SWIM
Software Interface Control Document

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CHANGE RECORD

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3	0	2006-12-14	Section 5 Section 9 Section 10.2 Section 10.3 Sections 10.5, 10.6 new Section 10.10 replaced Section 12.4, Section 12.7.6 new Section 12.8	Description Added NOOP command Initialization sequence: Added delay between SWIM power on and TDC init, added NOOP command. Added delay time between read-out cmd, NOOP inserted. Switch off procedures Added high voltage ramping sequence. HK Added reference to external doc split from 12.7 for clarity .
3	1	2007-02-05	Section 9.4.5 Section 10.9	TDC power on to TDC communication delay
3	2	2008-02-04	10.4.2, Section 12,	Added command sequences at end of 8s cycle, HK reporting, inserted links to references to new documents, updated table 20, editorial changes.

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1 INTRODUCTION

This document defines the interaction between the SWIM sensor and the DPU as well as general requirements for onboard data processing software. The purpose of this document is to provide the DPU development team with an introduction to how the SWIM sensor works and what is required from the DPU. The most important parts are section 0 describing the command and data sequences sent between the DPU and the SWIM sensor and section 10 describing how data should be handled by the DPU, and thus essentially describes what the DPU should transfer to the spacecraft telemetry system.

2 APPLICATION

This document is the reference for the design of the SWIM software.

3 REFERENCE DOCUMENTS

Normative:
RD1 CHA-SARA-DS-0007-IxRy (SARA Instrument Description)

Informational:
RD2 CHA-SARA-DS-0011-IxRy (SWIM DPU Data Processing)
RD3 CHA-SARA-DS-0012-IxRy (Linear to logarithmic data compression)
RD4 CHA-SARA-DS-0006-IxRy (CENA Softeware Interface Control Document)
RD5 CHA-SARA-DS-0015-IxRy (SARA HK Decoding)
RD6 CHA-SARA-TR-0014-IxRy (SAS Housekeeping Calibration Functions)
RD7 CHA-SARA-DS-0011-IxRy (SWIM DPU Data Processing Pseudo Code)
RD8 CHA-SARA-DS-0003-IxRy (SWIM Mass Accumulation Mode Lookup Tables)

4 SARA DESCRIPTION

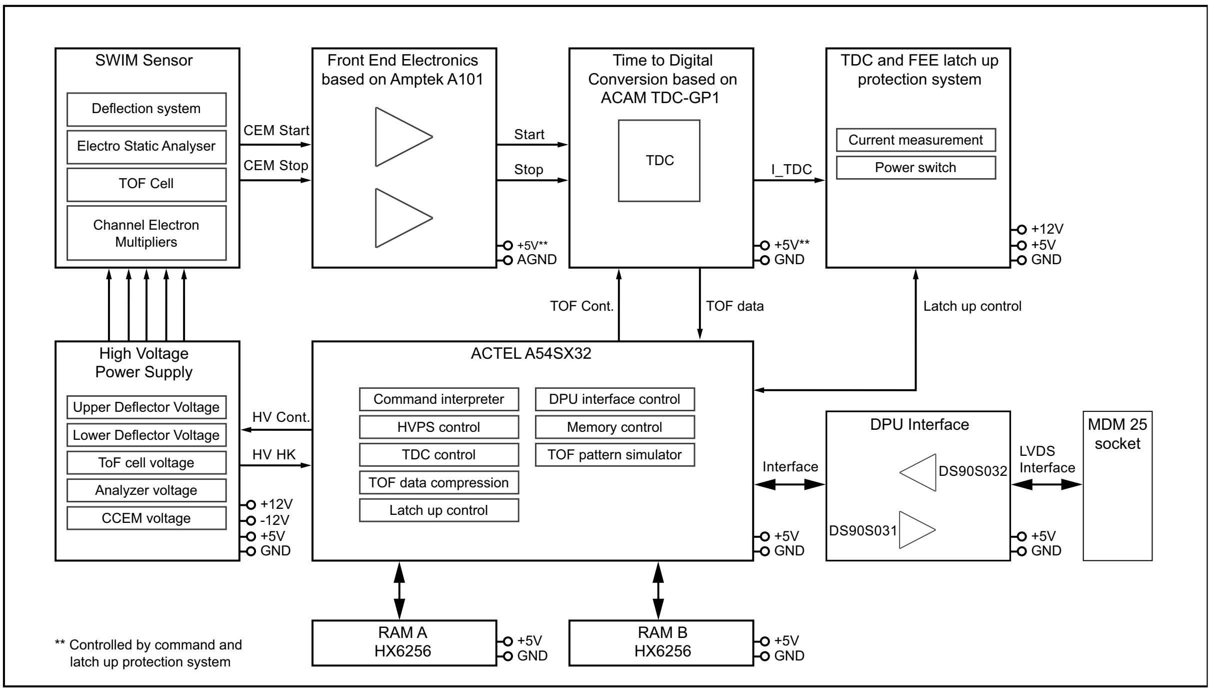
SARA consists of three separate units:

- CENA – Chandrayaan-1 Energetic Neutral Analyser (IRF)
- SWIM – Solar Wind Monitor (IRF)
- DPU – Digital Processing Unit (ISRO)

CENA and SWIM are sensor units, which trough the DPU, are connected to the spacecraft. The DPU contains the processor, Experiment Interface Unit (EIU), Power Distribution Unit (PDU) and Spacecraft Interface Unit (SIU).

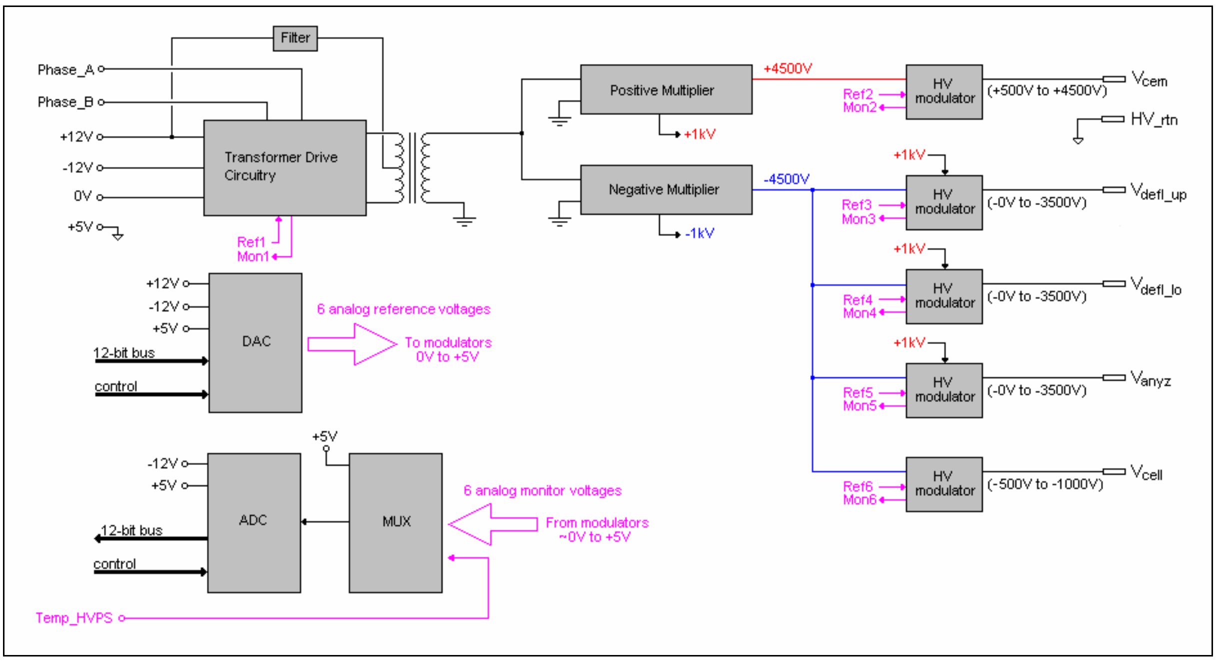
5 SWIM DESCRIPTION

SWIM SEM Block Schematics



Figur 1 SWIM SEM block schematics

A more extensive description of the SWIM SEM can be found in RD1.



