SESAME Flight Software User Manual

Software Release Notes
Version FM 1.0

	Function	Name	Company	Signature	Date
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Document History

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1 Applicable Documents

Title	Code
SESAME Flight Software Specification	RO-LSE-DS-3401
SESAME Operations Plan A, Modes Timeline and Requirements	RO-LSE-PL-3102
SESAME Flight Software Quality Assurance Plan	RO-LSE-PL-3401
SESAME Software, Forth Coding Rules and Style Conventions	RO-LSE-PR-3401
Software User Requirements	RO-LSE-RD-3401
CASSE Software Description	RO-LSE-SP-3420
DIM Software Description	RO-LSE-SP-3440
PP Software Description	RO-LSE-SP-3460
SESAME E-Box Specification	RO-LSE-SP-3802
SESAME Flight Software, Science Data Compression with ESTEC-1	RO-LSE-TN-3401
Housekeeping Procedure	RO-LSE-TN-3402
Interaction of SESAME with other Lander Units	RO-LSE-TN-3403
CASSE EQM2 Extended Functional Test	RO-LSE-TR-3320
CASSE EQM2 Foot Test	RO-LSE-TR-3321
Software Verification and Validation Reports	RO-LSE-TR-3401
CASSE and DIM EQM2 PCB Tests	RO-LSE-TR-3402
SESAME Short Functional Test, Bench Test	RO-LSE-UG-3203
SESAME EGSE User Manual	RO-LSE-UG-3301
CASSE FM PCB User Guide	RO-LSE-UG-3821
UR FORTH Manual, Laboratory Microsystems Inc., 1997	-
LMI Forth-83 Metacompiler Manual, Laboratory Microsystems Inc., 1997	-
HS-RTX2010 RH Programmer's Reference Manual, Harris Corporation, 1991	-
HS-RTX2010RH Radiation Hardened Real Time Express Microcontroller, Datasheet, http://www.semi.harris.com/data/fn/fn3/fn3961/fn3961.pdf	-
CDMS Subsystems & Instruments EID (Extract from REID-A) and Generic Payload Control	-
ROSETTA Lander Common DPU (FM), User's Manual	-

1 Conventions used in this Document

Source code is given in fixed-width, bold type, e.g. **`AddRequest ( n -- erc)`**. SESAME Style and Naming Conventions for FORTH Words are given in the Coding Rules and Style Conventions Guide (RO-LSE-PR-3401).

The present document provides information about software written in FORTH. The term “word” has a special meaning in FORTH: it describes entries in the FORTH dictionary. FORTH Words can be very different objects, which would be called e.g. number, operator, subroutine (or procedure) or program in higher programming languages. Although FORTH does not distinguish, concise terms are used, whenever it serves comprehension. Especially the term “routine” is used as an analogy for subroutine or procedure. A routine may take parameters from the stack and leave parameters on the stack after its execution, e.g. **`AddRequest ( n -- erc)`** takes the parameter **`n`** and leaves **`erc`** on the stack. Parameters are called input or return parameters of the routine, respectively, and the phrase “The routine returns ...” is used, e.g. **`AddRequest`** returns **`erc.`**

Data Structures
A byte contains eight bit (0..7), with bit 0 being the least significant bit (LSB) and bit 7 the most significant bit (MSB). A word contains 16 bit (0..15), with bit 0 being the LSB and bit 15 being the MSB. A word is composed of two byte, the low byte (bit 0..7) and the high byte (bit 8..15).

2 Scope

The present document describes the SESAME Flight Software, which is used to command and control the SESAME instruments CASSE, DIM, and PP and to deliver their measuring data. It explains the basic principles and provides detailed information for the maintenance of the Flight Software and the continuation of the iterative S/W development process. Apart from programming details, which are primarily interesting for the software developer, operational aspects are covered. All implemented telecommands and the expected science data are summarized in a separate chapter. Features of the current S/W version are given in the chapter "Software Release Notes".

3 Hardware Environment

The SESAME H/W consists of the Central Electronics, which is installed in the E-Box, and the peripheral devices of the instruments CASSE, DIM, PP. The sensors and transmitters of the instruments represent one end of the SESAME H/W, the other end is the interface board of the Central Electronics. It connects SESAME to the data lines of the central control unit of the Lander called CDMS (Command and Data Management System) and to the power supply. The Central Electronics can be further divided into the Common Electronics and the instruments boards. The SESAME block diagram is shown in Fig 1.

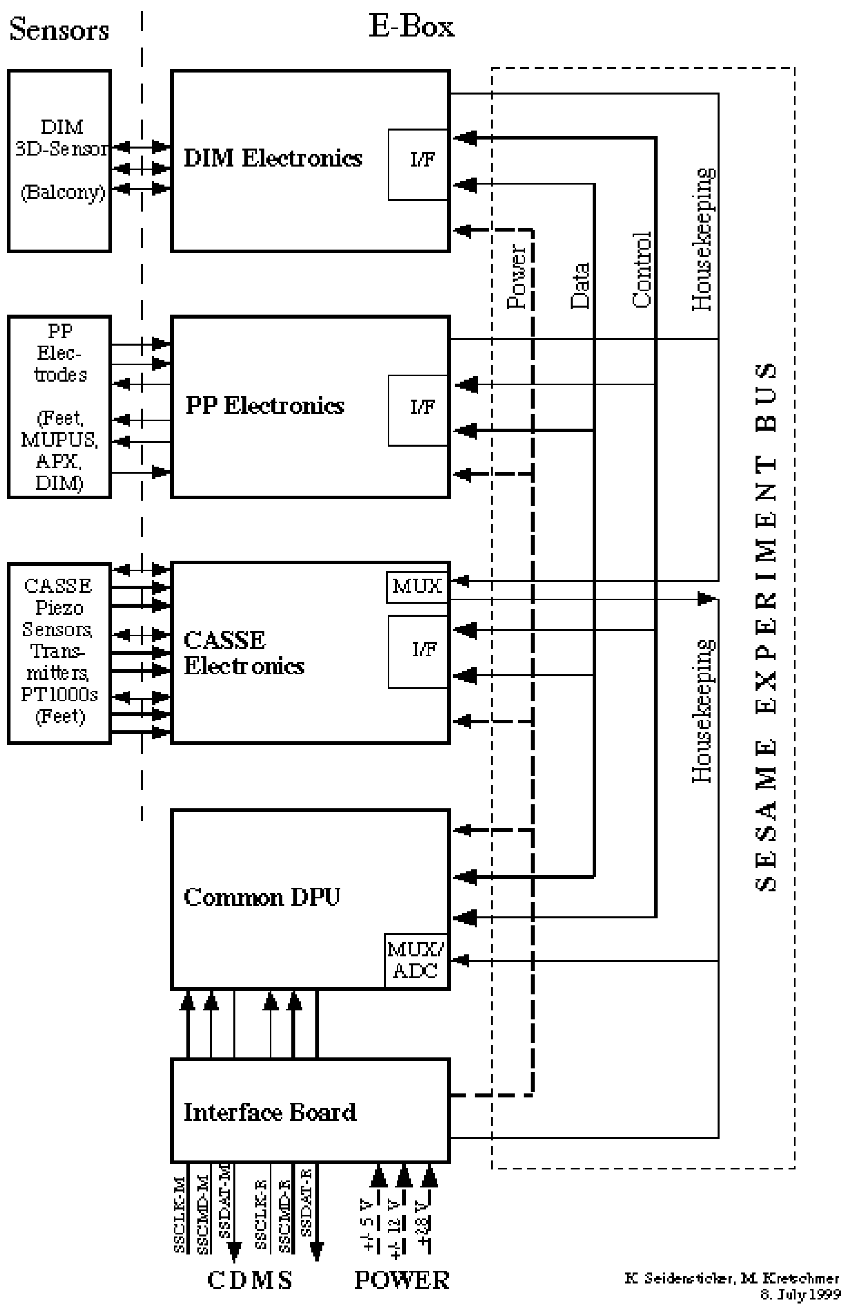

Figure 1: SESAME Block Diagram

3.1 Common Electronics

The Common Electronics includes the Common DPU board (C-DPU), the interface board (connecting the central electronics to the Lander CDMS bus) and an interconnecting printed circuit board (PCB) used as an internal bus, the SESAME Experiment Bus (SEB). The interface board contains power switching equipment, the CDMS interface and a small additional board with HK acquisition and latchup protection circuitry. A detailed description of these components can be found in the SESAME E-Box Specification (RO-LSE-SP-3802).

Common DPU
The C-DPU is a universal processor board, designed for the Rosetta Lander and dedicated versions of this board are used by the experiments CIVA/ROLIS, COSAC, MUPUS, SESAME and the subsystem SD2. Cf. fig. 2 for a block diagram of the C-DPU.

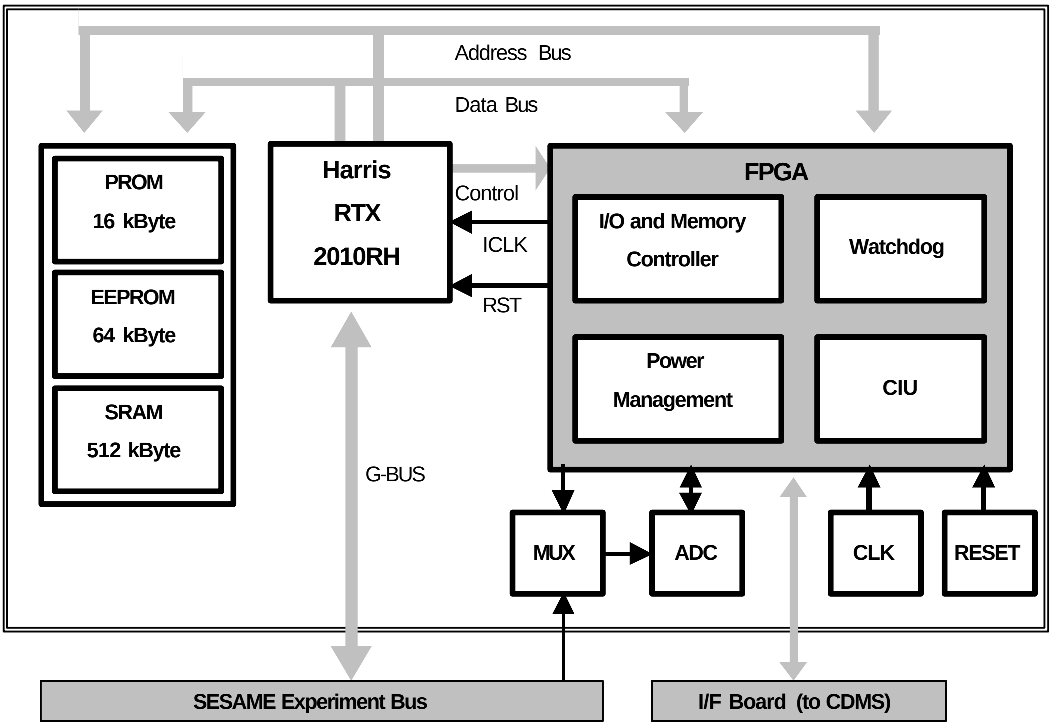

Fig. 2: Block Diagram of the SESAME C-DPU Board

The C-DPU is equipped with the radiation hardened RTX2010 processor (Harris corporation), which is a 16-bit microcontroller with a stack oriented multiple bus architecture. The adjusted processor instruction frequency is 5 MHz. External data is transferred to and from the micro-controller via the 16-bit memory data bus and the 16-bit ASIC bus. The memory bus addresses 16 pages with 64 KByte each, which compose the one Megabyte of memory bus address space. The ASIC bus addresses eight external locations and is used for communication with the instrument PCBs ("G-BUS").

Memory components on the C-DPU are a 16 KByte PROM, an EEPROM (64 KByte) and static RAM. The PROM contains the Common DPU software kernel, called the C-DPU Debug Monitor. Upon a system reset the PROM contents is copied to static RAM and executed. The SESAME flight S/W is stored in the EEPROM, its booting is initiated by the Debug Monitor.

For that the flight S/W is copied to the first page of the SRAM ("Code Page") and executed. The SESAME version of the C-DPU contains two 512 KByte SRAM modules, but only a total of 512 KByte can be addressed, because memory bus addresses above 512 KByte are used to access external hardware. Therefore up to 64 Kbyte can be used for the SESAME flight S/W program code and data on the first SRAM page and another 7 pages (64 Kbyte each) for data.

The C-DPU is equipped with a 14-bit A/D converter and a 16-channel multiplexer. One channel is reserved for the measurement of the C-DPU supply voltage on the +5 V line, thus 15 channels are available for A/D conversion of SESAME specific analog values.

The H/W interface to the CDMS is implemented in the FPGA (in fig. 2 marked as "CIU", i.e. Central Interface Unit). If SESAME is addressed by the CDMS an interrupt is generated, and the interrupt vector is set according to the contents of the CDMS message.

Deviating from the statement in the C-DPU User Manual a low power mode (with a reduced clock frequency) is not possible. The low power mode has been disabled via H/W means on the SESAME C-DPU board because switching between low and normal power mode might cause malfunction (C-DPU bug #3, mail by R. Schrödter, 15. Jan. 2001).

Further details on the C-DPU H/W can be found in the C-DPU User Manual. A comprehensive description of the processor architecture and its programming is contained in the HS-RTX2010RH data sheet and the Programmer's Reference Manual.

3.2 CASSE Instrument

The CASSE instrument consists of a PCB connected to the SEB in the E-Box and transmitters and sensors (accelerometers and temperature sensors) at the feet of the Lander. The PCB contains a 12-channel transient recorder with a programmable sampling rate up to 83 kHz (tbc) and a 3-channel frequency generator. Incoming sensor signals are selected by an analog multiplexer and after amplification (with integrated dynamic compression) converted by an 8-bit ADC. Measured data are written to the data acquisition RAM, where up to 128 Kbyte can be stored. It is possible to select any combination of sensor channels (which can be the X, Y, or Z axis of each accelerometer and the three transmitters) by an appropriate setting of the sensor lookup table (SLT). During data acquisition the sensor channel is switched to the next channel in the SLT after each sample, thus the sampling data flux is distributed among the adjusted channels. An additional event detection unit on the PCB may be used to indicate that measuring data exceed programmable trigger thresholds. The transmitter frequency is derived from the sampling frequency by a programmable frequency divider. Any combination of transmitters may be selected to emit a rectangular shaped oscillation.

An 8-channel multiplexer on the CASSE PCB is used to select some of the analog SESAME HK data and SD. The conversion to digital values takes place via the ADC of the C-DPU, therefore the output of the CASSE multiplexer is connected to the INR14 input channel of the C-DPU MUX. Data measured this way include all DIM measured values and the CASSE PT1000 measurements (temperature sensors on feet and on the CASSE PCB may be selected separately by register setting). Additionally the offset voltage of a **Rad**iation-sensitive **F**ield-**E**ffect **T**ransistor (RadFET) mounted on the CASSE PCB may be selected for a measurement of total ionizing dose.

ASIC bus address 26 is assigned to the CASSE status and control register, and bus address 27 to the CASSE address register. More details can be found in the CASSE PCB User Guide (RO-LSE-UG-3821).

