	Repetition count for LP	UB	*N/A*	10 *(not used)*
3	3 to 4	NSAMP	Number of used samples for Passive Mode (excluding skipped samples)	UW	$2^{10}, 2^{11}, 2^{12}, 2^{13}$	8192
4	5 to 6	SFREQ	Sampling frequency [Hz] for Passive Mode (1)	UW	4095 .. 65535	40000
5	7 to 8	NSKIP	Number of skipped samples for Passive Mode	UW	≤ 1024	512
6	9	NBIN	Number of frequency bins for onboard evaluation of Passive Mode data	UB	1 .. 10	10
7	10	NFREQ	Number of used transmitting frequencies in Active Mode	UB	1 .. 20	20
8 to 27	11 to 50	freq00 to freq19	20 transmitting frequencies [Hz] for Active Mode (2)	20*UW	Each frequency must be in the range 20 to 11000 Hz.	20, 60, 140, 280, 400, 600, 800, 1000, 1200, 1400, 1800, 2000, 2400, 3000, 3500, 5000, 6000, 7000, 8500, 10000
28	51 to 52	ELEC	Electrode combination for Active Mode	UW	*N/A*	0x0121 *(not used)*

(1) The ADC frequency divider ADC_DIV is calculated by flight software using
ADC_DIV = INTEGER(5 MHz / SFREQ).
(2) The Control Table has a fixed length and must always contain 20 frequency values, even if NFREQ < 20.

4.4.3 PP Health check (PP_HC)

During PP health check a variety of voltages and currents are measured on PP board, thus checking the electrical status of PP.

Expected SD output for PP Health Check (PP_HC)			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 13	SD header	BCDE BCDE 5000 0000 0024 tttt tttt	Total length: 0x24 = 36 byte; last two words are SESAME Local Time
14, 15	Langmuir Probe with clock divider=0	e.g. 3A44	Depends strongly on environment and sensor location
16, 17	ADC offset	e.g. 0080	Should be close to 0x0080 (0x0080 represents zero with bipolar ADC)
18, 19	-2.5 V reference	e.g. 0051	Should be nearly symmetrical to ADC offset
20, 21	+2.5 V reference	e.g. 00AE	
22, 23	Differential voltage (receiver 2) – (receiver 1)	e.g. 0069	
24, 25	Direct voltage from receiver 1	e.g. 00FF without sensors connected	Depends on connection of receiver and environment
26, 27	Direct voltage from receiver 2	e.g. 00FF without sensors connected	Depends on connection of receiver and environment
28, 29	Transmitter current at electrode 1; no voltage applied	e.g. 0080	Should be close to ADC offset
30, 31	Transmitter current at electrode 2; no voltage applied	e.g. 0080	Should be close to ADC offset
32, 33	Transmitter current at electrode 3; no voltage applied	e.g. 0080	Should be close to ADC offset
34, 35	Error code	0	PP errors summed for all measurements.

One science data packet is generated. The execution duration is less than 8 seconds.

4.4.4 PP Langmuir Probe Test (PP_LM)

Langmuir Probe Measurement Principle

During a Langmuir Probe measurement, an integration counter in PP hardware counts the time (clock ticks) needed to collect a particular amount of charge defined by the H/W. The measurement stops, when the target charge value is reached or the range of the 16-bit integration counter is exceeded. The counter is driven by an internal integration clock, which is derived from the FPGA clock. The measuring range can be adjusted by setting an appropriate integration clock divider (INT_DIV), which translates the FPGA clock frequency to the integration clock frequency. The shortest integration time period before the 16-bit counter overflows and the measurement stops can be set with INT_DIV = (INT_DIV_{min} + 1) = 1; the maximum integration period can be achieved with INT_DIV = (INT_DIV_{max} + 1) = 16.

In telemetry, the result of a Langmuir Probe measurement is the content of the 16-bit integration counter. With a system clock period of 200 ns (5 MHz), the integration time counter value (TC) can be converted into time using $t = 2*10^{-7}$ s * (INT_DIV + 1) * TC. The maximum time period a Langmuir Probe measurement can take in PP H/W is thus $2*10^{-7} * 16 * (2^{16} - 1)$ s ≈ 210 ms.

A longer integration time corresponds to a lower external signal (it took longer to collect charges until the threshold was reached). The telemetry value 0xFFFF= 65535 indicates that the charge threshold was not reached until the measurement period elapsed.

PP Langmuir Probe Test

Telecommand PP_LM initiates a series of Langmuir Probe measurements with different periods of charge collection. Sixteen measurements are executed with integration clock divider values 0, 1, 2, .. 14, 15. An additional final measurement uses the default clock divider value of the Control Table. The magnitude of measured values depends strongly on electrode status and environmental conditions but the course of measured values related to the integration times gives strong evidence on the functionality of PP. This measurement sequence is mainly used for ground tests.

Science data is contained in one science data packet. The execution duration of PP_LM depends on the integration clock divider setting in the PP Control Table and the environment. It is dominated by the 0.5 s waiting period after power switching for each of the 17 measurements plus the 17 integration periods. It ranges from 8.5 to 12.1 seconds (confirmed by ground tests with the PP electrode simulator and w/o applying an external signal).

Expected SD output for PP Langmuir Probe Test			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 13	SD header	BCDE BCDE 5100 0000 0052 tttt tttt	total length: 0x52 = 82 byte; last two words are SESAME Local Time
14, 15, 16, 17	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: result of LP measurement	0000 3A44	Nominal clock divider value and actual value (read back from register) must be equal. Constant signal strength provided, the result of the LP measurement should be proportional to (integration clock divider + 1)$^{-1}$
18, 19, 20, 21	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: result of LP measurement	0101 1D38	
22, 23, 24, 25	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: result of LP measurement	0202 137C	
(...)			
74, 75, 76, 77	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: result of LP measurement	0F0F 03A8	
78, 79, 80, 81	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: result of LP measurement	0F0F 03A8	Measurement with default clock divider value from Control Table; result should be similar to already measured value with the same clock divider (constant signal provided).