Figur 2 SWIM HVPS FM block schematics.

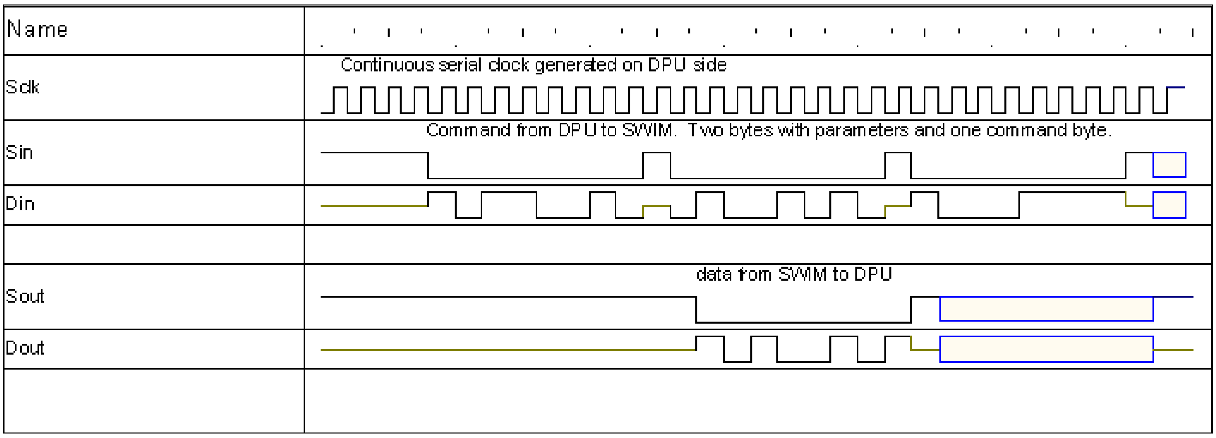
6 OPERATION

The SWIM unit is set to measure a certain energy from a certain angle of arrival by the DPU (by setting High Voltages according to 9.2), and delivers measured time-of-flight (TOF) values and other control values, once for each 31.25ms slot. This slot corresponds to the sampling time for the electrostatic analyzer, i.e. the time during which particles of one particular energy and angle of arrival is measured. The sampling time is 31.25 ms. The DPU is thus to set a number of voltages in the SWIM instrument which determines the measured energy and angle of arrival, as well as read out the collected data. The values, which the DPU should write to the sensor, will be stored in tables of 32 high voltage settings for 32 energy steps and 8 entrance deflection settings (which requires two values, one for the upper and one for the lower deflection plate) for each of the 32 energy steps (2 x 8 x 32 values). It is also foreseen that test sequences will be generated at start-up and possibly at regular intervals. The details of the commands sent to SWIM are described in section 9.2. Table 1 summarizes the command sequences for the sensor. Note also that the SWIM sensor only operates in one mode. The data is reduced by the DPU according to the telemetry mode (TM mode), see section 12.

7 TIMING AND SYNCHRONISATION

The basic operation consists of stepping through 8 different entrance HV deflection steps for each of the 32 energy HV analyser steps. A complete cycle (scan) takes 8 seconds. The sampling time is 31.25 ms. Each sample produces up to 4 kbyte of 8 bit TOF values for each angle of arrival (entrance HV deflection) and energy step. Four 16 bit words are inserted at the beginning of the datablock as defined in section 10.12. They contain number of start pulses, stop pulses, undercounts and overcounts.
No hardware or software handshake will be used in communication between the DPU and the SWIM sensor. The data read out will be in RAW format without checksums. Therefore, no check / recover of data are foreseen for the DPU - SWIM communication. No time delay between commands is necessary.

8 INTERFACE TIMING



Figur 3 Signal timing

Signal descriptions
S_{clk}+/S_{clk}- 2 MHz continuous running clock generated by the DPU
S_{in}+/S_{in}- Frame sync from DPU to SWIM, which goes high between every byte
D_{in}+/D_{in}- Three byte command from DPU to SWIM
S_{out}+/S_{out}- Frame sync from SWIM to DPU, which goes high between every byte
D_{out}+/D_{out}- Data from SWIM to DPU. Number of bytes depends on command

The interface is synchronous to Sclk. With 2 MHz clock frequency, one byte (8+1 bit) takes 4.5 µs to transmit and a command with three bytes, 13.5 µs.

8.1 Sync feature

The sensor has an auto-sync feature which requires that the three command bytes are received within a certain time. If not, a time out will be generated and the sensor will start waiting for the first command byte again. **The delay time between each of the three bytes (param1, param2, command) forming a complete command can not be longer than 15 µs.**

9 SENSOR COMMANDS

9.1 General

All software and pre-programmed command sequences must be reprogrammable from ground.

All commands, which are sent from the DPU to the Sensor during normal operation, will also have a corresponding telecommand (TC), which can be used to explicitly set switches and reference voltages (Section 9.2).

The following high level commands are foreseen:

a) Commands relating to command sequences
   - Execute command sequence (Section 10)

b) Direct commands to the sensor
   - Send single SWIM command to sensor and report return values, if any (Section 9.2).

c) Commands relating to the binning of the data
   - Set number of 8 sec measurement cycles to bin
   - Set number of angles of arrival to resolve (valid: 8, 4, 2, 1)
   - Set number of mass bins to resolve
   - Set to calibration mode
   - Set TM rate

d) Commands relating to health check
   - Set time between automatic health check
   - Perform immediate health check

e) Commands relating to housekeeping parameters
   - Set interval of HK data packets

f) Commands relating to the TM buffer memory
   - Empty TM FIFO memory
   - Flush TM FIFO memory
   - FIFO overflow - skip measurement cycles until free

g) Commands relating to commissioning and bench tests
   - Generate test pattern
   - Enable/disable compression

h) Commands relating to HV safety
- HV switch on confirmation. **Note: HV switch on in non-vacuum may destroy the sensor.**

i) Commands relating to updating S/W
- Update in-flight tables (on demand)
- Update sequences (on demand)

Section 9.2 lists the available commands, Section 9.3 contains a detailed description of each command, and command sequences are described in Section 10.

9.2 List of commands

A SWIM command consists of three bytes, sent on the synchronous serial line. No hardware or software handshake is used in communication between the DPU and the SWIM sensor. The data read out sent back from SWIM to the DPU is in RAW format without checksums. Therefore, no check/recover of data are performed for the DPU - SWIM communication.