3.3 DIM Instrument

DIM is composed of a PCB in the E-Box and a 3D-sensor, which will be located above the "balcony" at the upper part of the lander. The sensor has sensing faces looking into 3 directions (X,Y, Z), each assembled of piezo segments. Each direction is connected with a shielded cable to the electronics. The data acquisition unit includes input selector switches (X, Y, Z), a preamplifier, a logarithmic-amplifier, peak detector, average and impact-time measuring circuits, threshold circuit, bus-transceivers, power-down circuits and overcurrent circuits. Besides its main (passive) measuring mode, which registers dust impacts on the sensor, DIM sensor segments will be actively excited by applying electric pulses for calibration purposes.

The DIM PCB does not contain an A/D converter nor a multiplexer, thus all DIM analog data have to be converted using the C-DPU ADC (via the CASSE and C-DPU MUX). In case of overcurrent at either supply line the DIM overcurrent circuit generates an interrupt (RTX external interrupt 4 - EI4). DIM power supply may be switched by S/W using the DIM select line (cf. RO-LSE-SP-3802).

ASIC bus address 28 is assigned to the DIM index register, and bus address 29 to the DIM data address register.

3.4 PP Instrument

PP consists of the PP PCB in the E-Box and (active) receivers and transmitters at the Lander feet and at the sensor assemblies of APX and MUPUS. Additionally an electrode for Langmuir Probe measurements is fixed at the DIM sensor on the Lander's "balcony".

The transmitter part of the PP PCB has three electrode drivers including current measurement circuits, an 8-bit DAC as voltage generator, and a switch set to select two out of the three electrodes. The receiver electronics includes two sensor amplifiers, an analog multiplexer and an ADC. Measured transceiver current and receiver voltage values are stored into a 32 KByte RAM on board. The electronics for Langmuir Probe like measurements includes a preamplifier, an integrator and a reset logic.

ASIC bus address 24 is assigned to the PP control and status register, and bus address 25 is used for PP register and memory access.

4 Software Development Process

Software development follows the guidelines defined in the S/W QA document (RO-LSE-PL-3401). An iterative incremental model has been applied because hardware was subject to change during S/W development and user requirements have been specified with increasing precision.

Basic software user requirements have been collected and are listed in RO-LSE-RD-3401. More detailed information on instrument-specific requirements and operational aspects is given in the

S/W descriptions of CASSE (RO-LSE-SP-3420), DIM (RO-LSE-SP-3440) and PP (RO-LSE-SP-3460).

Programming language is Forth-83 (cf. LMI UR-FORTH manual). The Forth language corresponds best to the processor's specific architecture and allows the programming of a small and fast code. A simple DOS environment on a PC is used to implement the code and compile it to the RTX target (cf. LMI metacompiler manual). The programming environment and Forth itself give little assistance to the developer in avoiding programming errors. Therefore careful programming and intensive testing is necessary. The implementation status of user requirements in a S/W version and the tests performed are described in the S/W Release Notes for that version.

5 Software Description

It should be emphasized once again that two different S/W programs (the C-DPU Debug Monitor and the SESAME Flight Software) run on the C-DPU during different operational phases of SESAME. Each has its specific telecommand processing (and does not understand TCs addressed to the other program) and delivers different HK parameters. After power-on the C-DPU Debug Monitor is booted from PROM. This program is almost identical for all experiments and subsystems using the C-DPU. Its features are described in the C-DPU User Manual. Upon a specific telecommand to the Debug Monitor or automatically, if no TC is received within one minute after power-on, the SESAME Flight Software is booted. The following chapters describe the SESAME Flight S/W only. Further details may be found in the S/W code, which has been commented in detail. Special features of the current S/W release are listed in the S/W Release Notes.

5.1 Overview

See figure 3 for an overview of the functional groups of the SESAME Flight Software. Data flow between SESAME and earth takes place via the central computer on the Lander, the Command and Data Management System (CDMS), which in turn communicates with earth via the Orbiter. Along with the H/W interface the S/W interface to CDMS is responsible for the keeping of the communication protocol between CDMS and SESAME. Incoming telecommands are decoded and are used to control the main task of the Flight Software, i.e. the execution of measurements of the instruments CASSE, DIM and PP. The S/W code for measurement control, data evaluation and formatting of Science Data is the central part of the Flight S/W. Additional telecommands are used to perform non-instrument specific actions (e.g. memory check) and to control the TC processing itself. SESAME S/W retrieves Lander and environmental status information from the CDMS, on the other hand it delivers SESAME status information to CDMS. Apart from low level information concerning the communication status between SESAME and the CDMS SESAME software actively measures or acquires a set of housekeeping parameters, which allow to check the health status of SESAME electronics. Communication with other Lander units may be achieved by the passing of trigger words or via the Backup RAM Buffer in the CDMS memory. The preferred way is writing to the own section in the Backup RAM Buffer and the reading of the sections of other units, therefore it is contained in figure 3.

The functionality of the SESAME Flight Software is achieved by the program flow of the S/W loop and several interrupt service routines.

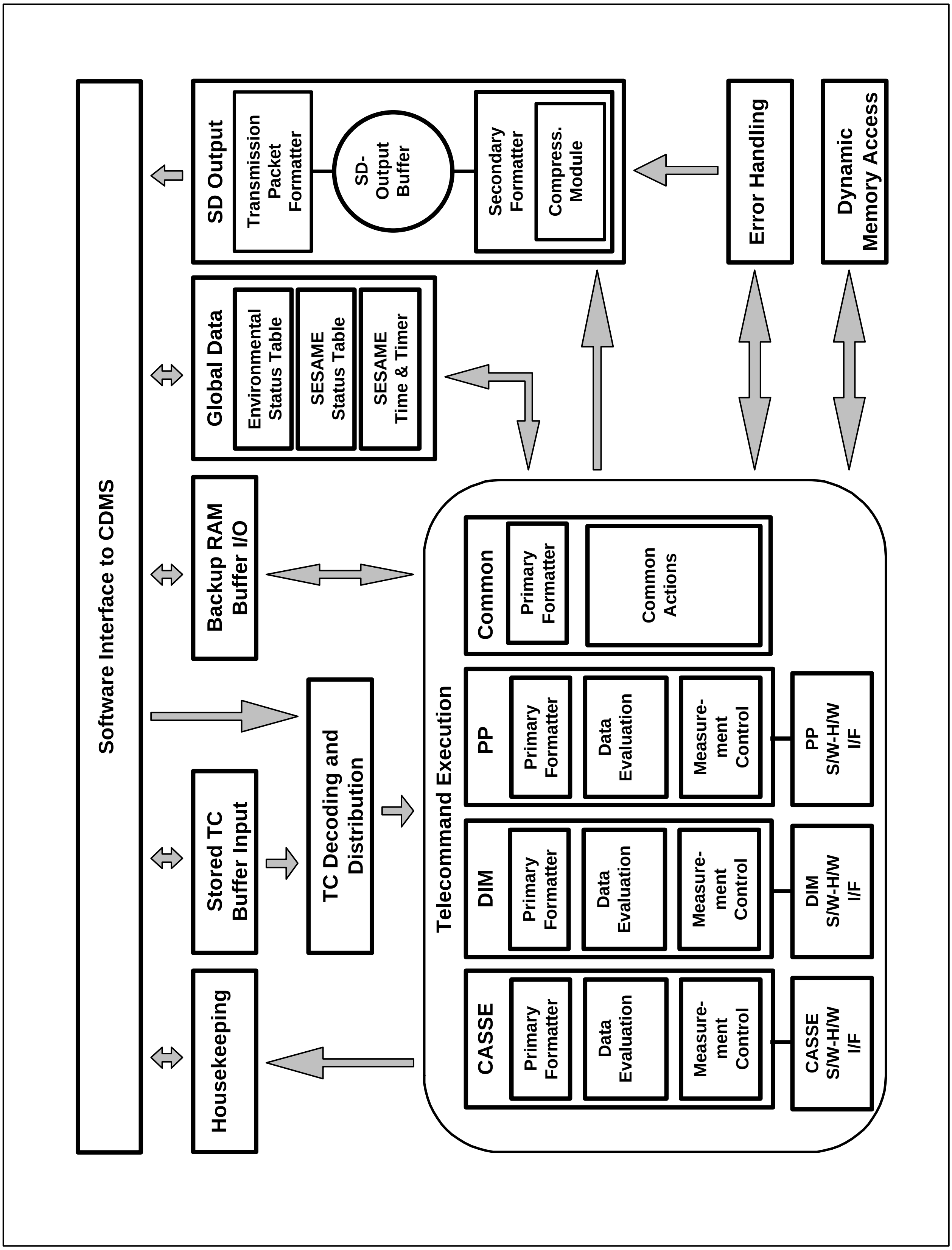

Fig. 3: SESAME Flight Software: Main Functional Groups and Data Flow

5.2 Main Loop and Interrupt Sources

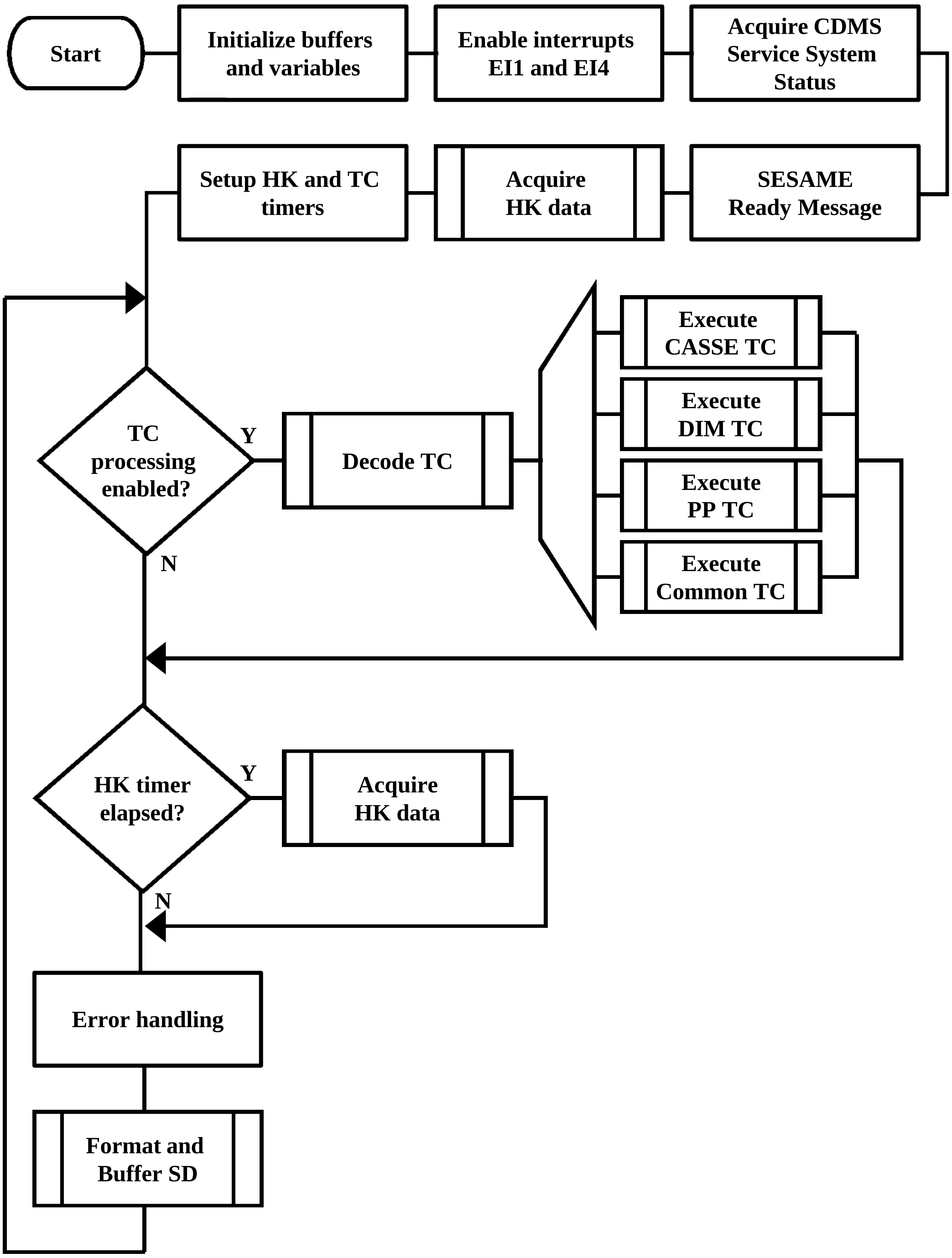

Fig. 4: Main Software Loop

After some initialization it is checked if a TC has arrived. If yes, the TC is passed to dedicated S/W modules for further processing. TC processing is skipped, if it is disabled (TC processing can be disabled by TC for a certain period or until a certain Lander Onboard Time). Likewise, the acquisition of HK values is conditionally executed, depending on a HK acquisition period defined in the S/W code. The S/W loop is completed by a global error check and the preparation of generated SD for sending to the CDMS. Due to the rigid timing requirements of the CDMS communication protocol the actual reception and sending of data does not take place within the main program flow, but it is carried out by interrupt routines. Some other interrupts need to be treated as well. Tab. 1 contains a list of interrupt sources, which are recognized and evaluated by the SESAME Flight software. Together with the main program code the corresponding interrupt routines are described in the following chapters.

Table 1: Recognized Interrupt Sources

Interrupt Source (*)		**Used for...**	**Cf. Chapter...**
EI1	External Interrupt 1	CDMS Interface	"Interface to the CDMS"
EI2	External Interrupt 2	ADC	"Housekeeping and ADC"
EI4	External Interrupt 4	CASSE (**), DIM S/W	"DIM Operation"
TCI0	RTX Timer 0	Time, Timing	"Time and Timers"
TCI1	RTX Timer 1		
TCI2	RTX Timer 2		

(*) notation according to the RTX User Manual
(**) The CASSE trigger unit is a potential EI4 source, but signaling of an event via EI4 has never been enabled. Instead polling of the trigger status registers is used for event detection.

5.3 Interface to the CDMS

The software I/F to CDMS comprises two layers: a low-level layer ("transport layer"), consisting of interrupt service routines, fulfills along with the H/W interface the communication protocol laid down in the CDMS subsystem specification. A second layer ("application layer") provides routines for the data exchange with the CDMS which can be used without bothering with communication details.

The **application layer** routines are listed in table 2. The routines work non-blocking, i.e. a data transfer is initiated, but it is generally not completed when the routine returns. In worst case CDMS is occupied with high priority tasks (like TC reception from and SD transfer to Orbiter), when SESAME sends a request for data exchange. In this case a request processing can take approx. 35 seconds (private communication with CDMS developer team) and during that period CDMS may send a "Request Undue" error to SESAME along with a CDMS Receive Error Code Word (RERC) message. If the completion of data transfer is required for further processing, after a call of a transfer routine a loop with an appropriate timeout should be included, which repetitively checks whether an error occurred (using **`GetCDMSErc (-- n)`**) and if the transfer has been completed or not by checking the status word of the data transfer in question (cf. table 2).