4.4.5 PP Active Mode 2 (PP_AM2)

PP Active Mode 2 executes a series of active PP measurements. A modified wavelet method is used on-board to analyse the time series of each measurement. All measurement parameters but the electrode configuration are taken from the PP control table or are fixed in the software code. During each measurement, nine waves are transmitted und internally recorded, if the frequency is less than or equal 1560 Hz, else 17 waves. The number of samples per wave is:

Frequency range	Samples per wave
f <= 1560 Hz	64
1560 < ***f*** <= 3125 Hz	32
3125 < ***f*** <= 11000 Hz	16

Each active measurement is executed with three different transmitter signal amplitudes (Max, Max/2, Max/4).

Expected SD output for PP Active Mode 2 (PP_AM2)

Byte No.	Meaning	(Typical) Value	Remarks
0 to 13	Science data header	BCDE BCDE 6201 0000 030C tttt tttt	Typical (max.) total length: 780 byte
14, 15	Commanded electrode combination		Echoed command parameter
16, 17	Used electrode combination	for example: 0x0121 or 0x0122 or 0x0131, 0x0133 or 0x0232 or 0x0233	Used electrode combination checked for correct format and corrected if necessary
18, 19	Number of frequencies ***nFreq***	defined in the PP control table (1 to 20)	
for all frequencies (nFreq times):			
+1, +2	Nominal frequency		Nominal TX frequency [Hz]
for three adjusted transmitter signal amplitudes (tx_amp = 0, 1, 2):			
Active Mode Results Block			
+1, +2	Error code	0	Cf. list of error flags
if no fatal error in error code:			
+3	QUAL		Quality flags (cf. list of quality flags)
+4	NSPW		Number of points per wave
+5, +6	PHASE		Phase difference potential-current (1/16 degree)
+7, +8	Current amplitude		Scaling as raw data without offset: 128 = max. ADC current
+9, +10	Voltage amplitude		Scaling as raw data without offset: 128 = max. ADC voltage
+11, +12	Math Error Code		Cf. list of math error flags

In case of a fatal measurement error, the data after the error code word (from QUAL to Math Error Code) will not be present in telemetry; however the loops over the three different transmitter signal amplitudes and the transmitter frequencies continue.

Maximal data volume (with ***nFreq*** = 20 and no fatal error): 780 byte net (will be filled up to form four complete science packets).

The execution duration of PP_AM2 depends on the number and the values of the applied frequencies. Using the default values of the PP Control Table (with ***nFreq*** = 20) it has been measured to be 160 seconds (the mean time interval between the 60 single measurements is thus 2.7 s). The first measurement starts (502 -1/+5) ms after the point in time noted in the Science Data Header (cf. chapter "PP Active Mode Test 2").

4.4.6 PP Active Mode Test 2 (PP_AMTEST2)

One active PP measurement is performed. Adjusted and measured values (the DAC table computed onboard, written to the instrument and read back from PP memory; time series of transmitter current and receiver voltage samples) are sent to ground. Telemetry concludes with the results of the on-board data evaluation of the transmitter and receiver time series. Adjustable parameters of command PP_AMTEST2 are the configuration of electrodes, the transmitting frequency and amplitude as well as the number of sine waves, which should be sent and recorded. Because telemetry contains the raw time series data and the results of the on-board evaluation of that data, it is possible to check both, details of the time series and the correct working of the data evaluation.

Expected SD output for PP Active Mode Test 2 (PP_AMTEST2)			
Byte No.	**Meaning**	**(Typical) Value**	**Remarks**
0 to 13	Science data header	BCDE BCDE 6B04 llll llll tttt tttt	llll= total length (depends on command parameters)
14, 15	Electrode combination	For example: 0x0121, 0x0122, 0x0131, 0x0133, 0x0232, 0x0233	Command parameter (checked for correct format and corrected if necessary)
16, 17	Nominal TX Frequency [Hz]	20 to 11000 [Hz]	Echoed command parameter
18	Number of waves	3, 5, 7, ...,125	Command parameter (checked and corrected if less than 3)
19	TX output damping	0 or 1 or 2	Echoed command parameter
20, 21	ADC_DIV	31 to 4095	Adjusted clock divider for ADC
22, 23	ADC_ADR	255 + 2*NSPW*(number of waves)	Adjusted last address in PP memory
24, 25	DAC_DIV	20 to 2047	Adjusted clock divider for DAC
26	NSPW	16 or 32 or 64	Number of points per wave.
27	DAC_ADDR	1 to 255	Adjusted last used address in DAC table.

Expected SD output for PP Active Mode Test 2 (PP_AMTEST2)			
Byte No.	**Meaning**	**(Typical) Value**	**Remarks**
28, 29	Error code	0	
		if no fatal error in error code:	
30 to 285	DAC table read back from PP memory	256 DAC table entries, each ranging from 0 to 255	Complete DAC table section in PP memory. Bytes #0 to byte (DAC_ADDR) form the actually used DAC table.
286 to 287	Number of samples ***nSamp***	(NSPW+1)*(number of waves)	Includes the first wave, which is skipped during on-board analysis.
		nSamp times	
		Active Mode Samples Block	
+1	Transmitter current sample	0..255	One byte per sample
+2	Receiver voltage sample	0..255	One byte per sample
		Active Mode Results Block	
+1, +2	Error code	cf. list of error flags	
		if no fatal error in error code:	
+3	QUAL	cf. list of quality flags	Quality flags
+4	NSPW		Number of points per wave
+5, +6	PHASE		Phase difference potential-current (1/16 degree)
+7, +8	Current amplitude		Scaling as raw data without offset: 128 = max. ADC current.
+9, +10	Voltage amplitude		Scaling as raw data without offset: 128 = max. ADC voltage.
+11, +12	Math Error Code	cf. list of math error flags	

The net science data volume (excluding Science Packet Headers and the filling-up of the final packet) is (300 + (NSPW+1)*(number of waves)*2) byte, with NSPW=64 for transmitter frequency less or equal 1560 Hz, NSPW=32 (1560 < f/Hz <= 3125) or NSPW=16 (3125 < f/Hz <= 1100).