Function	Param1	Param2	Command	Note
Direct commands				
Read status	xxxxxxxx	xxxxxxxx	00000001 (0x01)	Returns one status byte.
Start sample, Goto sample mode	xxxxxxx1	xxxxxxxx	10000101 (0x85)	If already in sampling mode this command will switch memory bank and continue sampling.
Stop sample, Goto idle mode	xxxxxxx0	xxxxxxxx	10000101 (0x85)	Going from sampling mode to idle.
Select memory bank	xxxxxxxn	xxxxxxxx	10000110 (0x86)	Used in idle mode. Automatic when sampling.
No operation (NOOP)	00000000	00000000	00000000 (0x00)	No operation command.
Control reg command				
Write control register	xxxxnnxx	xxxxxxxx	10000010 (0x82)	SEM pulse generator control and enabling of Fill RAM block status byte readout
RAM commands				
Set block size	xnnnnnnn	nnnnnnnn	10011001 (0x99)	Set size for RAM block operations. Default value is 4kb.
Set address counter	xnnnnnnn	nnnnnnnn	10011011 (0x9B)	
Read address counter	xxxxxxxx	xxxxxxxx	00011011 (0x1B)	Returns two bytes.
Write single RAM pos.	xxxxxxxx	nnnnnnnn	10011010 (0x9A)	Auto increments address counter.
Fill RAM block	xxxxxxxx	nnnnnnnn	10011100 (0x9C)	Fill block of RAM with param2. Can return status byte when finished.
Read RAM block	xxxxxxxx	xxxxxxxx	00011100 (0x1C)	Returns a block of data. Clears the RAM positions it reads.
HVPS commands				
HVPS osc on	xxxxxxx1	10100101	10001111 (0x8F)	Switch oscillator to HVPS on
HVPS osc off	xxxxxxx0	10100101	10001111 (0x8F)	Switch oscillator to HVPS off
Set Main ref.	xxxxxxxx	nnnnnnnn	10001000 (0x88)	Set directly in idle mode. In sampling: set when new period starts. Different use in SEM.
Set CEM ref.	xxxxxxxx	nnnnnnnn	10001001 (0x89)	Set directly in idle mode. In sampling: set when new period starts.
Set Upper Deflection ref.	xxxxnnnn	nnnnnnnn	10001010 (0x8A)	Set directly in idle mode. In sampling: set when new period starts.
Set Lower Deflection ref.	xxxxnnnn	nnnnnnnn	10001011 (0x8B)	Set directly in idle mode. In sampling: set when new period starts.

Function	Param1	Param2	Command	Note
Set analyzer ref.	xxxxnnnn	nnnnnnnn	10001100 (0x8C)	Set directly in idle mode. In sampling: Set when new period starts.
Set CELL ref.	xxxxxxxx	nnnnnnnn	10001101 (0x8D)	Set directly in idle mode. In sampling: set when new period starts.
Read Main monitor	xxxxx000	xxxxxxxx	00001000 (0x08)	Returns two bytes. 12 bit value.
Read CEM monitor	xxxxx001	xxxxxxxx	00001000	Returns two bytes. 12 bit value.
Read Upper Deflection monitor	xxxxx010	xxxxxxxx	00001000	Returns two bytes. 12 bit value.
Read Lower Deflection monitor	xxxxx011	xxxxxxxx	00001000	Returns two bytes. 12 bit value.
Read Analyzer monitor	xxxxx100	xxxxxxxx	00001000	Returns two bytes. 12 bit value.
Read CELL monitor	xxxxx101	xxxxxxxx	00001000	Returns two bytes. 12 bit value.
Read temperature	xxxxx110	xxxxxxxx	00001000	Returns two bytes. 12 bit value.
TDC commands				
TDC latch up logic on	xxxxxxx1	xxxxxxxx	10010001 (0x91)	
TDC latch up logic off	xxxxxxx0	xxxxxxxx	10010001 (0x91)	
TDC power on	xxxxxxx1	xxxxxxxx	10010010 (0x92)	
TDC power off	xxxxxxx0	xxxxxxxx	10010010 (0x92)	
TDC write	xxxxaaaa	dddddddd	10010100 (0x94)	a + d = TDC address and data.
TDC read	xxxxaaaa	xxxxxxxx	00010100 (0x14)	a = TDC address. Returns a byte.
Set readout mask offset	xxxxnnnn	xxxxxxxx	10010011 (0x93)	8bit window msb offset
				Updated: 2006-09-04

Table 1 List of commands

x= not significant, n= values, a=address, d= data

9.3 Command descriptions

Syntax:

xxxxxxxx yyyyyyyy zzzzzzzz

with the following organisation:

	Byte 0 (Param1)								**Byte 1 (Param2)**								**Byte 2 (Command)**							
Bit	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Value	x	x	x	x	x	x	x	x	y	y	y	y	y	y	y	y	z	z	z	z	z	z	z	z

9.3.1 Read status

xxxxxxxx xxxxxxxx 00000001

Read one byte with sensor status. Can be used as a test command to verify that the sensor is responding. The bits in the status byte are as follows:

0 not used
1 mode: 0=idle, 1=sampling
2 selected memory bank
3 HVPS oscillator status: 0=disabled, 1=enabled
4 TDC latch up status: 0=TDC working, 1=TDC shut down (latch up protection enabled)
5 TDC latch up protection setting: 0=disabled, 1=enabled
6 TDC power status: 0=off, 1=on
7 not used

9.3.2 Start/stop sample and change mode

xxxxxxx**n** xxxxxxxx 10000101

This command is used for changing mode between idle and sample, but also for changing memory bank etc in sampling mode, n=0 is idle, and n=1 is sampling mode. When executed in sampling mode it switches memory bank, updates the HVPS references already uploaded and updates the readout mask offset.

9.3.3 Select memory bank

xxxxxxx**n** xxxxxxxx 10000110

Used in idle mode, to select which of the two RAM banks to read or write. n=0 for RAM bank 0 and n=1 for RAM bank 1. Not used in sampling mode.

9.3.4 No operation

00000000 00000000 00000000

No operation command. Does not change the state of the sensor, does not return any values.

9.3.5 Write control register

xxxxnnxx xxxxxxxx 10000010

Bit 2 defines if the sensor shall provide the status byte upon completion of Fill RAM block; 0=off, 1=on.
Bit 3 defines if the SEM pulse generator shall be switched on or off; 0=off, 1=on

9.3.6 Set block size

xnnnnnnn nnnnnnnn 10011001

Sets the block size to be used for RAM block operations. Default size is 4kb. It can only be changed in idle mode.

9.3.7 Set Address counter

xnnnnnnn nnnnnnnn 10011011

Each RAM bank has its own address counter. This command sets the counter of the current RAM bank. Since the first eight addresses contain counters, the first address that can be used for writing and reading of RAM content is 0x0008.

9.3.8 Read address counter

xxxxxxxx xxxxxxxx 00011011

Reads out two bytes with the current address in the address counter.

9.3.9 Write single RAM position

xxxxxxxx nnnnnnnn 10011010

Write a byte to the address that is selected by the address counter. Auto increments the address counter. Note that the first eight addresses contain counters and can’t be used for write/read.

9.3.10 Read RAM block

xxxxxxxx xxxxxxxx 00011100

This command is used for reading out a block of data, i.e. sampled data. The size is set by the block size command, and the first address read is the current address in the address counter. Clears the content of every cell which is read so that no extra clear is needed before next sample period.
Do not send other readout commands while this command is running. Note that address 0-7 contains counters.

9.3.11 Fill RAM block

xxxxxxxx nnnnnnnn 10011011

Fill a block of RAM with value nnnnnnnn. Starts from current address in address counter. Block size defined by block size command. This command takes some time to execute. It is possible to get a handshake byte back when it is ready. To enable this feature you must set one bit in the control register.
Known bug: On the SEM model the filled block sometimes is equal to selected block size and sometimes block size minus one byte.

9.4 Enable/Disable fill RAM block handshake

00000**n**00 xxxxxxxx 10000010

If n=1 the sensor will, following a complete upload of a RAM block, respond by sending the status byte. If n=0 the sensor will not respond.

9.4.1 Switch HVPS oscillator on/off

xxxxxxxn 10100101 10001111

Bit n controls the oscillator. n=1 sets HVPS oscilattor on and n=0 sets HVPS oscillator to off . When set to off, no high voltage will be generated. Default state at power on is off.

9.4.2 Set HV references

The commands for setting HV references works differently depending on which mode the sensor is running in. In idle mode the references are set in real-time when the command is executed, but in sampling mode the references are stored in local registers and are updated when a new sampling period starts.
There are six references in total. Three with 8 b resolution and three with 12 bit.