Main tasks of the SESAME S/W interface to the CDMS are the buffering of incoming data (e.g. TC and Backup RAM Buffer records), the sending of data (e.g. SD, HK) in appropriate amounts (words, records), and the correct setting of the SESAME Status Word. The **transport layer** is based on the Common DPU BIOS (cf. C-DPU User Manual). The BIOS is configured with **`CE/ME?`** compiler option on, i.e. the handling of the **Count Error (CE) flag** and the **Message Error (ME) flag** in the Status Word is enabled. The Count Error flag is set by the C-DPU BIOS, whenever the number of command words is different from the WRDC (word count) value in the Subsystem Address Word. The ME flag is set by the SESAME Flight S/W, whenever it encounters an invalid Action Code (ACTC) in the Subsystem Address Word. An Action Code is regarded invalid, if ACTC > 15.

SESAME S/W provides three callback routines (**`msgSTAT`**, **`msgCMD`** and **`msgDATA)`**, which are invoked by the BIOS upon CDMS status, command, broadcast and data messages (command and broadcast messages are handled by the same callback routine). The maximum execution time of a callback is determined by the transmission time of the Status Word, which is approx. 0.5 ms. Each callback is provided with at least one input parameter, the CDMS Subsystem Address Word. It is used to retrieve the subunit address, the Action Code of the message and **`WRDC`**, the number of words to receive or send. See table 3 for a list of all CDMS Action Codes and their handling by SESAME S/W.

The callback **`msgSTAT`** is invoked by the BIOS, if the Action Code of an incoming CDMS message is zero. If application layer routines have submitted a request (see table 3 for all applicable Request Codes) the callback sets the Service Request Flag in the Status Word, which will be submitted to the CDMS upon the next CDMS status request. The routine **`msgCMD`** is called, if the Action Code is non-zero, and the T/R-Bit in the SSADR word is not set. Depending on the Action Code, command words coming along with the CDMS message are distributed to different locations in SESAME RAM: the telecommand buffer, status table... Upon a non-zero Action Code, with T/R-bit set in SSADR, the callback **`msgDATA`** is invoked. Depending on the Action Code the callback delivers an address in SESAME RAM, where e.g. a HK value, a SD record etc. can be found.

Table 2: CDMS I/F: Application Layer Routines	
AddRequest (rqc -- erc)	submits a request to CDMS (see table 3 for valid Request Code names **rqc**).
GetAMDTId (-- n)	returns ID of AMDT according to last RMOD message.
GetCDMSErc (-- n)	returns the CDMS Error Code Word, which is delivered by CDMS if a SESAME request could not be served. The meaning of the Error Code Word is described in the CDMS Subsystem Specification.
GetCDMSMode (-- n)	returns CDMS mode according to last RMOD message.
GetSSCLKFreq (-- n)	returns SSCLK frequency according to last RMOD message.
NewCDMSmsg? (actc -- ?)	returns **TRUE**, if a CDMS message with action code **actc** has arrived since last call of **NewCDMSmsg?,** else **FALSE.** See table 3 for valid Action Code names.
RdBB (suadr nstart cnt pg adr -- erc)	read **cnt** records from the Backup RAM Buffer of unit **suadr** starting with record **nstart** and store to SESAME RAM starting at (page=**pg**, address=**adr**).
RdStoredTC (of len adr pg -- erc)	read **len** words from Stored TC buffer starting at offset **of** and store to SESAME RAM at (page=**pg**, address=**adr**).
WrBB (pg adr nstart cnt -- erc)	write **cnt** data records from SESAME RAM starting at (page=**pg**, address=**adr**) to SESAME Backup RAM Buffer (starting with record **nstart**).
WrTRG (n suadr -- erc)	send trigger word **n** to unit **suadr.** Valid subunit addresses are defined in the CDMS Subsystem Specification**.**
Access to Transfer Status Words Possible values of Status Words: **IO_WAIT** (transfer not yet completed) or **IO_DONE** (transfer completed)	
IOC +IOC.BB +BB.STAT @	status word for Backup RAM Buffer data transfer
IOC +IOC.STC +STC.STAT @	status word for Stored TC Buffer data transfer
IOC +IOC.TRG.STAT @	status word for passing of a trigger word

Table 3: Applicable Action and Request Codes

Action Code (name in SESAME Flight S/W)	**Short description**	**Implemented / not implemented**	**Implemented but not used in delivered S/W**
Transmit status word (**ACTC_TRSW**)	In status word, ME or CE flag are set upon error. SR flag is set upon request, BSY is never set.	implemented	
Transmit request code word (**ACTC_TRQC**)	fetches next request code word from SESAME request word queue and submits to CDMS.	implemented	
Stand-by/power down mode (**ACTC_STBY**)		not implemented	
Receive current CDMS mode (**ACTC_RMOD**)	store mode, frequency and AMDT id. in SESAME RAM		in future releases: S/W decisions may possibly depend on SSCLK frequency
Receive service system status (**ACTC_RSST**)	store System Status in SESAME RAM	implemented	
Receive action code/sub-address extension (**ACTC_RAXT**)		not implemented	
Receive housekeeping data format count (**ACTC_RHFM**)	prepare HK word	implemented	
Transmit housekeeping data word (**ACTC_THKD**)	submit HK word	implemented	
Receive telecommand sequence (**ACTC_RCMS**)	TC decoding /verification	implemented	
Transmit offset/length of stored telecommand buffer section (**ACTC_TCMO**)	used for CASSE jobcards	implemented	
Receive stored telecommand buffer section (**ACTC_RCMS**)	used for CASSE jobcards	implemented	

Table 3: Applicable Action and Request Codes (continued)

Action Code (name in SESAME Flight S/W)	Short description	Implemented / not implemented	Implemented but not used in delivered S/W
Receive allocated science data volume (**ACTC_RASV**)			in future releases: SD transfer procedure may depend on ASV
Transmit science data burst (**ACTC_TSCR**)		implemented	
Receive science data packet checksum (**ACTC_RSCS**)	SCS is compared with own checksum; next SD packet header depending on result of comparison	implemented	
Receive allocated Backup RAM Buffer size (**ACTC_RBUS**)			possibly used in future releases
Transmit pointer of Backup RAM record (ACTC_TBUP)	used for communication with other instruments	implemented	
Transmit Backup RAM record (**ACTC_TBUF**)			in future releases possibly used for temporary storage of data
Receive Backup RAM record (**ACTC_RBUF**)	used for communication with other instruments	implemented	
Transmit trigger word (**ACTC_TTRG**)			in future releases possibly used for communication with other instruments
Receive trigger word (**ACTC_RTRG**)			in future releases possibly used for communication with other instruments
Receive error code word (**ACTC_RERC**)	indicate error in HK (C-DPU Statusflags3); other action depending on error code	implemented	

Table 3: Applicable Action and Request Codes (continued)

Request code (name in SESAME Flight S/W)	Short description	Implemented / not implemented	Correct reaction
Send service system status (**RQC_SSST**)		not implemented	
Send stored telecommand buffer section (**RQC_SCMD**)	used for reading CASSE jobcards in STC buffer	implemented	
Send allocated science data volume (**RQC_SASV**)		not implemented; will possibly be implemented in future releases	
Science data ready (**RQC_SRDY**)	used for SD and messages	implemented	
Send allocated Backup RAM buffer size (**RQC_SBUS**)		not implemented; will possibly be implemented in future releases	
Write Backup RAM record (**RQC_WRBF**)		not implemented; will probably be implemented in future releases	
Read Backup RAM record (**RQC_RDBF**)	used for communication with other instruments	implemented	
Pass trigger word (**RQC_PTRG**)	not used	implemented	
Flush last science data packet (**RQC_FLSP**)		implemented	

5.4 Telecommand Processing

Telecommands may be delivered by the CDMS to SESAME without request of SESAME („direct telecommands“), or the CDMS delivers a portion of the Stored TC Buffer upon request of the SESAME S/W („indirect telecommands“). Direct TCs are received by the CDMS I/F and stored in a telecommand buffer. This buffer is examined in the main program. Within each S/W loop one telecommand is processed (as long as there are commands in the telecommand queue and TC processing is not disabled) and the corresponding action is initiated (fig. 5). Flight S/W does not autonomously acquire sections of its Stored Telecommand Buffer in the CDMS memory. However, it may be commanded to read a record from the Stored TC Buffer in order to demonstrate that indirect commanding from Stored TC buffer works.

```
: ProcessTC ( --)
   TCIN \ any unprocessed TC?   ( cmd par #par t | f)
   IF ROT DUP @ MA_TCCAT AND    ( par #par cmd cat)
      LAST_TC @ LAST_TC2 !   \ save last command executed
      OVER @ LAST_TC !       \ save command being executed
      CASE                   \ distribute command
         1000 OF doCASSECommand ENDOF
         3000 OF doDIMCommand   ENDOF
         5000 OF doPPCommand    ENDOF
         7000 OF doCDPUCommand  ENDOF
         3DROP 1601 ERRMSG  \ invalid command category
      ENDCASE
   THEN
;
```

Fig. 5: Command Decoding and Distribution

5.4.1 Format of a Telecommand

Each telecommand consists of a command word and up to 31 parameter words. A command word has the following bit structure:

Command Word Bit Structure															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Category				Action Code				*free*			Parameter Word Count PCT				

Category:

0x0	reserved
0x1	CASSE instrument control
0x2	CASSE instrument control (spare)
0x3	DIM instrument control
0x4	DIM instrument control (spare)
0x5	PP instrument control
0x6	PP instrument control (spare)
0x7	Common actions
0x8	Common actions(spare)
0xD	reserved for C-DPU debug monitor (0xDEBx commands)

Action Code: up to 15 actions per category

PCT: number of parameter words

The number of parameter words following a command word must be equal to the parameter count in the parameter count (PCT) field of the command word.

Command Records
Several commands may be combined to a command record with up to 32 words. No gaps are allowed between commands, a command must be completely contained in one record.

A comprehensive description of the defined telecommands is contained in the chapter "Telecommands and expected SD Output".

5.5 Operation of Instruments

This chapter contains a short description of the operation of instruments. A comprehensive compilation of operation modes of the SESAME instruments CASSE, DIM, and PP is given in the SESAME Operations Plan (RO-LSE-PL-3102).

5.5.1 CASSE Operation

The various application modes of the CASSE instrument are based on three principal operation modes, namely *sounding*, *listening*, and *health-check mode*.

The principal operational scenario of the **CASSE Sounding Mode** is:

- The 3 Piezo transmitters incorporated in the Lander feet can be activated to emit a well-defined signal ("ping") with respect to frequency, duration, and time interval between two pings.
- Each Lander foot contains a Piezo 3-axis accelerometer ((x-y-z)-sensor, z-sensor axis = 'vertical' axis of the Lander leg). When a specific accelerometer is switched on, all of its 3 sensor axes are ready to receive input signals.
- The 3 Piezo transmitters will sequentially emit single "pings" that are registered by the sensors of the two other feet and, sometimes, also on the emitting foot.

  The "ping" registration procedure may use one of two methods, depending on the details of signal and data processing:
  (i) For each of the 6 axes of the 2 target sensors a separate "ping" is emitted by a given transmitter and recorded by only 1 axis of a target sensor. The 3 transmitters have to emit 18 "pings" for all possible target axes.
  (ii) Each transmitter emits only 1 "ping" for *all* target sensors. Registration is done by reading out the x-, y- and z-axis output signals of the target sensors intermittently (time parallel). The 3 transmitters have to emit only 3 "pings" for all possible target sensors.
- Depending on the application mode, the sensor signals of 2 or all 3 feet may be read out. In certain cases the transmitters may also be utilized as sensors giving additional output signals.
- The SESAME DPU will take the recorded raw data and analyze or modify it according to the actual application mode. The data width of sampled CASSE raw data is 8 bit. The

results will be fed into the science data stream.

The main features of the **CASSE Listening Mode** are:

- The Piezo transmitters in the Lander feet are inactive.
- The Piezo 3-axis sensors of the Lander feet are in the state of listening. The output signals of up to 9 axes of the (x-y-z)-sensors are intermittently ("quasi parallel") read out.
- The trigger unit on CASSE PCB indicates, whether programmable trigger thresholds have been exceed by the signals on the selected sensor channels.
- The SESAME Common DPU will take the recorded raw data, possibly only after an event has been indicated by the CASSE trigger unit (triggered mode), with or without further evaluation, and feed them into the science data stream.

Additionally a **CASSE Health Check** is implemented. The objective of this operation mode is to provide the values of a standardized measuring sequence giving information on the health status of the CASSE PCB, sensors and transmitters.

The different operation modes are carried out by dedicated S/W modules in the CASSE part of Flight S/W, but the description of the applicable instrument and measurement settings has been unified by introducing the jobcard concept. According to the CASSE S/W Description each measurement is controlled using a 32 byte structure (called jobcard), which contains 21 parameters. Parameters include nominal values of CASSE PCB register settings, which are written to the registers by Flight S/W without conversion (e.g. the amplifier gain) and magnitudes (e.g. the sampling frequency), which require an onboard calculation of the appropriate register settings. Others entries in a jobcard describe the desired temporal course and the timing of a measurement. The setting and the combination of jobcard parameters determine the kind of measurement and thus each CASSE measurement is initiated after a jobcard has been analyzed.

```
: doCASSECommand ( par #par cmd --)
   NIP @    ( par @cmd)
   CASE
     CAS_HC  OF DROP CASHealthCheck ENDOF
     CAS_MES OF DROP CASMeasurement ENDOF
     CAS_RJC OF CASReceiveJC ENDOF
     CAS_TEST OF DUP >R 4 + @ R@ 2 + @ R> @ CASTest ENDOF
     CAS_PWRSW OF
        @ IF CASPrepare ELSE CASSE_Off THEN FALSE ENDOF
     1A11 ERRMSG DROP FALSE SWAP \ invalid command
   ENDCASE ?DUP IF ERRMSG THEN
;
```

Fig. 6: CASSE Command Processing

The main difference between healthcheck and other CASSE measurements is, that the controlling jobcard for the healtchcheck is fixed in the EEPROM (jobcard **`JOB_HC`**), and can only be updated by a S/W patch and not by a regular telecommand. A default jobcard (**`JOB_MES`**) for all other measurements is contained in the S/W code, it may be temporarily overwritten by telecommand (**`CAS_RJC)`**. An alternative way of CASSE commanding is the reading of jobcards from Stored TC Buffer (this is demonstrated by telecommand **`COM_RDJC`**). Apart from TCs for the control of measurements Flight S/W recognizes telecommands for the power control of the CASSE PCB and a special debug command, which is used during S/W and H/W testing, only (figure 6). The final CASSE commanding concept is still tbd, the currently implemented commands are described in the chapter "Telecommands and Expected Science Data Output".

5.5.2 DIM Operation

When the DIM instrument is measuring, there will be 2 operation modes that are activated by a supervising routine, depending on the impact rate of particles observed at the Piezo plates for the x-, y- and z-direction:
- DIM Burst (Single Event) Mode and
- DIM Continuous (Average) Mode.

DIM Burst Mode is the default option for medium to low particle impact rates, when the signals of the impact events are basically non-overlapping in time. The objective is to gather information on single impact events. An event is defined by an adjustable threshold for the output signal of the Piezo plate segments.

Peak Amplitude and *Half Contact Time* are registered for each event, whereas the *Signal Average* is determined periodically at a lower sampling rate. The 10 samples of the Signal Average will be equally spaced over the whole measuring time.