The duration of the actual measuring process by PP H/W depends on the adjusted frequency and the number of waves. It ranges from 0.3 ms (11000 Hz, 3 waves) to 6.25 s (20 Hz, 125 waves). A typical configuration (1100 Hz, 17 waves) takes 16.8 ms. The total execution duration of PP_AMTEST2 with that configuration is ca. 4 s. Most of the execution period is thus spent for PP H/W initialisation, data transfer between C-DPU and PP, and the on-board data evaluation.

The timestamp of the first sample of the time series can be inferred from the timestamp in the Science Data Header by adding 502 ms. The delta period consists basically of the waiting period (500 ms) after PP power switching. It’s accuracy is estimated to be [-1,+5] ms, which is sufficiently lower than the resolution of the timestamp in the measurement header (1/32 s).

4.4.7 PP Active Mode Test (PP_AMTEST)

Upon arrival of the PP_AMTEST command, flight software executes a PP_AMTEST2 measurement with transmitter amplitude damping set to 0 (i.e. full transmitting amplitude). Consequently telemetry data appear as a result of a PP_AMTEST2 measurement.

Flight software versions FM-2 and FM-3 support the command PP_AMTEST for downward compatibility.

4.4.8 PP Passive Mode 2 (PP_PM2)

PP Passive Mode 2 executes a Langmuir Probe measurement and subsequently one passive measurement. All measuring parameters (integration clock divider, sampling frequency, number of used and skipped samples, number of power spectrum frequency bins) are read from the PP Control Table. The input of one command data word is mandatory, although it is not evaluated on-board.

Expected SD output for PP Passive Mode 2 (PP_PM2)			
Byte No.	**Meaning**	**(Typical) Value**	**Remarks**
0 to 13	Science data header	BCDE BCDE 6301 llll llll tttt tttt	llll= total length (depends on PP Control Table settings)
14, 15	TC command parameter		Command parameter (currently not used)
16, 17	LP integrator clock divider	0 to 15	Determines integrating time of Langmuir Probe (LP) measurement
18, 19	LP value	0 to 0xFFFF	Result of LP measurement
20, 21	Error Code	cf. list of PP error flags	Error code for LP measurement
22, 23	ADC clock divider	depending on the sampling frequency defined in the PP control table; usually 125 representing 40 kHz sampling frequency	Instrument adjustment calculated from the used sampling frequency
24, 25	Number of used samples ***nSamp*** (excluding skipped samples)	2^{10} to 2^{13}	Parameter read from PP control table
26, 27	Error Code		Error code for passive measurement
If no fatal error:			
Passive Mode Results Block			
28, 29	Number of frequency bins ***nBin***	0 to 10	
nBin times: ***Power spectrum block***			
+1 to +2	Spectrum bin power for n^{th} bin; high word		
+3 to +4	Spectrum bin power for n^{th} bin; low word		
+1, +2	Math Error Code		

One science data packet is generated. The execution duration is less than 6 seconds. It is composed of the setup (502 ms) and the execution of the Langmuir Probe measurement (t = $2*10^{-7}$ s * (INT_DIV + 1) * TC; cf. chapter “PP Langmuir Probe Test) and the setup (502 ms) and execution duration (parameter dependent) of the Passive Mode measurement. It includes as well the data transfer between PP and C-DPU and the on-board evaluation. The recording of time series starts (1.004 + $2*10^{-7}$ * [INT_DIV + 1] * TC) s later than the time stamp in the Science Data header (estimated accuracy of delta time: -2 / + 10 ms).

4.4.9 PP Passive Mode Test 2 (PP_PMTEST2)

Like Passive Mode 2, PP_PMTEST2 executes a Langmuir Probe measurement and subsequently one passive PP measurement. The number of samples is encoded in the TC data word. In contrast to PP_PM2, raw measuring values are included into telemetry. Telemetry concludes with the results of the on-board data evaluation.

Expected SD output for PP Passive Mode Test 2 (PP_PMTEST2)			
Byte No.	**Meaning**	**(Typical) Value**	**Remarks**
0 to 13	Science data header	BCDE BCDE 6C01 llll llll tttt tttt	llll= total length (depends on parameter values in the PP Control Table)
14, 15	LP integrator clock divider	0 to 15	Determines integrating time of Langmuir Probe (LP) measurement
16, 17	LP value	0 to 0xFFFF	Result of LP measurement
18, 19	Error Code	cf. list of PP error flags	Command parameter errors and error flags for LP measurement
20, 21	ADC clock divider	depending on the sampling frequency defined in the PP control table; usually 125 representing a sampling frequency of 40 kHz	Instrument adjustment calculated from the used sampling frequency
22, 23	Number of used samples ***nSamp*** (excluding skipped samples)	2^{10} to 2^{13}	Interpreted command parameter
24, 25	Error Code	cf. list of PP error flags	Error flags for passive mode measurement
With a fatal error indicated in the Error Code (bytes 24, 25), telemetry stops here. If no fatal error:			
nSamp times: Samples block			
+1	n^{th} difference value	0 to 255	Sample read from even PP memory address
Passive Mode Results Block			
+1 to +2	Number of frequency bins ***nBin***	0 to 10	
nBin times: ***Power spectrum block***			
+1 to +2	Spectrum bin power for n^{th} bin; high word		
+3 to +4	Spectrum bin power for n^{th} bin; low word		
+1 to +2	Math Error Code		Errors encountered during PM data analysis; see list of math errors