Set main ref.	xxxxxxxx	**nnnnnnnn**	10001000 (0x88)
Set CEM ref.	xxxxxxxx	**nnnnnnnn**	10001001 (0x89)
Set upper deflection ref.	xxxx**nnnn**	**nnnnnnnn**	10001010 (0x8A)
Set lower deflection ref.	xxxx**nnnn**	**nnnnnnnn**	10001011 (0x8B)
Set analyzer ref.	xxxx**nnnn**	**nnnnnnnn**	10001100 (0x8C)
Set CELL ref.	xxxxxxxx	**nnnnnnnn**	10001101 (0x8D)

Table 2 HV references

9.4.3 Configure SEM Pulse generator

SEM has a built in pulse generator which can be used for test purposes. The *set main ref* command (see Table 1) is in SEM used to configure the pulse generator (instead of HV programming as in FM). It produces start and stop pulse-pair frequencies and start-stop delays under command control. The pulses are connected to the TDC circuitry. All communications between TDC and Actel as well as the SWIM DPU soft- and hardware interface can be verified by running the generator,

To use the generator, perform the following steps:

- Initialise SWIM SEM model (Table 6)
- Initialise TDC (Table 15)
- Set readout mask offset to 8 (0x08 0x00 0x93)
- Start pulse generator (0x08 0x00 0x82)
- Set SWIM SEM in sample mode (Table 8)
- Change main HV reference to obtain different TOF data according to:

Main HV reference (8 bits)							
x	x	x	**r1**	**r0**	**t2**	**t1**	**t0**

x = not significant

r = start and stop pulse-pair repetition frequency
t = time between start and stop pulse

r1	r0	Stop counts
0	0	0x01E5
0	1	0x03CB
1	0	0x0796
1	1	0x0F2B

t2	t1	t0	Data
0	0	0	0xF7
0	0	1	0x86
0	1	0	0x46
0	1	1	0x26
1	0	0	0x16
1	0	1	0x06
1	1	0	0x06
1	1	1	0x06

Table 3 Pulse generator settings

Note that values can vary due to timing, temperature etc. Therefore it is important to re-send TDC init command which includes TDC calibration.

9.4.4 Read HV monitors

xxxxx**nnn** xxxxxxxx 00001000

HV monitors and one temperature can be read through the built in ADC. These commands return two bytes containing a 12-bit value. nnn selects which channel to read. The AD conversion, which is started by the command, takes some time,. Because of this no commands can be sent without a delay period of 28µs after executing a read-out command. Due to the time it consumes it is probably best to not read all the channels at the same time.

Read main monitor.	xxxxx000	xxxxxxxx	00001000 (0x 08)
Read CEM monitor.	xxxxx001	xxxxxxxx	00001000
Read upper deflection monitor.	xxxxx010	xxxxxxxx	00001000
Read lower deflection monitor.	xxxxx011	xxxxxxxx	00001000
Read analyzer monitor.	xxxxx100	xxxxxxxx	00001000
Read CELL monitor.	xxxxx101	xxxxxxxx	00001000
Read temperature.	xxxxx110	xxxxxxxx	00001000

Table 4 HV Monitors

The **SEM** model has no ADC so the references are read out as monitors.

9.4.5 Switch TDC power on/off

xxxxxxx**n** xxxxxxxx 10010010

The Time to Digital Converter (TDC) circuit is off by default. It is turned on with this command with n=1 and off with n=0. There is a delay of 8 s needed between that TDC power has been switched on until communications with the TDC can start.

9.4.6 Enable TDC latch up logic

xxxxxxx**n** xxxxxxxx 10010001

There is a circuit that turns off the TDC if it starts to consume too much current. The function is disabled by default. It therefore needs to be enabled by command after TDC power on.

9.4.7 Write to TDC

xxxx**aaaa dddddddd** 10010100

Writes one byte (dddddddd) to address (aaaa) of the TDC circuits. Used for setup and initialisation of the circuit.

9.4.8 Read from TDC

xxxx**aaaa** xxxxxxxx 00010100

Read one byte (xxxxxxxx) from TDC address (aaaa).

9.4.9 Set readout mask offset

xxxx**nnnn** xxxxxxxx 10010011
n = Mask offset.

The TOF value read out from the TDC is 16 bits wide. This 16bit value is in the sensor converted to an 8 bit value by a moving mask. When calculating the real TOF-time, the 8bit value needs to be shifted back to its correct position. The uploaded mask is stored in a local register in the sensor and is changed when a new sample period starts.

Mask offset	Bits which are read out of the 16 bit TDC word (bit 15 = msb, bit 0 = lsb)
0x8	15 to 8
0x7	14 to 7
0x6	13 to 6
0x5	12 to 5
0x4	11 to 4
0x3	10 to 3
0x2	9 to 2
0x1	8 to 1
0x0	7 to 0

Table 5 Mask offset

9.4.9.1 Example of masking

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TDC 16b value	0	0	0	0	0	1	1	0	0	1	1	1	1	0	1	0
Mask with offset 4					1	1	1	1	1	1	1	1				
Resulting 8b value with offset 4					0	1	1	0	0	1	1	1				
Mask with offset 3						1	1	1	1	1	1	1	1			
Resulting 8b value with offset 3						1	1	0	0	1	1	1	1			

The mask value is always 0xFF

9.4.10 Valid results and Over- and Undercounts

The results are after masking stored in sensor RAM as 8b TOF data. Valid results are:

- masked data which have any number of bits set but without any bits set in the 16 b word above the mask
- masked data which have any number of bits set but without any data in less significant bits than the mask

Masked data which have bits set at higher significance than the mask are not stored in RAM but the event will increment the Overcount counter. Masked data which have all zeroes, no bits set at higher significance than the mask and with bits set at lower significance than the mask are not stored in RAM but the event will increment the Undercount counter.

9.4.10.1 Example of Overcount

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TDC 16b value	0	0	1	0	0	1	1	0	0	1	1	1	1	0	1	0
Mask with offset 4					1	1	1	1	1	1	1	1				
Resulting 8b value with offset 4					0	1	1	0	0	1	1	1				

This result is not valid since one bit with higher significance than the mask is set. It will not be stored in memory but the Overcounter will be incremented by one.

9.4.10.2 Example of Undercount

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TDC 16b value	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0
Mask with offset 7		1	1	1	1	1	1	1	1							
Resulting 8b value with offset 7		0	0	0	0	0	0	0	0							

This result is zero and not valid since only bits with lower significance than the mask is set. It will not be stored in memory but the Undercounter will be incremented by one.

10 DPU CONTROL OF SENSOR

10.1 Normal commanding sequences

Commands that are part of a sequence may be sent without time delay in between with the **exception of readout commands and between SWIM power on and TDC initialization. For the latter a delay period of 8s must be implemented.** After sending a readout command the data must be read back completely before the next command can be sent or the command sequence must be aborted. For detailed explanation of the commands used see Sections 9.2 and 9.3.

All sequences must be reprogrammable on demand. No regular updating is foreseen. The specific commands given in the tables are examples and subject to change, although they may be used for test purposes.