At higher dust impact rates, when single impacts are no longer distinguishable, the DIM measuring process will be switched to **DIM Continuous Mode**. In this mode only the Signal Average will be collected.

The objective of **DIM Health Check** is to provide a set of parameters that are indicative of the health status of DIM and that are measured independent of the CDMS housekeeping collecting cycle. The DIM Health-Check mode consists of several subroutines that perform dedicated tests of the various DIM functions, e.g. control of supply voltages, calibration and test of sensor.

```
: doDIMCommand ( par #par cmd --)
   NIP @ CASE DIM_PC OF DROP DIMCheckPower ENDOF
        DIM_NT OF DROP DIMNoiseTest DIM_Off ENDOF
        DIM_ST OF DUP @ SWAP 2+ @ DIMSensorTest DIM_Off ENDOF
        DIM_CA OF DUP @ SWAP 2+ @ DIMCalibration DIM_Off ENDOF
        DIM_HC OF DUP @ OVER 2+ @ ROT 4 + @ DIMHealthCheck
                  DIM_Off ENDOF \ switch power off TBC
        DIM_PWRSW OF @ DIMPowerSwitch ENDOF
        DIM_AV OF doDIM_AV ENDOF \ average continuos
        DIM_AVTEST OF doDIM_AVTEST ENDOF
        DIM_BC OF doDIM_BC ENDOF \ burst continuos
        DIM_BCTEST OF doDIM_BCTEST ENDOF
        DIM_SPEC OF DUP @ SWAP 2+ @ DIMSpecial ENDOF
        EBF1 ERRMSG DROP FALSE SWAP \ invalid command
   ENDCASE ?DUP IF ERRMSG THEN ;
```

Fig. 7: DIM Command Processing

A set of S/W modules has been implemented, which perform DIM test and calibration measurements: **`DIMCheckPower`**, **`DIMNoiseTest`**, **`DIMCalibration`**, **`DIMSensorTest`**. These modules are consecutively executed during a DIM healthcheck or may be individually invoked by TC. The S/W modules for burst and continuos mode dust impact measurements come in two versions, which differ in the format and amount of output data generated (fig. 7). All DIM telecommands are listed in the chapter "Telecommands and Expected Science Data Output".

If currents on +5V or -5V line exceed certain limits an EI4 interrupt is released, caused by the overcurrent sensing circuit on DIM PCB. Flight S/W provides the routine **`isr$int4`** for handling this interrupt. It notifies the occurrence of the interrupt (this will result in an error flag in the Error Code Word of the measurement) and switches DIM off. Because a couple of "false alarms" has been observed (probably due to an oversensitive overcurrent circuit) the switching off may be disabled by an appropriate setting ("**`FALSE`**") of the flag **`DIMOFF_ON_INT4?`** (fig. 8).

```
: isr$int4 ( --)
   CR@ >R SELCPR  \ access BIOS vars at code page
   CASSE_INT4?
   IF    \ ignore
   ELSE  \ DIM overcurrent
      INT4_REG DUP @ MA_OVERCURR OR SWAP !  \ DIM overcurrent
      DIMWriteINT_ACK
      DIMOFF_ON_INT4? IF DIM_Off THEN
   THEN
   INT4$RESET
   R> CR!
;
```

Fig. 8: EI4 Interrupt Routine

5.5.3 PP Operation Modes

The PP instrument has 3 operation modes utilising 5 sensors (3 transmitting electrodes [1 foot, MUPUS-PEN and APX] and 2 receiving active sensors [on 2 feet]) and one Langmuir Probe (receiving sensor). Main measuring parameters are voltages and currents observed between 2 of the 5 sensors or currents received by the Langmuir Probe.

In **PP Passive Mode**, the potential difference (voltage) between the two receiving sensors is measured with a fixed sampling rate (default 20 kHz) for a short time interval (default 50 ms). This data set is then analysed by the SESAME flight software with respect to the power distributed across 20 frequency bands, using a simplified wavelet approach for conversion between time and frequency domain.

In **PP Active Mode**, two electrodes out of three are selected to inject an electrical current produced by a controllable AC-voltage source. Any current frequency between 10 Hz and 10 kHz can be selected. Since the injected signal is generated via a table-controlled Digital-to-Analogue-Converter (DAC) with subsequent low-pass filtering, a wide variety of voltage levels or waveforms may be created. The current will induce a potential field in the landing site material that is probed with the two receiving electrodes. Both, the injected current and the resulting potential difference are sampled simultaneously (on the same clock signal edge) with a sampling rate high enough to give a 1 degree phase difference resolution between the two signals.
An active measurement consists of (i) current injection, (ii) current and voltage sampling, and (iii) subsequent off-line analysis by the SESAME flight software for 20 frequencies between 10

Hz and 10 kHz. For each of the 20 frequencies the result will be four 16-bit words giving frequency, averaged peak current, averaged peak voltage, and phase difference.

The electrical current measured by the **Langmuir Probe** (receiving sensor) will be utilised to record the ambient electron flux and to determine the respective electron density. The sampling duration per value will be <1 s, typically less than 1 ms, and the sampling rate is chosen to be one measurement every 2 s. The data width of one Langmuir measurement is 16 bit.

The objective of the **PP Health Check** is to provide a measurement of PP health-check parameters that is independent of the CDMS housekeeping collecting cycle.

The implementation of the PP part of Flight S/W includes a control table **`PPCTL`**, which contains default parameter settings for active and passive mode measurements. Invoking these modes with telecommands **`PP_AM`** or **`PP_PM`**, respectively, results in a sequence of measurements with e.g. frequency ranges, electrode selection etc. specified in **`PPCTL`**. Using telecommands **`PP_AMTEST`** and **`PP_PMTEST`** specific measurement settings may be selected. The measured raw data (transmitter current and receiver voltage) are included in the SD stream. Additionally, Langmuir Probe measurements with different integration times are possible. A direct register access allows the reading and setting of PP registers via TC (fig. 9). The currently recognized telecommands are described in the chapter "Telecommands and Expected Science Data Output".

```
: doPPCommand ( par #par cmd --)
   NIP @    ( par @cmd)
   CASE PP_HC OF DROP PPHealthCheck ENDOF
        PP_LM OF DROP PPLMTest      ENDOF
        PP_AM OF DROP PPAMCycle     ENDOF
        PP_PM OF DROP PPPMCycle     ENDOF
        PP_DA OF DUP @ SWAP 2+ @ SWAP PPDA ENDOF
        PP_AMTEST OF DUP @ OVER 2+ @ ROT 4 + @ PPAMTest ENDOF
        PP_PMTEST OF DUP @ OVER 2+ @ ROT 4 + @ PPPMTest ENDOF
        PP_PWRSW  OF @ PPSwitchPower ENDOF
        PP_SPEC   OF DUP @ OVER 2+ @ ROT 4 + @ PPSpecial ENDOF
        ECE1 ERRMSG DROP FALSE SWAP \ invalid command
   ENDCASE ?DUP IF ERRMSG THEN ;
```

Fig. 9: PP Command Processing

5.6 Science Data Processing

Each measuring module allocates a memory segment in the SESAME RAM, where data can be stored. Upon a successful allocation a descriptor structure called Measurement Handle is used for further referencing to that memory segment. A science data header is written to the allocated memory segment, which gives some key information on the measurement. Subsequently the measuring module adds science data in a measurement specific format (primary formatting). After the termination of a measuring process the Measurement Handle, pointing to the data generated, is added to a measurement buffer. This buffer is examined during each S/W loop and data contained are formatted, possibly after compression, and added to the SD output buffer. Science data records, which may be 4 or 32 words long depending on CDMS mode, are taken from these buffer and delivered to CDMS. After the transmission of 128 science data words (one science data packet) SESAME S/W waits for a CDMS message containing the checksum for this science data packet and compares the value with the checksum calculated by itself. The result of the comparison is used to generate a science data packet header word for the next science data packet, which reflects the status of the transmission of the previous packet.

5.6.1 Science Data Header

Science data which are transferred to the CDMS are identified with a science data header. The structure of the science data header is

Byte	Meaning
0-3	sync (0xABCD,0xABCD)
4-5	measurement id, which can be one of the following: a) 0x0000: identifies SESAME ready message (after boot) b) 0x7F00: identifies error messages c) the ident of a telecommand. The science data result from the execution of this telecommand.
6-7	total length of data (including science data header, without science data packet header)
8-11	SESAME local time at which data were generated (high word, low word). SESAME local time runs with a resolution of 31.25 msec and is synchronized with LOBT (mid and low word) each CDMS RTIM message.

5.6.2 Science Data Packet Header

After the transmission of 128 science data words (one science data packet) SESAME S/W waits for the reception of the CDMS checksum for these science data. It generates a science data packet header word for the next science data packet, which reflects the status of the transmission of the previous packet:

Packet Header Word	meaning
0xEEFF	no error during transmission of last SD packet
(bit 0 cleared)	checksums calculated by SESAME and by CDMS differ for last SD packet
(bit 1 cleared)	Sync-error CDMS-SESAME; i.e. a RSCS action code was received from CDMS, but less than 128 SD words were sent by SESAME to CDMS. If the “flush-bit” is cleared, too, this indicates most probably no error.
(bit 2 cleared)	Last SD packet has been flushed upon a FLSP request of SESAME (“flush bit”).

5.7 Science Data Compression Algorithm

A reversible (lossless) compression algorithm, similar to the ESTEC1 algorithm, has been implemented in Forth and tested with simulated measuring data (cf. RO-LSE-TN-3401). It consists of a one-dimensional Differential Pulse-Code Modulation (DPCM), followed by Huffmann coding of the resulting differences. Advantages of this method are fair compression ratios over a range of probability distributions of measuring data, the moderate complexity and low memory requirements during execution.

5.8 Housekeeping and Analog to Digital Conversion

The set of SESAME Housekeeping parameters comprises 30 quantities from analog and digital sources. All values are measured or acquired at once after SESAME Flight S/W has been booted and every two seconds during idle states, i.e. if no telecommand is being executed. The most significant bit (bit 15) in each HK value is set to indicate a "new" value. The measured values are submitted to CDMS in word by word mode (i.e. one parameter value per CDMS HK scanning period) upon CDMS command. After passing a parameter value to CDMS the most significant bit is cleared, therefore it is possible to distinguish whether a parameter value has been updated after the last passing of that parameter to CDMS (by a new measurement) or not.

Along with the CDMS RHFM command comes a CDMS HK Data Format Count (0..255), which is mapped to the SESAME HK Format Count (0..31). Via a lookup table the SESAME HK Format Count is assigned to an analog or digital source identifier.

5.8.1 Analog Sources

Each analog source is unequivocally identified with a one byte analog source identifier. The structure of the identifier is:

Analog Source Identifier: Bit Structure							
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
A/D	**Category**		**SubID**				

A/D
A/D = 1 indicates analog source.

Category
indicates the meaning of SubID:
00: channel of C-DPU multiplexer
01: channel of CASSE multiplexer; C-DPU MUX channel is 14.
11: CASSE temperature sensor number; C-DPU MUX channel is INR=14. CASSE MUX channel is ANR=4.

SubID
Category = 00:
C-DPU MUX channel number (INR = 1..16)
Category = 01:
CASSE MUX channel number (ANR = 1..8)
Category = 11:
CASSE temperature sensor number (1..7)

Each A/D conversion via the ADC of the C-DPU is controlled by the routine

`StartWaitADC ( aid -- val t | f).` It accepts an analog source identifier, sets the appropriate MUX channels and registers (on the C-DPU and on the CASSE PCB), waits until A/D conversion is completed, and scales the output of the ADC to voltage **`val`** [milliVolt]. A non-successful A/D conversion is indicated by a "false" flag.

The format of an analog HK value, passed to CDMS upon a THKD command, is

Analog HK Value: Bit Structure															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
n	S			v	v	v	v	v	v	v	v	v	v	v	v
y/n	±	Spare		Housekeeping value in [mV]											

Bit 14 (S) set for negative (cleared for positive) ***s***ign of HK values
Bit 15 (n) set for ***n***ew, i.e. updated (cleared for old, i.e. repeatedly delivered) HK values

The voltages must be scaled to the physical units of the measured quantity by ground S/W. Appropriate scaling factors are given in the HK Technical Note.

5.8.2 Digital HK Parameters

In order to allow a flexible and simple collection of all HK parameters, HK parameters from digital sources are coded in a way, which is compatible to the coding of analog sources:

Digital HK Source Identifier: Bit Structure							
7	6	5	4	3	2	1	0
A/D	Number						

A/D
A/D = 0 indicates digital source.

Number
unique number identifying the digital source.

A S/W-Mode Identifier (id = 0x1F, HK Parameter No 26) indicates that HK data have been acquired by SESAME Flight S/W and not by C-DPU Debug Monitor. It has the constant value 0x05E5.

HK parameter CE_F2 (id = 2) indicates the status of memory pages 1..7. If a memory check finds faulty data in the memory page, in the HK word the bit at position [(memory page no) - 1] is set. HK parameter CE_F3 (id = 3) contains the sum of all CDMS error codes received by SESAME (with CDMS Action Code RERC) since the last passing of that parameter to CDMS. S/W flags 1 (CE_F1, id = 1) is left free for future use. An error free execution of Flight Software thus implies that all S/W flags are cleared.

5.8.3 Table of Analog Sources and Digital HK Values

Table 4 contains a list of all analog sources (including two DIM sources evaluated during DIM measurements) and digital HK values and the assignment to the SESAME HK Format Count.

Table 4: Identifiers of Analog Sources and Digital HK Values

ID (Hex.)	Source	SESAME HK Parameter (*)		
		Name	No	Form. Count
	Voltages on Central Electronics			
81	+ 12 V line	CE_U3	14	6
82	+ 28 V line	CE_U5	16	8
83	+ 5 V line	CE_U1	12	4, 20
84	- 5 V line	CE_U2	13	5, 21
85	- 12 V line	CE_U4	15	7
90	+ 5 V on C-DPU board	CE_U6	17	9
	Currents			
87	+ 28 V line	CE_I5	22	15
89	- 12 V line	CE_I4	21	14
8B	+ 5 V line	CE_I1	18	11
8D	- 5 V line	CE_I2	19	12
8F	+ 12 V line	CE_I3	20	13
	CASSE Instrument			
A1	Offset voltage of RadFET dosimeter	CA_U2	7	10
A2	FPGA supply voltage (3.3 V nominal)	CA_U1	6	0
E1	Foot temperature sensor 1	CA_T1	0	22
E2	Foot temperature sensor 2	CA_T2	1	23
E3	Foot temperature sensor 3	CA_T3	2	24
E4	Foot temperature sensor 4	CA_T4	3	25
E5	Foot temperature sensor 5	CA_T5	4	26
E6	Foot temperature sensor 6	CA_T6	5	27
E7	Temperature sensor on PCB	CA_T7	27	17
	DIM Instrument			
A3	Average measurement	n/a	n/a	n/a
A5	Voltage on + 5 V line	DI_U1	8	1
A6	Peak measurement	n/a	n/a	n/a
A8	Voltage on - 5 V line	DI_U2	9	2
	PP analog			
A7	Voltage on + 5 V line	PP_U1	10	3
	Digital sources			
01	S/W flags 1	CE_F1	23	29
02	S/W flags 2	CE_F2	24	30
03	S/W flags 3	CE_F3	25	31
04	Last TC received	CE_C1	28	18
05	Last but one TC received	CE_C2	29	19
08	PP electron density	PP_D	11	28
1F	SESAME ID (0x05E5)	CE_ID	26	16

(*) according to the HK Technical Note (RO-LSE-TN-3402)

5.9 Interaction with other instruments

It was proposed by the SESAME S/W team that data exchange between SESAME and units APX, MUPUS and SD2 shall take place via the Backup RAM Buffer (cf. RO-LSE-TN-3403). SESAME S/W implements reading and writing of its own Backup RAM Buffer in CDMS memory and the reading of the Backup RAM Buffer of other units. Additionally the exchange of Trigger Words and reading of the System Status Table (containing the on/off status of units) are implemented (cf. chapter "Interface to the CDMS").