The net science data volume depends on the number of used samples nSamp (to be inferred from the TC parameter) and the number of frequency bins nBin (PP Control Table) and is (30 + nSamp + nBin*4) byte. The execution duration is less than 7 seconds. The time stamp of the first sample of the time series is (1.004 + $2*10^{-7}$ * [INT_DIV + 1] * TC) s later than the time stamp in the Science Data header.

In case INT_DIV = 15 and no Langmuir Probe signal is detected, the expected delta between the time stamp in the Science Data header and the beginning of the time series is (1.004 + $2*10^{-7}$ * [15 + 1] * 65535) s = 1.214 s. Parallel operations of SESAME/PP and Consert during PC13 interference tests, when three Consert signals were recorded by PP, suggest a slightly higher value in that case: (1.356 ± 0.078) s. The reason for the discrepancy of 4.5 times the resolution of the LOBT is TBD.

4.4.10 PP Update Control Table (PP_RCTL)

The command PP_RCTL (0x591A) comes with 26 data words, which are written to the PP control table in SESAME RAM. The parameters of the uploaded table will be used for subsequent PP measurements until a further table is uploaded or SESAME is switched off. Because the telemetry of all PP measurements includes the basic instruments settings, PP_RCTL itself does not produce a dump of the updated table. It is, however, possible to create a dump of the table by using the PP_DCTL command.

After power cycling of SESAME, the default control table is valid again.

A (not very realistic) example: The following telecommand causes that measurements with only ten different frequencies from 1000 to 1090 Hz (nominal) are executed during later PP_AM2 mode measurements.

591A 0F0A 2000 9C40 0200 0A**0A 03E8 03F2 03FC 0406 0410 041A 0424 042E 0436**
0442 0708 07D0 0960 0BB8 0DAC 1388 1770 1B58 2134 2710 0121

The differences to the default control table in SESAME EEPROM are written in bold face.

Note: Two parameters of the control table (the repetition count for LP measurements and the electrode combination for Active Mode measurements) are not evaluated by flight software. Nevertheless, the telecommand must always consist of the command word and 26 data words.

No science data are generated. The execution duration is less than 1 second.

4.4.11 PP Direct Hardware Access (PP_DA)

PP_DA is used to write and read PP registers directly (used for H/W debugging).

Expected SD output for PP Direct H/W Access (PP_DA)			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 13	SD header	BCDE BCDE 5802 0000 0016 tttt tttt	Total length: 0x16 = 22 byte
14, 15	Bus address	0018 or 0019	Echoed command parameter
16, 17	Parameter written to bus address		Echoed command parameter
18, 19	Value read from bus address		= -2 if wrong bus address
20, 21	Measured voltage on +5V power supply line	09C4	Multiply by 2 to yield voltage in mV.

One science data packet is generated. The execution duration is less than one second.

4.4.12 PP Test/Debug (PP_SPEC) and PP Dump Control Table (PP_DCTL)

The operations executed upon a PP_SPEC command are generally used for dedicated test and debug purposes, only. The PP_SPEC command with fixed mode = 1 has, however, been given the alias PP_DCTL (Dump Control Table) and will be used as a regular flight operation mode after hibernation.

The first TC parameter ("mode") of PP_SPEC determines which operation is executed. Upon mode = 0, the Forth data stack depth and the stack contents are dumped to telemetry. This mode should only be used on ground. Telemetry is not documented in this chapter.

With mode = 1, the content of the currently active PP Control Table is dumped in two ways: (a) 26 words are copied from the memory start address of the control table to telemetry, (b) the values of the single parameters in the table are interpreted by flight software and included into telemetry.

Expected SD output for PP_DCTL (aka PP_SPEC with mode = 1)					
No.	Byte No	Data Type	Meaning	Typical value	Remarks
1	0 to 13	DB	Science Data Header		ID = 0x1A03
2	14 to 15	UW	Block header		Mode = 1
3	16 to 55	26*UW	PP_CTL		Word-wise copy of the active control table
4	56 to 57	UW	INTDIV		Clock divider for Langmuir Probe (LP)
5	58 to 59	UW	LMREP		Repetition count for LP
6	60 to 61	UW	NSAMP		Number of used samples for Passive Mode (excluding skipped samples)
7	62 to 63	UW	SFREQ		Sampling frequency [Hz] for Passive Mode
8	64 to 65	UW	NSKIP		Number of skipped samples for Passive Mode
9	66 to 67	UW	NBIN		Number of frequency bins for onboard evaluation of Passive Mode data
10	68 to 69	UW	NFREQ		Number of used transmitting frequencies for Active Mode
11	70 to 109	20*UW	freq00 to freq19		20 transmitting frequencies [Hz] for Active Mode

One science data packet is generated. The execution duration is less than one second.