10.2 SWIM initialization

No	Item	Example of command (hex)	Remark/Response
1	Turn on +5V		
2	Turn on +/-12V		
3	Wait 8 sec		
4	Setup TDC circuit:	(several)	Requires several commands. See Section 10.9
5	Set Main HVPS reference to 0	0x00 0x00 0x88	
6	Set HVPS Analyzer ref. to 0.	0x00 0x00 0x8C	
7	Set HVPS Upper Defl. ref. to 0	0x00 0x00 0x8A	
8	Set HVPS Lower Defl. ref. to 0	0x00 0x00 0x8B	
9	Set CELL ref. to 0	0x00 0x00 0x8D	
10	Set CEM ref. to 0	0x00 0x00 0x89	
11	No operation	0x00 0x00 0x00	For SWIM SEM this command is replaced with a *write control register* command. See table below.
12	Turn on HVPS oscillator	0x01 0xA5 0x8F	
13	Set HVPS main reference (ramp up to selected default value)	(several)	Requires several commands. See sections 10.10 and 10.11
14	Set HVPS CELL reference (ramp up to selected default value)	(several)	Requires several commands. See sections 10.10 and 10.11
15	Set HVPS CEM reference (ramp up to selected default value)	(several)	Requires several commands. See sections 10.10 and 10.11

Table 6 Initialisation sequence for FM

SWIM SEM has a slightly different initialization sequence due to the need to switch on the pulse-generator simulating sensor data. The differences to the FM initialization sequence are shown in **bold.**

No	Item	Example of command (hex)	Remark/Response
1	Turn on +5V		
2	Turn on +/-12V		
3	Wait 8 sec		
4	Setup TDC circuit:	(several)	Requires several commands. See Section 10.9
5	Set Main HVPS reference to 0	0x00 0x00 0x88	
6	Set HVPS Analyzer ref. to 0.	0x00 0x00 0x8C	
7	Set HVPS Upper Defl. ref. to 0	0x00 0x00 0x8A	
8	Set HVPS Lower Defl. ref. to 0	0x00 0x00 0x8B	
9	Set CELL ref. to 0	0x00 0x00 0x8D	
10	Set CEM ref. to 0	0x00 0x00 0x89	
11	**Enable pulse generator**	**0x04 0x00 0x82**	
12	Turn on HVPS oscillator	0x01 0xA5 0x8F	
13	**Set HVPS main reference (ramp up to 0x0A)** (note 1)	**(several)**	**Requires several commands. See sections 10.10 and 10.11**
14	Set HVPS CELL reference (ramp up to predefined value)	(several)	Requires several commands. See sections 10.10 and 10.11
15	Set HVPS CEM reference (ramp up to predefined value)	(several)	Requires several commands. See sections 10.10 and 10.11

Table 7 Initialisation sequence for SEM.

Note 1: Other values for the reference than 0x0A may be taken to get other timing. See chapter 9.4.3 for other possible values.

10.3 Sampling (measurement cycle)

Every 31.25 ms (i.e. for every slot) the DPU shall perform the following:

No	Item	Example of command (hex)	Remark/Response
1	Start sampling	0x01 0x00 0x85	The sensor switches RAM bank automatically, updates HVPS with references updated during previous sampling period and continues the sampling.
2	Upload next readout mask.	0x0n 0x00 0x93	
3	Command slot for insertion of any command received by TC (note 1)	0xnn 0xnn 0xnn	Default value is the *No operation* command, but shall be replaced for one slot by a command received by TC.
4	Upload next analyzer voltage	0x0n 0xnn 0x8C	0xnn depends on energy step and viewing direction
5	Upload next upper deflection voltage	0x0n 0xnn 0x8A	
6	Upload next lower deflection voltage	0x0n 0xnn 0x8B	
7	HK request command	0x0n 0x00 0x08	Request one of 7 monitor values. **Wait until 2 Bytes response are received (or alternatively wait for 200us) before continuing with the command sequence.**
8	Set address counter to 0	0x00 0x00 0x9B	
9	Send Read out block command	0x00 0x00 0x1C	Receives a block of data. Size is default or set by command at init. The addresses read out are cleared automatically. **Do not send further commands until all data has been received.** See Section 9.3.10

Table 8 Sampling sequence

Note 1: Direct commands received by TC will be sent during this step to the sensor while in sampling mode. For convenience a *No operation* command may be sent if no direct command by TC is pending to keep the length of the sequence constant. Direct commands by TC will be used e.g. during commissioning or for trouble shooting.

10.4 TDC calibration at end of sampling cycle

10.4.1 TDC calibration

Once every measure cycle (every 8 second), a calibration measurement and calibration calculation must be run in order to compensate for temperature and supply voltage changes. Every 8 second, the DPU must set the SWIM sensor to idle mode, calibrate the TDC. The sensor will be set to sampling mode again by the next sampling sequence (Table 8). Note that the TDC-calibration command is also part of the Init sequence (Table 6, Step 3 and Section 10.9). In order not to introduce an offset to the 8 second cycle, TDC calibration is performed in the last slot (slot nr 255) of every 8 sec cycle. No science data is taken during this slot.

Nr	Item	Example of command (hex)	Remark/Response
1	Stop sampling, goto idle mode	0x00 0x00 0x85	
2	Disable TDC hit	0x07 0x00 0x94	
3	Calibrate TDC	0x00 0xc0 0x94	TDC setup, auto cal + calibrate
4	Enable TDC hit	0x07 0x01 0x94	

Table 9 TDC calibration sequence

10.4.2 Command sequence at end of sample cycle

The following table shows the commands that must be sent at the end of the sampling sequence for TDC calibration. The scheme also provides a slot for extended data processing with no sensor data to be received during slot 255. Read the table columns from top to bottom to get the command sequence:

Slot:	**251**	**252**	**253**	**254**	**255**	**0***	**1**	**2**
TDC calibration: *Steps 1 to 4 of TDC calibration sequence*	-	-	-	-	HERE	-	-	-
Commanding to start a measurement (will use settings for indicated slot). *This is step 1 of sampling sequence:*	251	252	253	-	-	0	1	2
Commanding of new voltages for slot: *This are steps 2 to 6 of the sampling sequence.*	252	253	254*5	-	0***	1	2	3
Housekeeping request:**** *Step 7 of sampling sequence*	yes	yes	yes	yes	-	-	yes	yes
Readout and processing of data from slot**: *This are steps 8 and 9 of sampling sequence:*	250	251	252	253	-	-	0	1
Compression & TM formatting:	-	-	-	-	HERE	-	-	-
Data volume received, N = Blocksize	N + 2	N + 2	N + 2	N + 2	0	0	N + 2	N + 2

Table 10 Command sequence at end of 8s cycle

*	Sync pulse is assumed to happen at the beginning of slot 0.
**	this assumes you can receive and process the data received in a slot in the same slot.
***	Settings for slot 0 must be programmed to the sensor here, otherwise no data can be taken during slot 0.
****	This is a recommendation only: The housekeeping request is only made if subsequently science data is read out. By only sending a HK request in this case the number of bytes received in one slot is either blocksize +2 or 0.
*5	Programming in this slot is optional, it may be kept to have slot 253 identical to slot 252.

Note that TDC calibration step 3 only takes about 4 micro seconds to execute on the sensor which is less than the time needed to send the next command.

10.5 Normal switch off sequence

Nr	Item	Example of command (hex)	Remark/Response
1	Stop sampling, goto idle mode	0x00 0x00 0x85	
2	Set HVPS main reference to zero (ramp down from current value).	(several)	Requires several commands. See sections 10.10 and 10.11.
3	Switch off +5V, +12V, -12V		

Table 11 Normal switch off sequence

10.6 Emergency switch off sequence

Emergency shutdown is used upon booting of the DPU after a Watchdog reset or a reset caused by the S/C.