5.10 Time and Timers

5.10.1 Sources of Time Information

Absolute time information is provided by the CDMS: the least significant 32 bit of the Lander Onboard Time (LOBT) are delivered to SESAME by an RTIM message (every second in CDMS normal mode), the most significant 5 bits of the LOBT (which should change rather seldom) are contained in the System Status Table (coming with an RSST message). LOBT has a resolution of 1/32 seconds.

The three RTX timer/counters and a S/W loop are used for relative timing: during SESAME S/W initialization timer interrupts from counter **TCI1** are permanently enabled and set to 100 ticks/second. Each interrupt increments the contents of the 32-bit variable **`TIMER1_VAR`** by one, thus providing a resolution of 10 milliseconds. The contents of **`TIMER1_VAR`** is used to calculate the SESAME Local Time and to adjust or measure time differences in the range of seconds to hours. Interrupts from timer counter **TCI2** are enabled only if required for the adjustment of delays in the range of milliseconds to seconds. A S/W loop is used to adjust delays in the range 8 to 1000 microseconds. The RTX counter **TCI0** is managed by the C-DPU BIOS and used for BIOS internal purposes, only.

5.10.2 Derived Time Information

For all actions, which require an absolute time information and for timestamps in the SD stream, the **SESAME Local Time** is used. It is the sum of the LOBT delivered by the last CDMS RTIM message and the time elapsed since the arrival of this message, which is derived from **`TIMER1_VAR.`** SESAME Local Time is calculated each time routine **`GetLocalTime`** is invoked. It has a resolution of 1/32 seconds and consists of two words, containing the 16 least and most significant bits, respectively.

For the adjustment of delays the routines **`SEC2`**, **`MSEC2`** and **`USEC2`** and the specialized routines **`CASLongWait`**, **`CASShortWait`**, **`DIMWaitMsec`**, **`DIMWaitUsec`** and **`PPWaitMes`** have been implemented.

5.11 Integer Arithmetic and Mathematical Functions

SESAME S/W does not use floating point arithmetic, it calculates with 8, 16 and 32 bit integers. The majority of operators and routines for single and double integer calculations are contained in the LMI Forth core, however some routines have been added (e.g. **`DU>`**, **`DU<`** and some routines from algorithm 46 of Forth scientific library, http://www.taygeta.com/fsl/sciforth.html) in order to simplify and shorten calculations.

No trigonometric or transcendental functions are included in the LMI Forth core. Therefore mixed tabular-algorithmic approximations of sine and logarithmic functions have been implemented, which provide sufficient accuracy for the generation of the PP DAC table (sine) and for the compression of DIM peak values (logarithm).

For arguments **`arg`** = 0..255, routine **`SinQt ( arg -- sin)`** returns the first quarter of a sine wave **`sin`** = 0..255, in other words the domain $[0,\pi/2]$ is mapped to [0,255] and the range of values [0,1] is mapped to [0,255].

For arguments **`arg`** = 0..65535, the routine **`1000*log10 ( arg -- lg)`** returns the common logarithm of **`arg`** multiplied by 1000.

5.12 Error Handling

Error handling takes place on different levels: communication problems occurring during the low level data exchange with the CDMS are indicated in the SESAME Status Word (count error and message error flag). Instrument malfunctions detected during measurements are registered in an Error Code Word or Byte, which is part of the measuring data submitted to earth. An appropriate S/W action upon a malfunction is executed, which may range from ignoring the error to the abort of a measurement. Errors detected in common S/W parts, or with global impact, result in the formatting of an error message, which is processed like a science data packet and sent to earth. Different error levels are assigned to an error (e.g. warning, fatal error), which indicate the severity. Warning level errors are benign and are healed by e.g. the substitution of an unexpected parameter value by a default value.

The instrument specific Error Code Words/Bytes, the format of an error message and the meaning of error codes in an error message are described in the chapter "Telecommands and Expected Science Data Output".

6 Telecommands and Expected Science Data Output

6.1 CASSE Instrument

CASSE: Defined Telecommands
(all numerical values in this table are hexadecimal)

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 parameter words. Valid until next CAS_RJC command arrives or SESAME is switched off. No SD are generated.
CAS_PWRSW	1501	1.	Power Mode	0000=Standby, 0001=all circuits on	CASSE power switching. No SD are generated.
CAS_TEST	1A03	Three parameters depending on S/W implementation			CASSE S/W and instruments debug mode. Used during H/W and S/W ground tests only. Functionality depends on test item.

6.1.1 CASSE Healthcheck (CAS_HC)

CASSE healthcheck performs a default measuring sequence (combining active and passive measurements), which gives information about the status of the CASSE sensors, transmitters and electronics. A ping (2000 Hz, duration 5 msec) is successively transmitted by the transmitters at each foot and simultaneously a listening measurement is performed on that foot (X, Y, Z direction; total listening duration per foot: 20 msec). The controlling jobcard is fixed in the Flight S/W code. Length of generated SD is approx. 3116 (± 3) byte, if no fatal error has occurred.

Expected SD output for CASSE Healthcheck

Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 11	SD header	ABCD ABCD 1100 llll tttt tttt	llll: total length of measurement data (approx. 3116 byte) tttt: SESAME Local Time
2	12, 13	Block header: parameters of jobcard	0707	
3	14 to 45	parameters of jobcard	4301 0003 07D0 0032 0640 1103 0000 0000 40C0 0096 1007 0000 0000 0000 7F00 0000	
4	46, 47	Block header: foot temperatures	1414	
5	48 to 51	T1, T2	e.g. FEBD FEC2	scaling approx. T[K] = (0.0459*X+304.7); e.g. X=0xFEBD= -323 => T1=290 K
6	52 to 55	T3, T4	e.g. FEBD FEC2	
7	56 to 59	T5, T6	e.g. FEBD FEC2	
remaining data (item 8 to 25) appear three times (for three feet), if no fatal error in Error Code Word indicated				
8	+1 to +2	Block header: Burst Measurement	2121	
9	+3	Frequency Divider	0C	Adjusted TFC Register Value
10	+4 to +5	Frequency Increment	0075	Adjusted SR1, SR2 Register Value
11	+6	(nchn-1) = No of Channels minus one	02	Adjusted SLTLA Register Value
12	+7 to +8	Adjusted Sound Frequency	07CF	should be close to 0x07D0 (2000 Hz)
13	+9 to +12	Adjusted Sampling Frequency	0000 BB78	high word, low word (should be close to 3*16000 =48000 [Hz])
14	+13 to +16	Start Time of Measurement		high word, low word of SESAME Local Time
15	+17 to +20	Tlen: Total Length of Measurement (# byte)	03C5	high word, low word (should be close to 965)
16	+21 to +22	Block header: channel data	6666	
next data block (item 17 and 18) appears three times (three sensor channels per foot)				

17	+1 to +4	dchn: Data Count for one Channel (# byte)	0000 0142	high word, low word (dchn = 320..323)
18	+5 to (+4 + dchn)	dchn Sensor Data for one Channel; data length: one byte	depending on sensor activation	
19	+1 to +2	Trigger Status	0000	
20	+3 to +4	Block Header: Error Code	8888	
21	+5 to +6	Error Code for Measurement	0000	
22	+7 to +8	Block Header: foot temperatures	1414	
23	+9 to +12)	T1, T2	e.g. FEBD FEC2	scaling approx. T [K] = (0.0459*X+304.7); e.g. X=0xFEBD= -323 => T1=290 K
24	+13 to +16	T3, T4	e.g. FEBD FEC2	
25	+17 to +20)	T5, T6	e.g. FEBD FEC2	

6.1.2 CASSE Measurement (CAS_MES)

Perform a CASSE measurement controlled by the CASSE jobcard JOB_MES. A default jobcard is copied from SESAME EEPROM to RAM at boot time. It can be overwritten using telecommand CAS_RJC. The actual setting of jobcard parameters is included in the telemetry data.

```
\ default jobcard for measurement; can be temp. modified by TC
CREATE JOB_MES
   43 C,   01 C,    \ ID,         SUB_ID
   00 C,   03 C,    \ STRT_COND, REP_AVG
 03E8  , 0032  ,    \ SND_FREQ,  (SND_DURA; TRG_TIMEOUT)
 0640  ,   11 C,    \ SAMP_FREQ, TX_STATUS
   07 C, 0000  ,    \ AMP_GAIN,  TRG_SRC
 0000  ,   40 C,    \ TRG_DLY,   TRG_PLEV
   C0 C, 0096  ,    \ TRG_NLEV,  MSR_DURA
 1007  , 0000  ,    \ RX_STATUS, GPW1
 0000  , 0000  ,    \ GPW2,      GPW3
   7F C,   00 C,    \ FTEMP_CH,  PAG_OBUF
 0000  ,            \ ADR_OBUF
```

Expected SD output for CASSE Measurements

Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 11	SD header	ABCD ABCD 1100 llll tttt tttt	llll: total length of measurement data tttt: SESAME Local Time
2	12, 13	Block header: parameters of jobcard	0707	
3	14 to 45	parameters of jobcard	4301 0003 03E8 0032 0640 1107 0000 0000 40C0 0096 1007 0000 0000 0000 7F00 0000	example: default parameters for JOB_MES jobcard
4	46, 47	Block header: foot temperatures	1414	
5	48 to 51	T1, T2	e.g. FEBD FEC2	scaling approx. T [K] = =(0.0459*X+304.7); e.g. X=0xFEBD=-323 => T1=290 K
6	52 to 55	T3, T4	e.g. FEBD FEC2	
7	56 to 59	T5, T6	e.g. FEBD FEC2	
remaining data (item 8 to 25) for each measurement (number of measurements according to jobcard; as long as no fatal error in Error Code Word indicated)				
8	+1 to +2	Block header: Burst Measurement	2121	
9	+3	Frequency Divider		Adjusted TFC Register Value
10	+4 to +5	Frequency Increment		Adjusted SR1, SR2 Register Value
11	+6	(nchn-1) = No of Channels minus one		Adjusted SLTLA Register Value
12	+7 to +8	Adjusted Sound Frequency		
13	+9 to +12	Adjusted Sampling Frequency		high word, low word
14	+13 to +16	Start Time of Measurement		high word, low word of SESAME Local Time
15	+17 to +20	Tlen: Total Length of Measurement (# byte)		high word, low word
16	+21 to +22	Block header: channel data	6666	
next data block (item 17 and 18) for each channel in measurement (i.e. nchn times)				
17	+1 to +4	dchn: Sensor Data Count for Channel (# byte)		high word, low word
18	+5 to +(4+	dchn Sensor Data for channel; data	depending on sensor activation	

	dchn)	length: one byte		
19	+1 to +2	Trigger Status		
20	+3 to +4	Block Header: Error Code	8888	
21	+5 to +6	Error Code for Measurement		
Item 22 to 25 only, if additional temperature measurement requested in jobcard				
22	+1 to +2	Block Header: foot temperatures	1414	
23	+3 to +6)	T1, T2	e.g. FEBD FEC2	scaling approx. T [K] = =(0.0459*X+304.7); e.g. X=0xFEBD=-323 => T1=290 K
24	+7 to +10	T3, T4	e.g. FEBD FEC2	
25	+11 to +14)	T5, T6	e.g. FEBD FEC2	

6.1.3 CASSE Read Jobcard (CAS_RJC)

The jobcard parameters contained in the parameter words override the default jobcard JOB_MES. The new settings in JOB_MES are valid until another CAS_RJC command arrives or until SESAME is switched off. After power down the default jobcard becomes active again.

The order of jobcard parameters in the parameter words of CAS_RJC correspond to the byte order of parameters in the JOB_MES structure. A simple program (written in the programming language C) demonstrating the generation of parameter words is contained in the appendix.
No SD are generated.

6.1.4 CASSE Power Switch (CAS_PWRSW)

Switching of the power supply for the CASSE RAM and analog circuits (± 5 V) and the accelerometers (28 V). No SD are generated.

6.1.5 CASSE Error Codes

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.

```
HEX
00 EQU EB_NOERROR \ no error
01 EQU EB_FREQ    \ range of frequency divider exceeded, set to default
02 EQU EB_DIVRAT  \ range of sampling rate increment exceeded, set to
                  \ default
04 EQU EB_CDPU_ADC \ error during foot temperature A/D
40 EQU EB_FATAL   \ bit indicates that error is fatal
42 EQU EB_NCHAN   \ invalid number of sensor channels
44 EQU EB_TIMEO   \ timeout
46 EQU EB_NOSTRT  \ start condition for measurement not fulfilled
48 EQU EB_RAMOVR  \ allocated memory exhausted
```

6.2 DIM Instrument

DIM: Defined Telecommands
(all numerical values in this table are hexadecimal)

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	0000..0046	DIM Sensor Test
		2.	Direction	0000=X, 0001=Y, 0002=Z	
DIM_CA	3302	1.	Margin (low level)	0000..0046	DIM Calibration
		2.	Margin (high level)	0000..0046	
DIM_AV	3404	1.	Direction	0000=X, 0001=Y, 0002=Z	DIM Average Continous Measurement
		2.	Energy control	0000=no limit, 0001=limited, 0002=distributed	
		3.	Sampling time [sec]	> 0; less than T_AVER_SETTL not meaningful	
		4.	Measuring time [sec]	> 0	
DIM_PWRSW	3501	1.	Power Mode	0000=power off 0001=power on	DIM power switching (no SD are generated)
DIM_BC	3606	1.	Direction	0000=X, 0001=Y, 0002=Z	DIM Burst Continous Measurement (storage of measured values in (U,T) matrix)
		2.	Margin	0000..0046	
		3.	Energy control	0000=no limit, 0001=limited, 0002=distributed	
		4.	Decay time [msec]	0 < t < 00FF	
		5.	Sampling time [sec]	= 0: no sampling > 0: sampling	
		6.	Measuring time [sec]	> 0	
DIM_HC	3A03	1.	Margin (low level calibration)	0000..0046	DIM Health Check
		2.	Margin (high level calibration))	0000..0046	
		3.	Margin (Sensor Test)	0000..0046	
DIM_AVTEST	3B04	1.	Direction	0000=X, 0001=Y, 0002=Z	DIM Average Continous Measurement Test Mode
		2.	Energy control	0000=no limit, 0001=limited, 0002=distributed	
		3.	Sampling time [sec]	> 0; less than T_AVER_SETTL not meaningful	
		4.	Measuring time [sec]	> 0	
DIM_BCTEST	3C06	1.	Direction	0000=X, 0001=Y, 0002=Z	DIM Burst Continous Measurement Test Mode (verbose output of measured values for each event)
		2.	Margin	0000..0046	
		3.	Energy control	not evaluated	
		4.	Decay time [msec]	0 < t < 00FF	
		5.	Sampling time [sec]	not evaluated	
		6.	Measuring time [sec]	> 0	
DIM_SPEC	3D02		2 parameters (variable)		Used for S/W and H/W debugging only.