4.4.13 Error Codes and Quality Flags

PP General Software Error Flags (TM parameter "PP Error Code")			
Flag (hex.)	**Flag (DEC(HEX XOR 8000))**	**Name**	**Meaning**
8001	1	EB_PPINVREG	Invalid register address.
8002	2	EB_PPVERREG	Error verifying register write.
8004	4	EB_PPPWRREG	Error accessing power register.
8008	8	EB_PPMUXSET	MUX setting not allowed.
8010	16	EB_PPMEMACC	Error accessing PP RAM.
8020	32	EB_PPMESRUN	Tried to start measurement but a measurement is already running.
0040	64	EB_PPWRITE	Error during writing to instrument.
0080	128	EB_PPREAD	Error during reading from instrument.
0100	256	EB_PPCDUADC	Error using ADC of C-DPU.
0200	512	EB_PPDACTAB	Error during DAC table generation.
0400	1024	EB_PPNSAMP	Calculated number of samples > N_SAMP_MAX.
8800	2048	EB_PPNOMEM	C-DPU memory exhausted.
9000	4096	EB_PPTOUT	Measurement time out.
2000	8192	EB_PPINVCMD	Invalid command parameter.
8000	0	EB_PPFATAL	Flag indicates fatal error.

A separate error code word ("PP Math Error Code") is used to indicate errors, which can only occur during on-board data reduction:

Errors which can occur during on-board data reduction ("PP Math Error")			
Flag (hex.)	**Flag (decimal)**	**Name**	**Meaning**
0001	1	EB_PPMATHNRED	Reduce: number of vector elements odd or less than 2; fatal.
0002	2	EB_PPMATHNEXP	Expand: less than four elements in input vector; fatal.
0004	4	EB_PPMATHNHIH	Too much data for analysis; truncating.
0008	8	EB_PPMATHNLOW	Too few data for analysis; padding with "128".
0010	16	EB_PPMATHPOW2	Used number of waves is not a power of 2; truncated.
0020	32	EB_PPMATHNFLT	Not the expected number of elements in filtered arrays; fatal.
0040	64	EB_PPMATHSINE	Argument for sine_table() not in valid range 0<= deg2 <=720.
0080	128	EB_PPMATHDSIN	Overflow in divsin() or result inexact.
0100	256	EB_PPMATHTRIM	Too few data for trimmed mean calculation; regular mean used.
0200	512	EB_PPMATHNODA	No data for warr.mean; particularly: analysis yields no data.
0400	1024	EB_PPMATHNBIN	Passive mode: not enough data in bin.
0800	2048	EB_PPMATHNMEM	Not enough memory for data reduction.

More than one flag can be set in each error code word.

Quality flags are used to indicate saturated signals in active and passive modes. More than one flag can be simultaneously set in parameter "QUAL":

PP Quality Flags (bit setting in TM Parameter "QUAL")	
Flag	**Meaning**
1	At least one sample = 255 in current (transmitter) time series
2	At least one sample = 0 in current (transmitter) time series
4	At least one sample = 255 in voltage (receiver) time series
8	At least one sample = 0 in voltage (receiver) time series

4.4.14 New/modified PP Features with Flight Software FM-3

With TC PP_RCTL, it is now possible to upload a PP Control Table, which will temporarily overwrite the default table in SESAME flight software. The active control table can be dumped to telemetry with PP_DCTL.

4.5 Common Telecommands and Science Telemetry

4.5.1 Table of Telecommands

IDENT	Com-mand Word	Parameter Words			Description
		No	Meaning	Valid Range	
COM_HK	7200	n/a	n/a	n/a	SESAME Health Check
COM_WDLY	7501	1	Waiting period [s]	1 to 0xFFFF	Subsequent telecommand shall be executed after a pause of "waiting period" seconds
COM_WLOBT	7603	1	LOBT low word	1 to 0xFFFF	Subsequent telecommand shall be executed not before the given LOBT.
		2	LOBT midth word	1 to 0xFFFF	
		3	LOBT highest (5) bits	0 to 0x001F	
COM_RBUF	7A02	1	Unit	Valid subsystem address of a unit	Read record of Backup RAM Buffer of unit "unit" starting at "offset"
		2	Offset	Valid offset in units Backup RAM Buffer	
COM_RDJC	7B01	1	Offset	Valid offset in SESAME STC buffer	Read Stored TC record and store it to CASSE jobcard JOB_MES
COM_WPENZ	7703	1	Depth threshold	Same length unit as used in MUPUS BRAM (0 to 0x1FFF)	Subsequent telecommand shall be executed not before MUPUS PEN meets the given depth condition.
		2	Slope factor	1 or -1 (0xFFFF). See text.	
		3	Timeout	Timeout (s)	
COM_SPEC	7C03	three parameters		Parameters depend on programmed code.	Special command for debugging (used for H/W and S/W tests only). Functionality depends on test item.

4.5.2 SESAME Health Check (COM_HK)

All SESAME HK parameters are measured or collected and values are included into the SD stream. CASSE analogue power (± 5 V) is switched on during the execution of the command to allow the reading of the RadFET offset voltage on CASSE PCB. The RadFET offset voltage is measured twice. Particular measurements of the CASSE temperature channels and some reference voltage channels are executed. The data obtained using dedicated A/D conversion routines allow the comparison of temperature measurements using the old and the new measuring method. Regular HK scaling and interpretation of measured values apply.