Nr	Item	Example of command (hex)	Remark/Response
1	Switch off +5V, +12V, -12V		*No HV ramping takes place*

Table 12 Emergency switch off sequence

10.7 Sensor health checks

Nr	Item	Example of command (hex)	Remark/Response
1	Stop sampling, goto idle mode	0x00 0x00 0x85	
2	Set Block Size	0x10 0x00 0x99	
3	Select memory bank 0	0x00 0x00 0x86	
4	Set address counter to 0	0x00 0x00 0x9B	
5	Fill ram with testpattern	0x00 0xnn 0x9C	The value of 0xnn is is either 0xAA or 0x55. Both values should be used on a rotating basis
6	Set address counter to 0	0x00 0x00 0x9B	
7	Readout memory	0x00 0x00 0x1C	Wait until complete data block is received. See Section 10.12 for layout of data block.
8	Compare with test pattern (count unequal bytes)		If equal: ok continue with 8 If not equal: repeat step 5 to 7. If error is persistent after 3 repetitions report count of unequal bytes in HK and continue with step 9 *Note: Address 0-7 is not writable (contains counters)*
9	Select memory bank 1	0x01 0x00 0x86	
10	Fill ram with test pattern	0x00 0xnn 0x9C	
11	Set address counter to 0	0x00 0x00 0x9B	
12	Readout memory	0x00 0x00 0x1C	Wait until complete data

Nr	Item	Example of command (hex)	Remark/Response
			block is received. See Section 10.12 for layout of memory readout.
13	Compare with test pattern(count unequal bytes)		If equal: ok, continue with 12 If not equal: repeat steps 9 to 11. If error persistent after 3 repetitions report count of unequal bytes in HK and continue with step 12
14	Report result in HK		

Table 13 Memory test sequence

10.8 HVPS test

The HVPS test will turn on high voltages. Depending on the values programmed for the high voltages, it **must not be run while not in vacuum. HVPS test will not be run periodically, only on command will the HVPS test be run.**

Nr	Item	Example of command (hex)	Remark/Response
1	Stop sampling, goto idle mode	0x00 0x00 0x85	
4	Set main HVPS reference to 0	0x00 0x00 0x88	
5	Turn HVPS oscillator on.	0x01 0xA5 0x8F	
6	Set HVPS main (ramp up to selected default value).	(several)	Require several commands. see Section 10.10
7	Set HVPS CELL reference (ramp up to selected default value).	0x00 0xnn 0x8D	Require several commands. See section 10.10
8	Set HVPS CEM reference (ramp up to selected default value).	0x00 0xnn 0x89	Require several commands. See section 10.10
9	Set HVPS analyzer reference.	0x00 0xnn 0x8C	
10	Set HVPS upper deflection ref.	0x00 0xnn 0x8A	
11	Set HVPS lower deflection ref.	0x00 0xnn 0x8B	
12	Read main monitor.	0x00 0x00 0x08	Returns 2 bytes
13	Read CEM monitor.	0x01 0x00 0x08	Returns 2 bytes
14	Read upper deflection monitor.	0x02 0x00 0x08	Returns 2 bytes
15	Read lower deflection monitor.	0x03 0x00 0x08	Returns 2 bytes
16	Read analyzer monitor.	0x04 0x00 0x08	Returns 2 bytes
17	Read CELL monitor.	0x05 0x00 0x08	Returns 2 bytes
18	Compare monitors with programmed reference values		
19	Set HVPS main to 0 (ramp down).	(several)	Require several commands. see Section 10.10
20	Turn HVPS oscillator off.	0x00 0xA5 0x8F	

Table 14 HVPS test sequence

10.9 Init TDC

This sequence initializes the TDC to operating mode.

Nr	Item	Example of command (hex)	Remark/Response
1	Select idle mode	0x00 0x00 0x85	
2	Set block size	0x10 0x00 0x99	
3	TDC power on	0x01 0x00 0x92	Wait >200ms after this command. (No TDC commands while TDC-power is unstable.)
4	TDC latch up protection.	0x01 0x00 0x91	
5	TDC setup, hit disable	0x07 0x00 0x94	
6	TDC setup, clock divider. 5MHz reference clock to TDC	0x04 0x60 0x94	
7	TDC setup, init ALU + TDC	0x0b 0x03 0x94	
8	TDC setup, auto cal + calibrate	0x00 0xc0 0x94	Calibrations versus temperature and supply voltage variations
9	TDC setup, one start / one stop	0x02 0x01 0x94	
10	TDC setup, retrigger on, int= ALU rdy	0x06 0x20 0x94	
11	TDC setup,hit enable	0x07 0x01 0x94	

Table 15 TDC initialization sequence

10.10 High voltage ramping

Main high voltage, CEM high voltage and CELL high voltage should be ramped up or down when changing to new values. When ramping the high voltage references, the step values should not exceed 50 decimal. Also the delay between high voltage stepping commands should be at least 1s.

There must be (by TC modifiable) default values for each of these 3 voltages. These default values will be used by the initialization sequence. Until commissioning, these default values are 0x00.

Do only ramp high voltage while in vacuum conditions. Failure to do so can cause loss of sensor.

No	Item	Example of command (hex)	Remark/Response
1	Turn HVPS oscillator on	0x01 0x01 0x8F	The sensor switches RAM bank automatically, updates HVPS with references updated during previous sampling period and continues the sampling.
2	Upload next voltage ref.	0x0n 0xnn 0x8x	0xnn depends on energy step. 0x8x depends on which voltage is to be ramped.
3	HK request command	0x0n 0x00 0x08	Request one of 7 monitor values. **Wait until 2 Bytes response are received (or alternatively wait for 200us) before continuing with the command sequence.**
4	Wait for 1s.		The stepping period, τ, is 1s.
-	Repeat from 2 until specified reference value is reached.		

10.11 High voltage confirmation

Confirmation is required to allow ±12 V on HV ‘switch on’.

TC sent to the DPU that will result in sending a ‘HVPS osc on’ command to the sensor, require a HV confirmation TC sent immediately before to the DPU. This applies to:

a) Sensor Initialization Sequence (see Section 10.2)
b) HVPS test sequence (see Table 14)
c) Direct TC containing a HVPS osc on command for SWIM (Section 9.1, Item b)

The HV confirmation TC must contain a reference to the TC that will turn on the HVPS osc. A valid TC sequence for the DPU is:

Nr.	TC	Remarks
1	HV confirmation for HVPS test sequence	
2	Execute HVPS test sequence	Valid

Table 16 Valid HV confirmation example

The following example TC sequences for the DPU **must** result in an error at the HV command and **must not** be executed.

Nr.	TC sent to DPU	Remarks
1	HV confirmation for HVPS test sequence	
2	any other TC	
3	Execute HVPS test sequence	Invalid. TC inbetween.
1	HV confirmation for Direct HVPS osc on command	
2	Execute HVPS test sequence	Invalid. Wrong reference in HV confirmation.
1	Execute HVPS test sequence	Invalid. No prior HV confirmation TC has been sent.

Table 17 Invalid HV confirmation examples

10.12 Memory map

Ram read out commands (Section 9.3.10) sent to the sensor will dump one of the memory banks in the sensor. The memory map which is identical for both memory banks is shown in Table 18.

Address (hex)	Content
0x0000	Start counter MSB
0x0001	Start counter LSB
0x0002	Stop counter MSB
0x0003	Stop counter LSB
0x0004	Over counter MSB
0x0005	Over counter LSB
0x0006	Under counter MSB
0x0007	Under counter LSB
0x0008	8bit TOF-data
0x0009	8bit TOF-data
…	…
0x1000	8bit TOF-data (or padding with 0x00 if there were not enough TOF-data bytes recorded)

Table 18 Memory map

The start address of the memory dump initiated by a read-out command, is set by the address counter (usually set to 0) and the number of bytes sent by the value programmed by the 'set block size' command.

11 DATA HANDLING AND REDUCTION OF DATA FROM SENSOR

The SWIM sensor records the time-of-flight (TOF) of each valid (START - STOP) event and with a TOF window of 1 μs it can produce an event rate up to 300 KHz. However, such large amounts of data are not desirable to transfer to the DPU and the geometric factor is tuned to avoid such high data rates for realistic conditions. The largest expected data generation rate (the incoming flux (10^9 cm^{-2} s^{-1} sr^{-1} at 1 keV) for the measurement situation is expected to be 200 kHz. The measured TOF values are stored in a RAM bank of suitable size so that the contents can be transferred to the DPU during less than one slot of 31.25 ms, i.e. 4 kbyte for 2 Mbit/s communication speed between the DPU and SWIM. The memory bank contain four 16 bit words containing total start pulse counts, total stop pulse counts, and two control counters as defined in section 10.12.