6.2.1 DIM Power Check (DIM_PC)

DIM Power Test verifies that DIM supply voltages are within predefined limits on DIM board.

Expected SD output for DIM Power Check			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 3000 0016 tttt tttt	total length: 0x16 = 22 byte; last two words are SESAME Local Time
12, 13	Block header: Power Check Data	6363	
14, 15	Voltage on +5V line	e.g. 1388	voltage in HK format; e.g. 0x1388 => 5000 mV
16, 17	Voltage on -5V line	e.g. 5388	voltage in HK format; e.g. 0x5388 => -5000 mV
18	Error Code	e.g. 00	EB_BAD_HEALTH if power out of limits
19, 20	Block delimiter: end of Power Check Data	9C9C	
21	Padding character	00	

6.2.2 DIM Noise Test (DIM_NT)

DIM Noise Test measures electronic noise on DIM amplifier.

Expected SD output for DIM Noise Test			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 3100 0012 tttt tttt	total length: 0x12 = 18 byte; last two words are SESAME Local Time
12, 13	Block header: Noise Test Data	1818	
14	Margin, for which no amplifier noise was measured	e.g. 1E	Margin range is 0-70. Lower margin means less noise on amplifier (typ. 20-30).
15	Error Code	e.g. 00	
16, 17	Block delimiter: end of Noise Test data	E7E7	

6.2.3 DIM Sensor Test (DIM_ST)

An electric pulse is applied to one of the three sensing faces of the DIM sensor, and the response is measured. Parameters are margin, which determines the detection threshold of the measuring amplifier, and the direction (X, Y, Z).

Expected SD output for DIM Sensor Test			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 3202 001E tttt tttt	total length: 0x1E = 30 byte; last two words are SESAME Local Time
12 to 13	Block header:	3636	
14	Direction/Margin		Bits 7,6,5: Direction (100: X, 010: Y, 001: Z) Bits 2,1,0: Margin divided by ten
15	Error Code	00	
16 to 17	Data Block Header	7272	
18 to 19	Average Sample [mVolt]		
20 to 21	Measured Voltage of Signal [mVolt]		
22 to 23	Timer Count		
24	Average Sample [dB]		
25	Measured Voltage of Signal [dB]		
26	Measured Time of Signal [dB]		
27 to 28	Block delimiter: end of Sensor Test data	C9C9	
29	Padding character	00	

6.2.4 DIM Calibration (DIM_CA)

Two electric pulses (low level and high level) are applied to the input of the measuring circuit. If the measured peak voltage and impact time values exceed predefined limits, the procedure is repeated (up to a total of four trials per calibration level). It is not crucial, if a total error is indicated, but that there is no error for the last trial of each calibration level.

Expected SD output for DIM Calibration				
Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 11	SD header	ABCD ABCD 3302 llll tttt tttt	llll = total length; last two words are SESAME Local Time
2	12 to 13	Block header:	2727	
3	14	Low Margin	1E	
4	15	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 [mVolt]		
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	
15	+5	Padding character	00	

6.2.5 DIM Average Continous (DIM_AV)

Sampling of average values of the signals for one sensor direction.

Expected SD output for DIM Average Continuos Mode (DIM_AV)				
Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 11	SD header	ABCD ABCD 3404 llll tttt tttt	llll = total length depending on measuring and sampling time; last two words are SESAME Local Time
2	12, 13	Block header:	4545	
3	14	Direction	00 (X) or 01 (Y) or 02 (Z)	Echoed Command Parameter
4	15	Energy Control	00 or 01 or 02	Echoed Command Parameter
5	16, 17	Sampling Time		Echoed Command Parameter
6	18, 19	Measuring Time		Echoed Command Parameter
7	20, 21	Data Block header	7272	
8	22, 23	Sampling Time		
9	24, 25	nsamp: Number of measured Samples		
next data block (item 10) occurs nsamp times				
10	+1	Average Sample [dB]		

11	+1 to +4	SESAME Local Time after last sampling		High Word, low word
12	+5	Error Code		
13	+6, +7	Block delimiter: end of Calibration data	BABA	

6.2.6 DIM Power Switch (DIM_PWRSW)

Switching of DIM ±5 V power supply. A simple interface circuit on DIM PCB is not affected; it is always powered if SESAME is powered.
No SD are generated.

6.2.7 DIM Burst Continuos (DIM_BC)

Single events on one sensor face are registered. Measured values (peak amplitude U and impact time T) are stored in a compressed way. They are logarithmically scaled to 0..90 dB and the counts for events with a specific (Udb, Tdb) combination are stored in memory cells of different sizes (one word, one byte, one nibble = 4 bit), depending on the expected frequency of such events. The resulting matrix of packed counts has a fixed size of 5250 byte (independent of the actual number of events). Additionally average samples can be measured.

Expected SD output for DIM Burst Continuos Mode (DIM_BC)

Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 11	SD header	ABCD ABCD 3606 llll tttt tttt	llll = total length; last two words are SESAME Local Time
2	12, 13	Block header:	5454	
3	14	Direction	00 (X) or 01 (Y) or 02 (Z)	Echoed Command Parameter
4	15	Margin		Echoed Command Parameter
5	16	Energy Control	00 or 01 or 02	Echoed Command Parameter
6	17	Decay Time		
7	18, 19	Sampling Time		Echoed Command Parameter
8	20, 21	Measuring Time		Echoed Command Parameter
9	22, 23	Data Block header	7272	
10	24, 25	Number of Events detected		
11	26, 27	Number of false Events		
12	28, 29	Number of long Events		
13	30, 31	nsamp: Number of Average Samples		

next data block (item 14) occurs nsamp times				
14	+1	Average Sample [dB]		
15	+1 to +4	SESAME Local Time at end of measuring period		High Word, low word
16	+5	Error Code	00	
17	+1 to +800	400 counts for Udb<21 and Tdb<21; data length: one word		order of (Udb, Tdb) pairs: (1,1),(2,1),(3,1), ...,(18,20), (19,20), (20,20)
18	+1 to +400	400 counts for Udb<21 and 20<Tdb<41; data length: one byte		order of (Udb, Tdb) pairs: (1,21),(2,21), ...,(18,40), (19,40), (20,40)
19	+1 to +800	800 counts for 20<Udb<41 and 0<Tdb<41; data length: one byte		order of (Udb, Tdb) pairs: (21,1),(22,1), ...,(38,40), (39,40), (40,40)
20	+1 to +1000	2000 counts for 0<Udb<41 and 40<Tdb<91; data length: one nibble		order of (Udb, Tdb) pairs: (1,41),(2,41), ...,(38,90), (39,90), (40,90); in a byte, the low nibble (bits 0..3) refers to the lower Udb value.
21	+1 to +2250	4500 counts for 40<Udb<91 and 0<Tdb<91; data length: one nibble		order of (Udb, Tdb) pairs: (41,1),(42,1), ...,(88,90), (89,90), (90,90); in a byte, the low nibble (bits 0..3) refers to the lower Udb value.
22	+1, +2	Block delimiter: BC data	ABAB	

6.2.8 DIM Healthcheck (DIM_HC)

DIM Healthcheck performs DIM Power Check and, if no error during Power Check occurred, subsequently the sequence DIM Noise Test, DIM Calibration, DIM Sensor Test (X segment), DIM Sensor Test (Y segment), DIM Sensor Test (Z segment). Science data generated are composed of the data of the single procedures.

6.2.9 DIM Average Continuos Test Mode (DIM_AVTEST)

Sampling of average values of the signals for one sensor direction. Like DIM_AV, but voltage values of average samples [mVolt] are additionally included into TM stream.

Expected SD output for DIM Average Continuos Test Mode (DIM_AVTEST)				
Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 11	SD header	ABCD ABCD 3B04 llll tttt tttt	llll = total length depending on measuring and sampling time; last two words are SESAME Local Time
2	12, 13	Block header:	4545	
3	14	Direction	00 (X) or 01 (Y) or 02 (Z)	Echoed Command Parameter
4	15	Energy Control	00 or 01 or 02	Echoed Command Parameter
5	16, 17	Sampling Time		Echoed Command Parameter
6	18, 19	Measuring Time		Echoed Command Parameter
7	20, 21	Data Block header	7272	
8	22, 23	Sampling Time		
9	24, 25	nsamp: Number of measured Samples		
next data block (item 10 and 11) occurs nsamp times				
10	+1, +2	Average Sample [mV]		
11	+3	Average Sample [dB]		
12	+1 to +4	SESAME Local Time after last sampling		High Word, low word
13	+5	Error Code		
14	+6, +7	Block delimiter: end of Calibration data	BABA	

6.2.10 DIM Burst Continuos Test Mode (DIM_BCTEST)

Single events on one sensor face are registered. In DIM_BCTEST mode measured values are not stored in a compressed way (as in DIM_BC mode), but for each event the peak voltage (in mVolt and dB) and the impact time (timer count and time[dB]) are included in TM stream. No average samples are measured.

Expected SD output for DIM Burst Continuos Test Mode (DIM_BCTEST)				
Item No.	Byte No.	Meaning	(Typical) Value (hex.)	Remarks
1	0 to 11	SD header	ABCD ABCD 3C06 llll tttt tttt	llll = total length; last two words are SESAME Local Time
2	12, 13	Block header:	5454	
3	14	Direction	00 (X) or 01 (Y) or 02 (Z)	Echoed Command Parameter
4	15	Margin		Echoed Command Parameter
5	16	Energy Control	00 or 01 or 02	Echoed Command Parameter
6	17	Decay Time		
7	18, 19	Sampling Time		Echoed Command Parameter
8	20, 21	Measuring Time		Echoed Command Parameter
9	22, 23	Data Block header	7272	
10	24, 25	nevent: Number of Events detected		
11	26, 27	Number of false Events		
12	28, 29	Number of long Events		
13	30, 31	Number of Average Samples	0000	
next data block (item 14 to 17) occurs nevent times				
14	+1, +2	Timer Count		
15	+3, +4	Peak Amplitude [mVolt]		
16	+5	Timer [dB]		
17	+6	Peak Amplitude [dB]		
18	+1 to +4	SESAME Local Time at end of measuring period		High Word, low word
19	+5	Error Code	00	
20, 21	+6, +7	Block delimiter: BC data	ABAB	

6.2.11 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.

```
HEX
01 EQU EB_OVERCURR       \ overcurrent interrupt detected
02 EQU EB_NOISY_AMP      \ noise level higher than limit (DIM_NT)
```

```
02 EQU EB_NO_AD_RDY     \ error using ADC of C-DPU
04 EQU EB_NO_PULSE      \ no pulse detected (DIM_ST)
04 EQU EB_BAD_HEALTH    \ voltage out of limits (DIM_PC)
08 EQU EB_LONG_T        \ long pulse measured (DIM_CAL, DIM_ST, DIM_BC)
10 EQU EB_BAD_CAL_LO    \ calibration (low level) failed
10 EQU EB_NOISY_TEST    \ average sample exceeds limit (DIM_ST)
20 EQU EB_BAD_CAL_HI    \ calibration (high level) failed
20 EQU EB_BAD_TEST      \ peak voltage and length out of range (DIM_ST)
40 EQU EB_MEM_FULL      \ reserved memory space exhausted
```

6.3 PP Instrument

PP: Defined Telecommands
(all numerical values in this table are hexadecimal)

IDENT	Com-mand Word	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_AM	5200	n/a	n/a	n/a	PP active measurements with default configuration
PP_PM	5300	n/a	n/a	n/a	PP passive measurements with default configuration
PP_PWRSW	5501	1.	Power Mode	0000=all circuits off 0001=all circuits on	PP power switching (no SD are generated)
PP_DA	5802	1.	Address	0018 or 0019	PP direct register address
		2.	Value		
PP_AMTEST	5B03	1.	TX settings: 0abi, with a=TX phase A, b=TX phase B, i=current source for ADC	for operations: 0121, 0122, 0131, 0133, 0232, 0233	one PP active measurement with raw data output
		2.	Frequency		
		3.	No. of waves		
PP_PMTEST	5C03	1.	MUX channel		one PP passive measurement with raw data output
		2.	Sampling frequency		
		3.	No. of samples	1.. N_SAMPLES_MAX	
PP_SPEC	5D03		3 parameters (variable)		used for debugging during S/W and H/W tests only.

6.3.1 PP Healthcheck (PP_HC)

During PP healthcheck a variety of voltages and currents are measured on PP board, thus testing the electrical status of PP.

Expected SD output for PP Health Check (PP_HC)			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 5000 0020 tttt tttt	total length: 0x20 = 32 byte; last two words are SESAME Local Time
12, 13	Langmuir Probe with clock divider=0	e.g. 3A44	depends strongly on environment and sensor location
14, 15	ADC offset	e.g. 0080	should be close to 0x0080 (0x0080 means zero with bipolar ADC)
16, 17	-2.5 V reference	e.g. 0045	should be nearly symmetrical to ADC offset (with PP EQM1 an erroneous value of the -2.5 V reference value is acceptable)
18, 19	+2.5 V reference	e.g. 00A4	
20, 21	differential value from +2.5V reference measurement	e.g. 0069	
22, 23	direct voltage from receiver 1	e.g. 00FF without sensors connected	depends on connection of receiver and environment
24, 25	direct voltage from receiver 2	e.g. 00FF without sensors connected	depends on connection of receiver and environment
26, 27	transmitter current at electrode 1; no voltage applied	e.g. 0080	should be close to ADC offset
28, 29	transmitter current at electrode 2; no voltage applied	e.g. 0080	should be close to ADC offset
30, 31	transmitter current at electrode 3; no voltage applied	e.g. 0080	should be close to ADC offset

6.3.2 PP Langmuir Probe Test (PP_LM)

Telecommand PP_LM initiates a series of Langmuir Probe measurements with different periods of charge collection. 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 and is not a regular flight measurement.

Expected SD output for PP Langmuir Probe Test			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 5100 0050 tttt tttt	total length: 0x50 = 80 byte; last two words are SESAME Local Time
12,13, 14,15	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: measured electron density	0000 3A44	nominal clock divider value and actual value (read back from register) must be equal. Measured value of electron density should decrease linearly with increasing clock divider value.
16,17, 18,19	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: measured electron density	0101 1D38	
20,21, 22,23	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: measured electron density	0202 137C	
(...)			
72,73, 74,75	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: measured electron density	0F0F 03A8	

76,77, 78,79	1st byte: Integration clock divider (nominal value) 2nd byte: Integration clock divider (actual value) 3rd –4th byte: measured electron density	0404 0BB5	measurement with default clock divider value (4); result should be similar to already measured value with clock divider=4.