Expected SD Output for COM_HK Telecommand				
Item No.	**Byte No.**	**Meaning**	**(Typical) Value (hex)**	**Remarks**
1	0 to 13	SD Header		ID = 0x7200; total length = 0x96 = 150 byte
2	14, 15	UFPG		HK parameter: 3.3V (FPGA)
3	16, 17	UD+5		HK parameter: +5V (DIM)
4	18, 19	UD-5		HK parameter: -5V (DIM)
5	20, 21	UP+5		HK parameter: +5V (PP)
6	22, 23	U+05		HK parameter: +5V (CE)
7	24, 25	U-05		HK parameter: -5V (CE)
8	26, 27	U+12		HK parameter: +12V (CE)
9	28, 29	U-12		HK parameter: -12V (CE)
10	30, 31	U+28		HK parameter: +28V (CE)
11	32, 33	UCDP		HK parameter: +5V (C-DPU)
12	34, 35	URAD		HK parameter: Total Dose (RADFET)
13	36, 37	I+05		HK parameter: Current +5V (CE)
14	38, 39	I-05		HK parameter: Current –5V (CE)
15	40, 41	I+12		HK parameter: Current +12V (CE)
16	42, 43	I-12		HK parameter: Current -12V (CE)
17	44, 45	I+28		HK parameter: Current +28V (CE)
18	46, 47	CEID	0xC5E5	HK parameter: SESAME ID
19	48, 49	TPCB		HK parameter: CASSE Board Temperature
20	50, 51	CLTC		HK parameter: Last Telecommand received
21	52, 53	CBTC		HK parameter: Last but one Telecommand
22	54, 55	LMID		HK parameter: SESAME Local Time (high word)
23	56, 57	LLOW		HK parameter: SESAME Local Time (low word)
24	58, 59	TT-Y		HK parameter: Foot –Y / TRM Temperature
25	60, 61	TA-Y		HK parameter: Foot –Y / ACC Temperature
26	62, 63	TT+X		HK parameter: Foot +X / TRM Temperature
27	64, 65	TA+X		HK parameter: Foot +X / ACC Temperature
28	66, 67	TT+Y		HK parameter: Foot +Y / TRM Temperature
29	68, 69	TA+Y		HK parameter: Foot +Y / ACC Temperature
30	70, 71	PPD		HK parameter: Electron Density
31	72, 73	SUPS		HK parameter: SRAM Usage/Power Status
32	74, 75	TIBO		HK parameter: Time since Boot [s]
33	76, 77	ERRF		HK parameter: Error Flags
The next item (no. 34) appears for each temperature channel, i.e. seven times. The order of temperature channels is foot –Y/TRM, foot –Y/ACC, foot +X/TRM, foot +X/ACC, foot +Y/TRM, foot +Y/ACC, CASSE PCB temperature.				
34	78, 147	Data Block: Extended Temperature Measurement (see separate table)		

Expected SD Output for COM_HK Telecommand				
Item No.	Byte No.	Meaning	(Typical) Value (hex)	Remarks
35	148,149	URAD-2		Second measurement of RadFET offset voltage.

Data Block: Extended Temperature Measurement				
Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0, 1	T-HK		Voltage of temperature channel using the old measuring method (used with FM-1 and FM-2)
2	2, 3	T-I1		Intermediate voltage measured shortly after switching from temperature channel to reference channel 1.
3	4, 5	T-R1		Voltage of reference channel 1 = UCDP.
4	6, 7	T-I2		Intermediate voltage measured shortly after switching from temperature channel to reference channel 2.
5	8, 9	T-R2		Voltage of reference channel 2 = U+28.

One science data packet is generated. The execution duration is reduced again to approximately one second (similar to the value obtained with FM-1), as the one minute waiting period between the two RadFET voltage measurements (introduced in FM-2) is not applied in FM-3.

4.5.3 TC processing: Pause (COM_WDLY)

The processing of incoming telecommands is stopped for the period specified in the parameter word. No science data are generated.

4.5.4 TC Processing: Wait until Lander Onboard Time (COM_WLOBT)

The processing of incoming telecommands is stopped until Lander Onboard Time specified in the parameter words. No science data are generated.

4.5.5 Read Backup RAM Buffer (COM_RBUF)

This command is used to check whether access to Backup RAM Buffer works and to verify the contents of a Backup RAM Buffer record. One record of a unit's Backup RAM Buffer in CDMS memory is read and the contents included in the telemetry stream. The unit is specified by the subsystem address (cf. CDMS Subsystem Specification) and can be SESAME itself. The expected content of specific records in the Backup RAM Buffer of some units was laid down in the interaction document (RD4).

Expected SD output for Read Backup RAM Buffer (COM_RBUF)			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 13	SD header	BCDE BCDE 7A02 0000 0052 tttt tttt	Total length: 0x52 = 82 byte
14, 15	Unit Subsystem Address		Echoed command parameter
16, 17	Offset in Backup RAM Buffer		Echoed command parameter
18 to 81	Contents of Backup RAM Buffer Record		Record is copied byte by byte to TM stream

One science data packet is generated. The execution duration is usually a few seconds only. A timeout value of 30 s is applied.

4.5.6 Read Jobcard from Stored TC Buffer (COM_RDJC)

This command is used to check whether access to Stored TC Buffer works and to demonstrate an alternative way of commanding the CASSE instrument. The TC is used for ground tests and should be applied with care because of the side effect (writing to the CAS_MES jobcard). One record of SESAME STC buffer in CDMS memory is read and the first 16 words of that record (length of a jobcard) included in the telemetry stream. Additionally these words are copied to the CASSE JOB_MES jobcard in SESAME RAM. Subsequent CASSE measurements commanded by telecommand CAS_MES are controlled by that jobcard, thus it should be ensured that the STC record contains a valid CASSE jobcard, if such measurements are intended without a preceding CAS_RDJC command.

Expected SD output for Read Stored TC Buffer (COM_RDJC)			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 13	SD header	BCDE BCDE 7B01 0000 0030 tttt tttt	Total length: 0x30 = 48 byte
14, 15	Offset in STC Buffer		Echoed command parameter
16 to 47	First 16 Words of STC Record		Record is copied byte by byte to TM stream

One science data packet is generated. The execution duration is usually a few seconds only. A timeout value of 30 s is applied.