The collected data are first stored in one of two RAM banks in SWIM (A and B). Data is stored in one RAM bank at the same time as the other RAM bank is read out by the DPU..

The TOF circuit generates a 32 bit TOF value. The 16 most significant bits are discarded without losses.. A sliding 8 bit window is applied to the remaining 16 bits. This window depends on the energy of the measured particles. Higher energy particles will have a shorter TOF and will thus produce TOF values in a lower bit-range of the original 16 bit word. Thus one further value has to be transferred to SWIM for each energy level; the bit-mask which is applied to the 16 bits of data.

Note. A simple analyses shows that for a fixed energy the TOF range for masses from 1 to 56 amu will be from T_0 to sqrt (56)*T_0. If 256 bits are used for TOF, the obtained accuracy will be T_0*(sqrt (56)-1)/256. Since all ions are postaccelerated up to 500 eV, the shortest T_0 corresponds to 500 eV protons. Therefore, the worst case accuracy will be around 1.4 nsec/bit. Because of the sliding window technique, a better accuracy than this can be obtained for the lowest TOF values.

12 DPU DATA HANDLING REQUIREMENTS

12.1 Overview of processing and reduction of data

The DPU receives a number of TOF values from SWIM during each measurement cycle. The energy and angle of arrival is set by the DPU for each cycle and are therefore known. Ions of the same mass will have different TOF depending on their energy. Therefore the DPU will sort the measured TOF into different mass bins depending on both the energy and the measured TOF of the ions. The relationship will come from the calibration of the instrument, and will be implemented through tables. In the first step the data is reduced to up to 32 mass bins (depending on binning parameter), which are defined from the known energy, post-acceleration and TOF. These can be further reduced to physical masses of the ion species resolved by the instrument. One basic SWIM measurement set consists of 1 to 32 mass bins for each of the 32 energy steps and 8 angles of arrival of the instrument. With a basic measurement time (or slot) of 31.25 ms, the duration of a complete cycle is 8 ssec.

Depending on the available telemetry, this is then further reduced by averaging over time, angle and mass. This is set by a telecommand, which sets the time binning (number of 8 s measurement cycles to bin), angle binning (number of angles resolved in final data) and finally mass binning (number of masses to transfer). Mass binning will either be energy corrected TOF bins (high mass resolution) or physical mass bins for a few selected ion species or range of species.

The reduced data sets are then further compressed by reduction to 8-bit hybrid floating point, and then further through loss-less Rice compression and stored in a buffer from which it is transferred to the spacecraft telemetry system. The buffer is needed to account for the variable success of the loss-less compression. It may be necessary to stop filling the buffer if it becomes full (i.e. more data is produced than can be transferred through telemetry also over an extended period). See also references RD2 and RD3 for more details.

12.2 Required tables

The following tables must be implemented in the DPU. They will be the results of the calibrations of the instrument. All in-flight tables must be rewritable on demand. No regular updating is foreseen during flight. Examples and layout of these tables is documented in RD8. A detailed description of the processing scheme using these tables is found in RD7.

12.2.1 Hardware related tables

E1: Energy step voltage setting, 32 index values. During calibration it is determined which voltage settings should be used in the energy sweep. During each slot the DPU sends one such value to SWIM to set the energy deflection value. The index values require 12 bits.

D1: Entrance deflection voltage setting, 32 x 8 x 2 index values. SWIM scans different angles of arrival through an electrostatic deflection entrance system. The desired setting for this high voltage depends on both angle of arrival (8 values) and measured energy (32 values). For each angle of arrival, two voltages must be set; for both the upper and the lower deflection plate. The index values require 12 bits.

B1: Bit-mask and bit-offset for time-of-flight range for different energies (32 values). Both are affected by post-acceleration settings and the table must allow for four different post-acceleration settings. Sent to SWIM, one energy step in advance of it’s use, to select which range of TOF values which will be stored and transferred to the DPU. Low energy (slow) ions do not need the least significant bits and high energy (fast) ions do not need the most significant bits of the TOF value.

12.2.2 Analysis related tables

M1: Mass table relating time-of-flight intervals to ion masses, start of time-of-flight and end time-of-flight value for each ion species. Because TM constraints sometimes allow only very few ions to be resolved, table M1 needs several rows, deciding which neighbouring ion species should be put in the same mass bin (i.e. progressively larger bins corresponding to many ion species). Transmitting 8, 4 and 2 ion mass ranges requires the following:
8 start + 8 stop values for a total of 8 mass ranges
Thus for all tables 2 x 8 + 2 x 4 +2 x2 = 22 values are needed. These will be used in calculations by the DPU and need to be in the format used for the calculations (at least 16 bit integer or float).

ETOF: The time of flight for a given ion mass varies with measured particle energy and post-acceleration. The time is proportional to the square-root of particle energy + post-acceleration (i.e. velocity of the particle). Thus a factor compensating the time-of-flight value for the energy and post-acceleration is needed. 32 energies and 4 post-acceleration settings requires 32 x 4 values in the format used for the calculations (at least 16 bit integers or float).

12.3 Health checks

Memory health check shall be performed periodically. The frequency shall be possible to reprogram, since some mission phase's call for more frequent health checks than others. See Section 10.7 for command sequences. For memory health check, science data taking is stopped for one 8 second interval, health check is performed, and science data taking is resumed in the next 8 sec interval.

Default interval for health checks (nominal operation) is once approximately every hour (every 4096 sec).

12.4 Housekeeping reporting

12.4.1 Obtaining Housekeeping from the sensor

The HK read-out will be performed once every slot (31.25 ms). To obtain good health check data, the periodicity by which it is read shall not coincide with a full measurement cycle (8 s). If 7 HK parameters are read in a continuous loop (one HK parameter readout in every 31.25ms slot, no gaps) this is automatically satisfied. As an exception, HK readout can be omitted during slots used for TDC calibration (e.g. slot 255).

Note that no further command must be sent after a HK (monitor) readout command until the 2 bytes HK response bytes are received or 200us have elapsed.

Prior to further processing, the following HK data related to SWIM are generated in the DPU:

– +12V current monitor (common for CENA and SWIM)
– +5V, -12V, +12V voltage monitors

12.4.2 Housekeeping reporting during commissioning

During commissioning a high bandwidth housekeeping scheme is used. During SWIM commissioning this bandwidth is exclusively given to SWIM sensor. A list with SWIM HK parameters is shown in Table 19.

58 Bytes can be transferred in each 4 sec cycle split into 2 requests of 29 Bytes every 2 sec. As 29 Bytes is sufficient to represent SWIM HK in commissioning mode, the reporting interval for all data is 2 sec. See also RD5 for a detailed description of the packet layout and RD6 of how to convert raw data to physical units.

Name	**Description**	**Size in Bytes (Bits)**
HK0	Main HV voltage	2 (12)
HK1	CCEM voltage	2 (12)
HK2	Upper deflector voltage	2 (12)
HK3	Lower deflector voltage	2 (12)
HK4	Analyzer voltage	2 (12)
HK5	TOF cell voltage	2 (12)
HK6	TOF board temperature	2 (12)
HK7	+12V current	1 (8)
HK8	+5V voltage	1 (8)
HK9	-12V voltage	1 (8)
HK10	+12V voltage	1 (8)
HK11	SWIM status bits; either the full byte or only B6..B3 of response to a "read status"-command to sensor may be reported.	1 (8 or 4)

Table 19 SWIM HK values

12.4.3 Housekeeping reporting during nominal operations

Because of the sharing of HK bandwidth between SWIM and CENA, the following explanation covers both sensors. For more details about the terminology used for CENA see CENA SICD RD4. Detailed layout of the packet stream is shown in RD5, its decoding and conversion to physical units in RD6.