6.3.3 PP Active Mode (PP_AM)

A series of active PP measurements is performed. All measurement parameters (e.g. the transmitter frequencies) are controlled by the default PP control table in C-DPU EEPROM.

```
\ Control table for all measuring modes
\ Length: 52 Byte
HEX
CREATE PPCTL
   04 C,   0A C,                 \ INTDIV, LMREP
 0121  , 03E8  ,  9C40 ,         \ ELEC  , NSAMP , SFREQ
   14 C,   05 C,   14 C,  14  C, \ NSKIP , NRANG , NFREQ , NWAV
 000A  , 003C  , 008C  , 0118  ,  0190 ,   \ freq00..freq04
 0258  , 0320  , 03E8  , 04B0  ,  0578 ,   \ freq05..freq09
 0708  , 07D0  , 0960  , 0BB8  ,  0DAC ,   \ freq10..freq14
 1388  , 1770  , 1B58  , 2134  ,  2710 ,   \ freq15..freq19
```

Caveats:
Because PP onboard data evaluation is not implemented yet, the acquired measured values (samples of transmitter current and receiver voltage) are not evaluated, but a set of significant parameters for each measurement is sent to ground.

Expected SD output for PP Active Mode (PP_AM) preliminary			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 5200 llll tttt tttt	llll= total length (depends on number of frequencies in control table); last two words are SESAME Local Time
12, 13	Number of measurements (= number of frequencies)	0014	Typically 20 active frequencies in the range 10..10000 Hz are used.

for each frequency and no fatal error			
1 word	Frequency [Hz]	000A..2710	
1 word	DAC stop address	0001..0100	
1 word	Number of samples	0001..3F80	
1 word	Error code	0000	
(...)			

6.3.4 PP Active Mode Test (PP_AMTEST)

One active PP measurement is performed. Adjusted and measured values (DAC table read back from PP memory, samples of transmitter current and receiver voltage) are sent to ground. Adjustable parameters of command PP_AMTEST are the configuration of electrodes, the transmitter frequency and the number of sine waves, which should be received. This operation mode is mainly used for ground tests and is not a regular flight mode.

Expected SD output for PP Active Mode Test (PP_AMTEST)

Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 5B03 llll tttt tttt	llll= total length (depends on command parameter settings); last two words are SESAME Local Time
12, 13	Electrode combination (control table format)		echoed command parameter
14, 15	Frequency [Hz]		echoed command parameter
16, 17	Number of waves		echoed command parameter
18, 19	Error code	0	
if no fatal error			
20 to 275	DAC table read back from PP memory		should include an adjusted sine table (one byte per data), starting from first byte. Length depends on parameter settings.
276 to 277	Number of samples (nsamp)	0001..3F80	
+1 to +nsamp	nsamp transmitter current samples		One byte per sample
+1 to +nsamp	nsamp receiver voltage samples		One byte per sample

6.3.5 PP Passive Mode (PP_PM)

A series of passive PP measurements is performed. All measurement parameters (e.g. the range of measured frequencies) are controlled by the default PP control table in C-DPU EEPROM.

```
\ Control table for all measuring modes
\ Length: 52 Byte
HEX
CREATE PPCTL
   04 C,   0A C,                  \ INTDIV, LMREP
 0121  , 03E8  ,  9C40 ,          \ ELEC  , NSAMP , SFREQ
   14 C,   05 C,   14 C,  14  C,  \ NSKIP , NRANG , NFREQ , NWAV
 000A  , 003C  , 008C  , 0118  ,  0190 ,   \ freq00..freq04
 0258  , 0320  , 03E8  , 04B0  ,  0578 ,   \ freq05..freq09
 0708  , 07D0  , 0960  , 0BB8  ,  0DAC ,   \ freq10..freq14
 1388  , 1770  , 1B58  , 2134  ,  2710 ,   \ freq15..freq19
```

Caveats:
Because PP onboard data evaluation is not implemented yet, the acquired measured values (samples of the receiver voltage) are not evaluated, but a set of significant parameters for each measurement is sent to ground.

Expected SD output for PP Passive Mode (PP_PM) preliminary			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 5300 llll tttt tttt	llll= total length (depends on number of frequencies ranges in control table); last two words are SESAME Local Time
12 to 13	Number of measurements (= number of frequency ranges)	0005	Typically 5 frequency are used
for each frequency			
1 word	Sampling Frequency [Hz]		
1 word	ADC clock divider value		
1 word	Number of samples	0001..3F80	
1 word	Error code	0000	
(...)			

6.3.6 PP Passive Mode Test (PP_PMTEST)

One passive PP measurement is performed. Adjusted and measured values (samples of transmitter current and receiver voltage) are sent to ground. Adjustable parameters of command PP_PMTEST are the analog channel for the first measurement, the sampling frequency and the number of samples. This operation mode is mainly used for ground tests and is not a regular flight mode.

Expected SD output for PP Passive Mode Test (PP_PMTEST)			
Byte No.	Meaning	(Typical) Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 5C03 llll tttt tttt	llll= total length (depends on command parameter settings); last two words are SESAME Local Time
12 to 13	Analog channel for first measurement		echoed command parameter
14 to 15	Sampling frequency [Hz]		echoed command parameter
16 to 17	Number of samples		echoed command parameter
18 to 19	Error code	0000	
if no fatal error			
20, 21	Number of measured samples (nsamp)	0001..3F80	
+1 to +nsamp	nsamp transmitter current samples		One byte per sample
+1 to +nsamp	nsamp receiver voltage samples		One byte per sample

6.3.7 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 11	SD header	ABCD ABCD 5802 0014 tttt tttt	total length: 0x14 = 20 byte; last two words are SESAME Local Time
12, 13	Bus address	0018 or 0019	echoed command parameter
14, 15	Parameter written to bus address		echoed command parameter
16, 17	Value read from bus address		= -2 if wrong bus address
18, 19	measured voltage on +5V power supply line	09C4	multiply by 2 to yield voltage [mV]

6.3.8 PP Error Codes

Error codes are composed of the following bit settings.

```
HEX
0000 EQU EB_PPNOERR
8001 EQU EB_PPINVREG \ invalid register address
8002 EQU EB_PPVERREG \ error verifying reg. write
8004 EQU EB_PPPWRREG \ error accessing power register
8008 EQU EB_PPMUXSET \ MUX setting not allowed
8010 EQU EB_PPMEMACC \ error accessing PP RAM
8020 EQU EB_PPMESRUN \ operation not allowed, measurement is running
0040 EQU EB_PPWRITE  \ error during writing
0080 EQU EB_PPREAD   \ error during reading
0100 EQU EB_PPCDUADC \ error using ADC of C-DPU
0200 EQU EB_PPDACTAB \ error during DAC table generation
8400 EQU EB_PPNSAMP  \ calculated no of samples > N_SAMP_MAX
8800 EQU EB_PPNOMEM  \ C-DPU memory exhausted
9000 EQU EB_PPTOUT   \ measurement time out
8000 EQU EB_PPFATAL  \ flag indicates fatal error
```

6.4 C-DPU Actions and Control of Command Processing

IDENT	Command Word	Parameter Words			Description
		No	Meaning	Valid Range	
COM_MEM	7100	n/a	n/a	n/a	memory check (data pages)
COM_HK	7200	n/a	n/a	n/a	all HK values to SD output
COM_WDLY	7501	1.	waiting period [s]	0001..FFFF	subsequent telecommand shall be executed after a pause of "waiting period" seconds
COM_WLOBT	7603	1.	LOBT low word	0001..FFFF	subsequent telecommand shall be executed not before LOBT.
		2.	LOBT midth word	0001..FFFF	
		3.	LOBT highest (5) bits	0000..001F	
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_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.

6.4.1 Memory Check (COM_MEM)

Check memory pages one to seven in SESAME SRAM (i.e. all memory pages apart from code page). The contents of each memory cell in a page is saved, the word 0xFFFF is written to that cell and the contents verified, subsequently the word 0 is written to that cell and the contents verified. The original contents of a memory cell is restored after checks. Each non-successful verify results in an increment of an error count for the corresponding page. This error count is included in the telemetry stream. Additionally HK parameter CE_F2 (S/W flags 2) is updated after a memory check. CDMS EI1 interrupts are disabled during checks, thus the procedure should be fairly save regarding any interference with running tasks.

Expected SD output for Memory Check (COM_MEM)			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 11	SD header	ABCD ABCD 7100 0021 tttt tttt	total length: 0x21 = 33 byte; last two words are SESAME Local Time
12	Memory Page No	01	
13, 14	Error Count	0000	
15	Memory Page No	02	
16, 17	Error Count	0000	
18	Memory Page No	03	
19, 20	Error Count	0000	
21	Memory Page No	04	
22, 23	Error Count	0000	
24	Memory Page No	05	
25, 26	Error Count	0000	
27	Memory Page No	06	
28, 29	Error Count	0000	
30	Memory Page No	07	
31, 32	Error Count	0000	

6.4.2 HK Values to SD Stream (COM_HK)

All SESAME HK parameters are measured or collected and values are included into the SD stream. CASSE analog power (± 5 V) is switched on during the execution of the command to allow the reading of the RadFET offset voltage on CASSE PCB. Regular HK scaling of measured values apply.

Expected SD output for COM_HK Telecommand			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 11	SD header	ABCD ABCD 7200 0048 tttt tttt	total length: 0x48 = 72 byte; last two words are SESAME Local Time

12, 13	CA_T1		
14, 15	CA_T2		
16, 17	CA_T3		
18, 19	CA_T4		
20, 21	CA_T5		
22, 23	CA_T6		
24, 25	CA_U1		
26, 27	CA_U2		
28, 29	DI_U1		
30, 31	DI_U2		
32, 33	PP_U1		
34, 35	PP_D		
36, 37	CE_U1		
38, 39	CE_U2		
40, 41	CE_U3		
42, 43	CE_U4		
44, 45	CE_U5		
46, 47	CE_U6		
48, 49	CE_I1		
50, 51	CE_I2		
52, 53	CE_I3		
54, 55	CE_I4		
56, 57	CE_I5		
58, 59	CE_F1	0000 or 8000	
60, 61	CE_F2	0000 or 8000	
62, 63	CE_F3	0000 or 8000	
64, 65	CE_ID	05E5 or 85E5	"5E5ame"
66, 67	CA_T7		
68, 69	CE_C1		Last TC
70, 71	CE_C2		Last but one TC

6.4.3 TC processing: Pause (COM_WDLY)

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

6.4.4 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 SD are generated.

6.4.5 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 contents of specific records in the Backup RAM Buffer of some units has been laid down in the interaction document (RO-LSE-TN-3403).

Expected SD output for Read Backup RAM Buffer (COM_RBUF)			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 11	SD header	ABCD ABCD 7A02 0050 tttt tttt	total length: 0x50 = 80 byte; last two words are SESAME Local Time
12, 13	Unit Subsystem Address		echoed command parameter
13, 14	Offset in Backup RAM Buffer		echoed command parameter
15 to 79	Contents of Backup RAM Buffer Record		record is copied byte by byte to TM stream

6.4.6 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_RBUF)			
Byte No.	**Meaning**	**(Typical) Value (hex.)**	**Remarks**
0 to 11	SD header	ABCD ABCD 7B01 002E tttt tttt	total length: 0x2E = 46 byte; last two words are SESAME Local Time
12, 13	Offset in STC Buffer		echoed command parameter
14 to 45	First 16 Words of STC Record		record is copied byte by byte to TM stream

6.5 Special Messages in Telemetry Data Stream

6.5.1 Ready Message

After booting SESAME S/W generates a message with measurement identifier 0x0000, containing the String “SESAME Flight S/W - Ready”.

SESAME Ready Message			
Byte No.	Meaning	Value (hex.)	Remarks
0 to 11	SD header	ABCD ABCD 0000 0100 tttt tttt	total length: 0x100= 256 byte; last two words are SESAME Local Time
12 to 255	Ready Message	2020 2020 5345 5341 4D45 2046 6C69 6768 7420 532F 5720 202D 2052 6561 6479 2020 2020 2020 2020 2020. 2020 2020 (...)	character representation: " SESAME Flight S/W - Ready "

6.5.2 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 11	SD header	ABCD ABCD 7F00 llll tttt tttt	lll is total length, depending on number of error code words contained; last two words are SESAME Local Time
12 to 25	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 level for debugging, no error
0x1: Warning Level
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.

The following error codes are used in the current S/W implementation.

Error Codes in Error Messages

Error Code	Subsystem	Source File	Meaning
1101	A/D	analog.scr	Tried to start A/D conversion, but ADC of C-DPU is in use.
1102	A/D	analog.scr	Unknown HK parameter ID, HK value set to HK_MISVAL
1103	A/D	analog.scr	Tried to read A/D converted value, but conversion is not ready.
1406	CDMS I/F	cdmsif.scr	Received CDMS message, which is not addressed to SESAME and is not a broadcast message; message ignored.
140A	CDMS I/F	cdmsif.scr	Received unknown CDMS data message (msgDATA)
140C	CDMS I/F	cdmsif.scr	Unknown Action Code (newCDMSmsg!)
140E	CDMS I/F	cdmsif.scr	Unknown Action Code (NewCDMSmsg?)
1412	CDMS I/F	cdmsif.scr	Wrong Word Count (rcvTRG)
1414	CDMS I/F	cdmsif.scr	Wrong parameters (check_actc)
1601	TC process.	tc.scr	Unknown command category, TC ignored.
1617	Common	cdpu.scr	Unknown common TC.
1A01	CASSE	casse_fm.scr	Wrong temperature channel, set to default (1).
1A11	CASSE	casse_fm.scr	Unknown CASSE TC.
1B01	DIM	dim.scr	Invalid margin, set margin to 0.
1B02	DIM	dim.scr	Invalid direction, set direction to X.
1D01	Common	cdpu.scr	Could not allocate memory (COM_MEM).
1D03	Common	cdpu.scr	Could not allocate memory (COM_HK).
1D08	Common	cdpu.scr	Error reading Backup RAM Buffer.
1D09	Common	cdpu.scr	Error reading Stored TC Buffer.
E106	Common	cdpu.scr	Could not allocate memory (COM_RBUF).
E402	CDMS I/F	cdmsif.scr	SESAME request buffer full.
E4Dx	CDMS I/F	cdmsif.scr	Received CDMS Error Code Word with contents x.
E501	SD process.	sd.scr	Invalid case in module SDOUT.
EA20	CASSE	casse_fm.scr	Could not allocate memory (CAS_HC).
EA22	CASSE	casse_fm.scr	Could not submit measurement (CAS_HC).
EA24	CASSE	casse_fm.scr	Could not allocate memory (CAS_MES).
EA26	CASSE	casse_fm.scr	Could not submit SD (CAS_MES).
EAFF	CASSE	casse_fm.scr	Allocated memory space exhausted.