4.5.7 Wait for MUPUS PEN Insertion Depth (COM_WPENZ)

The telecommand COM_WPENZ (0x7703) is used to delay the execution of the subsequent TC until MUPUS PEN has reached a particular depth. To this end the MUPUS Backup RAM Buffer (BRAM) is read. Word #2 (the 3rd word) of record #5 in MUPUS BRAM contains a raw value representing the insertion depth. Telecommand parameters include a “slope factor” (+1 or -1), which allows to adapt to raw values descending or ascending with depth [it is expected that raw values decrease with increasing PEN depth, though]. Further command parameters are the threshold depth and a time-out period. Applicable values of the command data words shall be fixed in cooperation with the MUPUS team, possibly after the depth information in MUPUS BRAM is verified and calibrated.

The content of the MUPUS BRAM record is checked at intervals of one second. [Usually (so far during cruise) the response of CDMS to a BRAM request is considerable faster than one second. On the other hand MUPUS hammer strokes take place at intervals of one second and the worst case CDMS-unit communication latency is 32 seconds.]

Exit criteria are

- (depth read from MUPUS BRAM) * (slope factor) >= threshold and “Mupus is deployed and hammering” (read from MUPUS BRAM)
- the time-out period is expired.

The contents of the MUPUS BRAM record and selected information from (requested) CDMS RSST message are included at the beginning and at the end of the waiting period. Housekeeping measurements are performed if pending.

The telecommand parameters are checked and corrected if necessary to avoid numerical problems and “endless” loops. The maximal time-out period is one hour (TBC).

Telemetry of COM_WPENZ						
Item No.	**Byte No.**	**Length [Byte]**	**Data Type**	**Name**	**Value**	**Remarks**
1	0 to 13	14	DB	SD Measurement header		The ID of the TC is 0x7703.
2	14 to 15	2	UW	Pen depth insertion threshold (TC parameter)	0 to 0x1FFF	Same unit as the MUPUS BRAM “Pen insertion depth” parameter.
3	16 to 17	2	W	SlopeFactor (TC parameter)	-1 or +1	Factor to be applied to the MUPUS BRAM “Pen insertion depth” parameter.
4	18 to 19	2	UW	Time-out [s] (TC parameter)]	1 to 3600 [TBC]	
5			DB	Initial system / MUPUS status		see data block “System/MUPUS Status”
6			DB	Final system / MUPUS status		see data block “System/MUPUS Status”
7	+1	1	UB	Commanding error?		Yes (0xFF) / No (0)
8	+2	1	UB	Final result: MUPUS is hammering and depth achieved?		Yes (0xFF) / NO (0)

Data Block: System/MUPUS Status						
No	**Byte No.**	**Length**	**Data Type**	**Contents**	**Value**	**Remarks**
1	0 to 1	2	UW	Time when BRAM & SST records were checked by flight software (high)		SESAME Local Time
2	2 to 3	2	UW	Time when BRAM & SST records were checked by flight software (low)		
3	4 to 5	2	BitP	First command word of last CDMS RSST message		System status
4	6 to 7	2	BitP	Second command word of last CDMS RSST message		Unit's On/Off status
5	8 to 9	2	UW	TBUP (BRAM pointer to unit / record)	0x3805	Unit = 7, record = 5
6	10 to 73	64	32*UW	BRAM record		Most recent MUPUS BRAM record
7	74 to 75	2	UW	Number of received and checked BRAM records so far		

One science data packet is generated. The maximal execution duration is determined with the command data word “timeout”.

4.5.8 Special Messages in Science Data Stream

4.5.8.1 Ready Message

After boot, SESAME S/W performs some basic initialization, transmits a Send Service System Status (SSST) request to CDMS, and waits two seconds. With CDMS running in normal mode, SESAME should receive at least one CDMS RTIM (Receive Onboard Time) message during the waiting period and the timestamp in the SD header of the Ready Message should than be adjusted to LOBT (showing SESAME Local Time approximately two seconds after boot). SESAME software does not wait for the requested RSST message from CDMS. If no RSST message has been received during the two seconds period, the fields of the RSST command words are filled with “0000”.

SESAME Ready Message				
Byte No.	**Type**	**Meaning**	**Value (hex.)**	**Remarks**
0 to 13	SD header		BCDE BCDE 0000 0000 0052 tttt tttt	Total length: 0x52 = 82 byte
14 to 39	String*26		5345 5341 4D45 2046 6C69 6768 7420 532F 5720 202D 2052 6561 6479	Character representation: "SESAME Flight S/W - Ready"
40 to 45	3*UW	n/a	0000 0000 0000	
46 to 53	String*8	Flight S/W version		Contains the S/W version, padded with trailing blanks if necessary (e.g. “FM3.00 “)
54 to 61	4*UW	n/a	0000 0000 0000 0000	
62 to 81	10*UW	1st to 10th command word of CDMS RSST message		Cf. CDMS specification (RO-LCD-SP-3101) for meaning and data type.

4.5.8.2 Error Messages

Science Data with measurement id 0x7F00 are error messages. Error messages contain the string “Error Message” followed by one or more error codes.

SESAME Error Message			
Byte No.	**Meaning**	**Typical Value (hex.)**	**Remarks**
0 to 13	SD header	BCDE BCDE 7F00 llll llll tttt tttt	lll lll is total length, depending on number of error code words contained; last two words are SESAME Local Time
14 to 27	Identifying character string	4572 726F 7220 4D65 7373 6167 6520	character representation: "Error Message "
one to eight error code words follow; for each error code word:			
+1 to +2	Error Code Word		

Error code words are constructed in the following way:

Error Code Word Bit Structure															
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Error Level				**Subsystem/Module**				**Error Number**							

Error Level:

- 0x0: Information for debugging, no error
- 0x1: Warning
- 0xE: Error
- 0xF: Fatal Error, Reboot required

Subsystem:

- 0x0: Global routines
- 0x1: ADC, HK
- 0x4: CDMS I/F
- 0x5: Science data processing
- 0x6: Telecommand processing
- 0xA: CASSE S/W
- 0xB: DIM S/W
- 0xC: PP S/W
- 0xD: Common actions

Error number:

Unique number within subsystem numbering.