All available HK data values of both sensors are then concatenated to a list as shown below.

Description		Source of data	Size [Bytes]
CENA HK data			
	Values from subcommutated HK data stream	Values DV1 to DV119 from Table 19 in [RD4]	119
SWIM HK data			
	Current SWIM HK data	HK0 ..HK6 and HK11 of SWIM HK parameters (12 bit wide, in packed form) as described in Table 19.	11
DPU HK			
	Currents and voltages measured by DPU related HK	5 voltages, 2 currents,.	7
	DPU HK	Flags	2
Total			136 (*)

Table 20 Combined SAS HK list

(*) this is without header bytes.

136 Bytes are divided in 4 packets, 34 Bytes each without header. One packet is transmitted every 32 sec resulting in a reporting frequency for all individual HK values of 128 sec.

12.5 Required system variables

These variables can be set by TC, but default values must exist. Default values should be changeable by TC:

- Post-acceleration voltage setting (index value, default TBD)
- Default values for Main, CELL and CEM voltages (Default is 0, value will be updated after calibration and after commissioning)
- Number of ion masses to resolve (default 8)
- Number of angles of arrival to resolve (default 8)
- Number of 8 second cycles to bin (default 1)

12.6 Output Variables

The basic result is an array with counts (successfully detected particles) per energy, direction and mass interval, sampled during some amount of measurement cycles. To interpret this on the ground the settings of the systems variables above must be known. Current values of system variables should be sent in telemetry because it is safer to provide these measurements in a packet header with each measurement cycle. The time of the measurement must also be possible to deduce. The full layout of the header and the data is TBD. See also reference RD2.

12.7 Structure of DPU sampling sequence

12.7.1 Send sampling commands to SWIM

Details are given in Section 0. Set direction and energy (direction varying faster) and bit-offset for time-of-flight readings. Sampling is done for 31.25 ms, during which the sampled data from the previous sampling is transferred to the DPU.

12.7.2 Retrieve time-of flight values from SWIM

The following variables are used:

byte array TOF (fixed size): TOF values (8 bit) + some other values (stored in fixed elements of the array, described below), fixed size of 4 kb

integer ntof: amount of valid time-of-flight values in array. The full SWIM memory bank is always transferred into array TOF, but depending on the amount of detected particles the memory bank need not be filled completely. Unused memory positions needs to have value 0 in order to search for first occurrence of 0 in TOF. This will provide ntof..

12.7.3 Reduce time-of-flight values into mass values

(a) Use bit-offset (table B1) to create a 16 bit TOF value from the 8 bit value transferred from SWIM (i.e. if bit-offset is 3, shift three bits towards most significant bit).
(b) Compensate time-of-flight values for different energy of particles through use of table ETOF.
(c) Determine number of TOF values corresponding to each mass bin. Full (half) mass resolution means dividing into 32 (16) equidistant time-of-flight intervals with true mass-separation performed on ground. For all lower resolutions the program checks which corrected time-of-flight interval the measured time-of-flight value corresponds to (determined by table M1 and number of masses to resolve) and increases corresponding counter by 1. This number will be referred to as the count for each energy, direction and mass bin.

A detailed description of the processing scheme is found in RD7.

12.7.4 Binning in direction

Above steps (steps 12.7.1, 12.7.2 and12.7.3) are performed for the 8 different directions. Depending on number of directions to resolve, the counts for the current energy in each mass bin are binned into the desired number of directions.

12.7.5 Binning in time

Step through 12.7.1, 12.7.2, 12.7.3 and 12.7.4 for all different energies (32). If number of 8 sec measurement cycles to bin is larger than one, run through above sequence required amount of times.

The output result is now a 3 dimensional array, counts as function of direction, mass and energy. These are sent to further reduction by conversion to 8 bit hybrid floating point and then compressed by loss-less compression.

In summary, the SWIM instrument always produces 32 energies * 4 kb TOF values * 8 directions per full 8 sec measurement cycle (corresponding to 32 * 8 slots) no matter which mode it operates in (there is only one hardware instrument mode) or available telemetry rate. The above reductions are made to fit the available TM rate. If the true data array is sparse (little data) it is better to have little initial compression and leave most of the compression to the loss-less compression which will be very effective for sparse data arrays. This must be tested during commissioning and adjusted during the mission. Because of varying success for the loss-less compression the resulting data should be saved in a TM buffer memory before transfer to spacecraft TM system. If this memory threatens to overflow one must decide what to do (flush memory, skip new measurements until buffer below some threshold value or something similar).

12.7.6 Telemetry requirements

Raw Data from Sensor to DPU [Kbps]	TM Data [Kbps]
Limited by DPU capability; otherwise 4 Mbps	Due to limitations by the 1553 bus and OBDH system memory allocation, the DPU will adopt SAS (CENA+SWIM) data rate to 28 Kbps peak and 4 Kbps average over 12 hours.

Table 19 Data flow

Note that SWIM TM rate and binning mode (TM mode) are set independently, though burst TM mode with low TM rate will quickly fill the buffer memory. This system (used in ICA on Rosetta and in IMA on Mars Express) allows for in situ fine tuning of the TM mode for the available TM rate.

To each science data packet, 1 HK packet must be appended prior transmission to S/C. The science data part must also contain values of the binning parameters used as well as information about compression. See RD7 for more details.

Some examples of possible software telemetry modes (science modes) are shown below, with TM rate assuming 50% reduction from Rice compression :

TM mode	Time res [s]	No of arrival angles	No of masses	TM rate [bits/s]
Minimum	8	1	1	16
Monitor	16	1	8	64
Burst	8	8	16	2048
Full	8	8	32	4096

Table 20 Possible software telemetry modes

These modes can easily be changed with TM commands by changing the binning parameters.

12.8 Instrument modes

During normal science data taking the instrument is run in normal mode. In this mode the sensor is sweeping the high voltages and the obtained data is fully processed as described in Chapter 12.

In addition to the normal mode, a calibration mode, which transmits the memory content of the sensor without any binning into mass bins will be needed. The calibration mode will keep energy step and direction at fixed values. It will mainly be used during lab calibration, but may also be used during in space commissioning. In the latter case all data that cannot be transmitted due to TM constraints will be flushed. Calibration mode memory requirements will be the same as during nominal operation mode.

To optimize memory usage on the S/C an idle mode, is required. In idle mode the sensor operates normally (e.g. in sample mode) but only HK is reported to ground.

Mode	Sensor voltages are sweeping	DPU data processing (binning, etc.)	HK is reported to S/C	Science data is reported to S/C
Power off	No	Off	Off	Off
Idle mode	Yes and No acceptable	Off	Yes, low bandwidth	No
Nominal mode (science)	Yes	On, binning takes place	Yes, low bandwidth	Yes, binned data
Commissioning mode	Yes	On, binning takes place	Yes, high bandwidth	Yes, binned data
Non-process mode (Raw mode)	Yes	Off, raw data is used	Yes, high bandwidth	Yes, raw data
Calibration mode (this mode is optional)	No	Off, raw data is used	Yes, high bandwidth	Yes, raw data

Table 20 Summary of sensor modes

13 LIST OF ACRONYMS

CENA	Chandrayaan-1 Energetic Neutrals Analyzer
DPU	Central Processing Unit
DPU	Digital Processing Unit
EIU	Experiment Interface Unit
LSB	Least Significant Bit
MSB	Most Significant Bit
OBDH	On Board Data Handling system
PDU	Power Distribution Unit
SIU	Spacecraft Interface Unit
SWIM	Solar Wind Monitor
TBD	To Be Determined
TC	Telecommand
T/M	Telemetry
TOF	Time Of Flight
TDC	Time to Digital Converter