EB20	DIM	dim.scr	Could not allocate memory (DIM_CA).
EB21	DIM	dim.scr	Could not submit SD (DIM_CA)
EB22	DIM	dim.scr	Could not allocate memory (DIM_NT).
EB23	DIM	dim.scr	Could not submit SD (DIM_NT)
EB24	DIM	dim.scr	Could not allocate memory (DIM_ST).
EB25	DIM	dim.scr	Could not submit SD (DIM_ST)
EB26	DIM	dim.scr	Could not allocate memory (DIM_PC).
EB28	DIM	dim.scr	Power Check failed.
EB2A	DIM	dim.scr	Could not allocate memory (DIM_AV, DIM_AVTEST).
EB2B	DIM	dim.scr	Could not submit SD (DIM_AV, DIM_AVTEST)
EB2C	DIM	dim.scr	Could not allocate memory (DIM_BC, DIM_BCTEST).
EB2D	DIM	dim.scr	Could not submit SD (DIM_PC)
EBF1	DIM	dim.scr	Unknown DIM TC.
EC30	PP	pp.scr	Could not allocate memory (PP_HC).
EC31	PP	pp.scr	Could not submit SD (PP_HC).
EC32	PP	pp.scr	Could not allocate memory (PP_DA).
EC33	PP	pp.scr	Could not submit SD (PP_DA).
EC52	PP	pp.scr	Could not allocate memory (PP_LM).
EC53	PP	pp.scr	Could not submit SD (PP_LM).
EC54	PP	pp.scr	Could not allocate memory (PP_AM).
EC55	PP	pp.scr	Could not submit SD (PP_AM).
EC57	PP	pp.scr	Could not allocate memory (PP_AMTEST).
EC58	PP	pp.scr	Could not submit SD (PP_AMTEST).
EC5C	PP	pp.scr	Could not allocate memory (PP_PM).
EC5D	PP	pp.scr	Could not submit SD (PP_PM).
EC5E	PP	pp.scr	Could not allocate memory (PP_PMTEST).
EC5F	PP	pp.scr	Could not submit SD (PP_PMTEST).
ECE1	PP	pp.scr	Unknown PP TC.
ED02	Common	cdpu.scr	Could not submit SD (COM_MEM).
ED04	Common	cdpu.scr	Could not submit SD (COM_HK).
ED05	Common	cdpu.scr	Could not submit SD (COM_RBUF).
ED07	Common	cdpu.scr	Timeout during Backup Buffer RAM reading..
ED0A	Common	cdpu.scr	Timeout during Stored TC Buffer reading..
ED0B	Common	cdpu.scr	Could not allocate memory (COM_RDJC).
ED0C	Common	cdpu.scr	Could not submit SD (COM_RDJC).

7 Software Release Notes FM 1.0

Current S/W release is FM 1.0. This S/W has been burned into the C-DPU (FM) EEPROM on 12. March 2001. S/W provides all mechanisms for the control of basic SESAME functionality, however, due to a couple of reasons, S/W development process is not yet terminated: a) user requirements are still incomplete. At least one more iteration of CASSE and PP software description documents is needed. The arrival of an update of the DIM S/W description coincided with the delivery of the SESAME C-DPU to Lander team and could not be taken into account, b) functional tests were handicapped by the limited availability of hardware, the amount of testing on FM H/W level is definitely insufficient, c) a final redesign with the aim of an overall optimization of the S/W code could not be carried out.

7.1 Implementation Status of User Requirements, Test Status and Caveats

7.1.1 Common Software Parts

Flight Software version 1.0 fulfills the global user requirements listed in RO-LSE-RD-3401 with the following exceptions:

UR-Id.	Description	Prior.	Comments
GEN-02	The software shall be qualified and accepted within a flight representative hardware /software environment (S/W verification test-bed)	E	Comprehensive testing with FM compatible electronics and sensors is missing.
GEN-07	The software shall support program update via telecommand.	E	Use C-DPU Debug Monitor.
GEN-07.1	The software shall allow the update of operational parameters by telecommand.	E	Use C-DPU Debug Monitor.
GEN-09	The software shall run in two different operation modes: 1) Main Science Operations Mode, 2) Low Power Mode (reduced SESAME processor clock rate).	E	Low Power Mode of SESAME C-DPU has been disabled by H/W means.
GEN-11	The software shall provide optional science data compression.	V	Compression algorithm has been implemented but not yet connected to Flight S/W.

Internal tests and tests after the integration of SESAME H/W into Lander showed no errors in common S/W parts (i.a. telecommand and SD processing, timing, Stored TC and Backup RAM Buffer access, ADC), however long term tests (with realistic operational scenarios of all instruments) were not possible and tests in Lander environment were partly handicapped by some malfunctions of the CDMS (cf. Software Validation and Verification Reports).

Possible future optimizations
It should be decided whether and where the Science Data compression module should be connected to the SD stream. The best place within SD processing will depend on whether

compression should be applied to measuring data of all instruments (e.g. if no PP data reduction will be implemented), or just to CASSE measurements. The latter will in turn depend on whether an averaging of measuring values should be implemented. If high frequency oscillations in the CASSE signals will still be present using FM feet and sensors, the already programmed ESTEC-1 compression algorithm might not be suitable (this might be true for any other lossless data compression algorithm).

The readout of the RadFET offset voltage requires that CASSE analog circuit power (±5 V) is switched on. However, during regular housekeeping the HK module does not switch on this circuit in order to keep power consumption low and to avoid current transients due to power switching. Thus the value of the RadFET voltage offset (HK parameter CA_U2) is currently meaningless if it has been acquired during regular HK. CASSE analog power is switched on if HK acquisition is initiated by the telecommand COM_HK. A measurement or collection of all HK parameters commanded by telecommand COM_HK is currently the only way to determine the RadFET offset voltage.

The segmentation of data pages for the memory allocation scheme should be optimized corresponding to the expected amount of SD for all measuring modes.

Final optimization
The listing of the LMI Forth metacompiler provides a means to detect Forth words, which are contained in the code but not used. These words can be removed after the completion of S/W development. The identification and more strict separation of configuration parameters from system constants may support the upload of parameter tables. The generation of error messages due to non-fatal errors should be carefully reviewed. Being helpful during S/W development and ground tests these messages can turn a non-fatal situation into a total blocking of S/W under rare circumstances.

7.1.2 CASSE Control Software

Basis for the CASSE part of Flight S/W was the CASSE Software Description (RO-LSE-SP-3420), Issue 3, 15. June 2000. Some modifications have been approved by CASSE group (M. Kretschmer). A draft version of issue 4 of the CASSE S/W Description has been comprehensively commented by S/W group ("Anmerkungen zur CASSE S/W Description Issue 4", 04.Feb. 2001, H.-H. Fischer). A final version of user requirements document is yet to come.

The basic functionality of CASSE S/W has been intensively tested, mainly on EQM2 H/W level (RO-LSE-TR-3402, RO-LSE-TR-3320, S/W Validation and Verification Reports). A comprehensive testing on FM H/W level will be necessary following the implementation of an extended CASSE S/W version according to an update of the CASSE S/W description.

Triggered listening mode and CASSE-MUPUS interaction are not well defined yet. While CASSE-MUPUS interaction is not implemented in the CASSE S/W code, a preliminary version of triggered mode has been programmed. However, the commanding of the triggered listening mode (i.e. the specification of a trigger source in the CASSE jobcard) is strongly discouraged, because it has not been tested sufficiently.

The current implementation of CASSE power switching via telecommand CAS_PWRSW includes a waiting period after power on to allow sensor warm-up. Without this delay CAS_PWRSW could be used in advance of a CASSE measurement to switch on sensor power and use the period until sensors are ready for measurements of other instruments. However, it has to be ensured that no CASSE measurement (using sensors) is executed until warm-up period has expired and the powering of all CASSE circuits does not affect the measurements of other SESAME instruments.

7.1.3 DIM Control Software

Basis for the DIM part of Flight S/W was the DIM Software Description (RO-LSE-SP-3440-pa), Issue 3, 25. February 2000. Additionally a Pascal implementation of S/W code was supplied by the DIM group. All defined measuring modes have been implemented (some additionally in a test version with extended SD output) and may be commanded, but the main module is missing. This module should allow an autonomous decision making on board, which of the measuring modules will be invoked. Some modifications to the measurement modules have been approved by DIM group (A. Péter): energy control options have partially been omitted; the smallest adjustable delay is 8 microseconds.

DIM measuring modules have been rather well tested, mainly on EQM2 H/W level (RO-LSE-TR-3402; S/W Validation and Verification Reports; SESAME internal test report "Test of DIM EQM Flight Software", H.-H. Fischer, 25. Aug. 2000). Comprehensive testing on FM H/W level will be necessary following the implementation of the main module and other S/W modifications according to DIM S/W Description, Issue 4, 25. Jan. 2001.

Still an open question is the handling of EI4 interrupts generated by the DIM overcurrent sensing circuit. According to the DIM S/W description S/W should switch off DIM power supply after an EI4 interrupt. These interrupts have been observed sporadically with DIM EQM2 PCB and during each second DIM healthcheck on DIM FM PCB, obviously due to the oversensitivity of the circuit, not to a harmful situation. As a workaround power is switched off after each DIM healthcheck and interrupts are ignored during DIM power on procedure (email to A. Peter 16. Feb. 2001, 19. Feb. 2001, 15. March 2001).

7.1.4 PP Control Software

Basis for the PP part of Flight S/W was the PP Software Description (RO-LSE-SP-3460), issue 1, 18. July 1999 and some portions of C code showing a possible implementation of S/W parts. The main drawback of the S/W description is the missing description of the onboard data evaluation algorithm ("modified wavelet method"). As far as measuring modules could have been identified in the user requirements document, they have been implemented, sometimes in a preliminary way due to the missing onboard data evaluation algorithm. All basic PP measuring modes can be commanded.

Availability of PP H/W (both on EQM and FM level) was very low, therefore only coarse S/W testing and verification of the basic functionality was possible. A revised user requirements document is needed. Comprehensive testing on FM compatible H/W level will be necessary following the implementation of the missing features.

8 Appendix

8.1 Directory Structure of Software Sources and Documents

```
\ARCHIVE RELEASED VERSIONS
+--FM1_0
+--FLIGHT SOFTWARE
|  +--APP
|  |  +--APPLICAT.DEF                   global unit settings
|  |  +--APPLICAT.SCR                   global unit include file
|  |  \--SESAME.SCR                     SESAME include file
|  +--CTL
|  |  \--MAIN01.SCR                     main loop
|  +--GLB
|  |  +--ANALOG.SCR                     ADC, HK
|  |  +--ERRMSG.SCR                     error handling routines
|  |  +--MEMORY.SCR                     dynamic memory allocation
|  |  +--GLOBAL.SCR                     Forth core extensions, common data
|  |  \--TYPES.SCR                      data structures
|  +--IO
|  |  +--CDMSIF.SCR                     I/F to CDMS
|  |  +--SD.SCR                         SD processing
|  |  \--TC.SCR                         TC processing
|  +--MES
|  |  +--CASSE.SCR                      CASSE control S/W: include file
|  |  +--CASSE_EM.SCR                   CASSE control S/W: version for EM PCB
|  |  +--CASSE_FM.SCR                   CASSE control S/W: version for FM PCB
|  |  +--CDPU.SCR                       control of common actions
|  |  +--DIM.SCR                        DIM control S/W
|  |  +--PP.SCR                         PP control S/W
|  |  +--t_math.4th                     test routines for math. functions (WinForth)
|  |  \--t_dimmat.4th                   test routines for DIM BC matrix (WinForth)
|  +--OS
|  |  +--BIOS.SCR                       C-DPU BIOS
|  |  +--RTX20R4.SCR                    Forth core
|  |  +--RTXARI.SCR                     LMI arithmetic routines
|  |  +--RTXDIS.SCR                     LMI Forth disassembler
|  |  +--RTXFLOAT.SCR                   LMI floating point arithmetic
|  |  +--RTXSTAT1.SCR                   LMI optimizing compiler state tables
|  |  \--RTXTRACE.SCR                   LMI debug routines
+--0EDIT.BAT                            invokes FORTH screen editor
+--0LOAD.BAT                            program upload via serial I/F (LM)
+--0RTX.BAT                             connection to C-DPU via serial I/F (LM)
+--EDITOR.BIN                           executable of screen editor
+--HOST.EXE                             communication with C-DPU via serial I/F (LM)
+--HOST.OVL                             communication with C-DPU via serial I/F (LM)
+--MAKEFILE                             invokes metacompiler for all source files
+--MC.COM                               LMI metacompiler
+--MC.SYM                               symbol table of metacompiler
+-\fm1_0.img                            SESAME Flight S/W program
+--AUXILIARY SOFTWARE                   GUI tkCDMS (DLR-BA)
+--SD COMPRESSION
|  +--FLIGHT
|  |  \--COMPRESS.SCR                   encoding algorithm
|  |  +  TEST                           test routines for encoding algorithm
|  +--GROUND                            decoding, tests
+--GROUND SOFTWARE
|  +--SRC
|  |  +--PARSE_SD.C                     parse TM packets (SD)
|  |  +--PARSE_HK.C                     parse TM packets (HK)
|  |  \--GEN_JC.C                       generate parameter words for TC CAS_RJC
|  +--BIN
+--DOCUMENTATION
```

8.2 Generation of Parameter Words for CASSE Command CAS_RJC

```
/*
  Simple program for the generation of CAS_RJC parameter words
  23. February 2001, H.-H. Fischer, Universitaet Koeln
  Jobcard structure according to CASSE S/W Description (RO-LSE-SP-3420),
  issue 3, 15 June 2000
*/

#include <stdio.h>

#define SWAP_BYTE_IN_WORD 0
#if SWAP_BYTE_IN_WORD
 #define PRINTW(w) { printf("%2.2x%2.2x ", (w&0x00FF),(w&0xFF00)>>8); }
#else
 #define PRINTW(w) { printf("%4.4x ",w); }
#endif

#define JOB_ID       0x42
#define SUB_ID       0x00
#define START_COND   0x00
#define NO_MEAS      01
#define SOUND_FREQ   1024        /* Hz */
#define SOUND_DURA   5           /* ms */
#define SAMP_FREQ    83000       /* Hz */
#define TX_STATUS    0x04
#define AMP_GAIN_SEL 0x0B
#define TRG_SRC      0x0000
#define TRG_DELAY    0x0000
#define TRG_LEV_POS  0x00
#define TRG_LEV_NEG  0x00
#define LIS_DURA     15          /* ms or sec for trg timeout */
#define RX_STATUS    0x1C0
#define GPW1         0x0000
#define GPW2         0x0000
#define GPW3         0x0000
#define FT_TEMP_CHAN 0x3F
#define CSPARE1      0x00
#define WSPARE1      0x0000
void main (void) {
 printf("\n%2.2x%2.2x ",JOB_ID,SUB_ID);
 printf("%2.2x%2.2x ",START_COND,NO_MEAS);
 PRINTW(SOUND_FREQ);
 PRINTW(SOUND_DURA * 10);
 PRINTW(SAMP_FREQ/10);
 printf("%2.2x%2.2x ",TX_STATUS,AMP_GAIN_SEL);
 PRINTW(TRG_SRC);
 PRINTW(TRG_DELAY);
 printf("%2.2x%2.2x ",TRG_LEV_POS,TRG_LEV_NEG);
 PRINTW(LIS_DURA*10);
 printf("%4.4x ",RX_STATUS);
 printf("%4.4x ",GPW1);
 printf("%4.4x ",GPW2);
 printf("%4.4x ",GPW3);
 printf("%2.2x%2.2x ",FT_TEMP_CHAN,CSPARE1);
 printf("%4.4x",WSPARE1);
}
```

With the settings given in the program code, the program generates the following command parameter words, witch result in an appropriate update of the CAS_MES jobcard:

Generated Command Parameter Words:

```
1310 4200 0001 0400 0032 206c 040b 0000 0000 0000 0096 01c0 0000 0000 0000 3f00 0000
```