Some potential error conditions, which were expressed by error messages in former software versions, are now indicated in HK parameter ERRF. The following error codes for error messages are used further on in error messages.

Error Codes in Error Messages			
Error Code	**Sub-system**	**Source File**	**Meaning**
1601	TC process.	TC.4TH	Unknown command category, TC ignored.
1617	Common	CDPU.4TH	Unknown common TC.
1A01	CASSE	CASSE_FM.4TH	Wrong temperature channel, set to default (1).
1A11	CASSE	CASSE_FM.4TH	Unknown CASSE TC.
1B01	DIM	DIM.4TH	Invalid margin, set margin to 0.
1B02	DIM	DIM.4TH	Invalid direction, set direction to X.
1D03	Common	CDPU.4TH	Could not allocate memory (COM_HK).
1D08	Common	CDPU.4TH	Error reading Backup RAM Buffer.
1D09	Common	CDPU.4TH	Error reading Stored TC Buffer.
E106	Common	CDPU.4TH	Could not allocate memory (COM_RBUF).
EA20	CASSE	CASSE_FM.4TH	Could not allocate memory (CAS_HC).
EA22	CASSE	CASSE_FM.4TH	Could not submit measurement (CAS_HC).
EA24	CASSE	CASSE_FM.4TH	Could not allocate memory (CAS_MES) or invalid number of channels.
EA26	CASSE	CASSE_FM.4TH	Could not submit SD (CAS_MES).
EAFF	CASSE	CASSE_FM.4TH	Allocated memory space exhausted.
EB20	DIM	DIM.4TH	Could not allocate memory (DIM_CA).
EB21	DIM	DIM.4TH	Could not submit SD (DIM_CA)
EB22	DIM	DIM.4TH	Could not allocate memory (DIM_NT).
EB23	DIM	DIM.4TH	Could not submit SD (DIM_NT)
EB24	DIM	DIM.4TH	Could not allocate memory (DIM_ST).
EB25	DIM	DIM.4TH	Could not submit SD (DIM_ST)
EB26	DIM	DIM.4TH	Could not allocate memory (DIM_PC).
EB27	DIM	DIM.4TH	Could not submit SD (DIM_PC)
EB28	DIM	DIM.4TH	Survey: Bad instrument health.
EB2A	DIM	DIM.4TH	Could not allocate memory (DIM_AV).
EB2B	DIM	DIM.4TH	Could not submit SD (DIM_AV, DIM_AV)
EB2C	DIM	DIM.4TH	Could not allocate memory (DIM_BC, DIM_BCTEST).
EB2D	DIM	DIM.4TH	Could not submit SD (DIM_BC, DIM_BCTEST)
EB2E	DIM	DIM.4TH	Autonomous Mode: Computed measurement duration for one AV- or BC measurement derived from total measurement duration (TC parameter) is too small.
EB2F	DIM	DIM.4TH	Autonomous Mode: Bad instrument health.
EB31	DIM	DIM.4TH	Survey: Allocated SRAM memory exhausted.
EB32	DIM	DIM.4TH	Survey: Excessive overcurrent interrupts.
EBF1	DIM	DIM.4TH	Unknown DIM TC.
EC30	PP	PP.4TH	Could not allocate memory (PP_HC).

Error Codes in Error Messages			
EC31	PP	PP.4TH	Could not submit SD (PP_HC).
EC32	PP	PP.4TH	Could not allocate memory (PP_DA).
EC33	PP	PP.4TH	Could not submit SD (PP_DA).
EC52	PP	PP.4TH	Could not allocate memory (PP_LM).
EC53	PP	PP.4TH	Could not submit SD (PP_LM).
EC54	PP	PP.4TH	Could not allocate memory (PP_AM2).
EC55	PP	PP.4TH	Could not submit SD (PP_AM2).
EC57	PP	PP.4TH	Could not allocate memory (PP_AMTEST2).
EC58	PP	PP.4TH	Could not submit SD (PP_AMTEST2).
EC5C	PP	PP.4TH	Could not allocate memory (PP_PM2).
EC5D	PP	PP.4TH	Could not submit SD (PP_PM2).
EC5E	PP	PP.4TH	Could not allocate memory (PP_PMTEST2).
EC5F	PP	PP.4TH	Could not submit SD (PP_PMTEST2).
ECE1	PP	PP.4TH	Unknown PP TC.
ED04	Common	CDPU.4TH	Could not submit SD (COM_HK).
ED05	Common	CDPU.4TH	Could not submit SD (COM_RBUF).
ED07	Common	CDPU.4TH	Timeout during Backup Buffer RAM reading..
ED0A	Common	CDPU.4TH	Timeout during Stored TC Buffer reading..
ED0B	Common	CDPU.4TH	Could not allocate memory (COM_RDJC).
ED0C	Common	CDPU.4TH	Could not submit SD (COM_RDJC).
ED0D	Common	CDPU.4TH	Could not allocate memory (COM_WPENZ).
ED0E	Common	CDPU.4TH	Could not submit SD (COM_WPENZ).

4.5.9 New/modified Common Features with Flight Software FM-3

(a) The duration of the SESAME Health-check (COM_HK) was reduced to one second.
(b) A new command (COM_WPENDZ) is available, which leads to a delay of subsequent measurements until the insertion depth of MUPUS PEN reaches a particular value.