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CASSINI MISSION - HUYGENS PROBE

HASI Experiment

Flight and FLIGHT SPARE Models

User Manual

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DOCUMENT CHANGE RECORD

ISSUE	DATE	TOTAL PAGES	PAGES AFFECTED	DESCRIPTION OF MODIFICATION
DRAFT 1	21/11/95	98	ALL	First DRAFT Issue.
DRAFT 2	Jan 96	--	ALL	Second DRAFT issue provided to DASA for the integration of HASI FM (sect. 7 only + Figures 1 to 10).
DRAFT 3	26/06/96	188	ALL	Third DRAFT Issue provided at EFAR.
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ISSUE 1	29/08/96	241	ALL	ISSUE 1 provided to ESA and UPD.
ISSUE 2	18/12/96	---	17	ISSUE 2 provided to UPD and ESA for ESOC verification test **(sect. 10 only + first and second pages).**
ISSUE 3	01/12/98		ALL	Removed all the ‘Preliminary information’. Added section 8 and Annex 1. All the changed pages are marked with right Bar.

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1 INTRODUCTION

1.1 Scope

Scope of this document is to give practical information useful to whom will operate the Flight and Flight Spare models of the HASI experiment during Probe integration and once the experiment has been integrated on the Probe (AIV, Launch and Flight Operations). Some FS model information are available in the relevant sub-system Acceptance Data Packages (i.e. ACC, STUB, DBS and DPU FS model). However for completeness all the FS model information are marked **as per ADP**.

In order to be a self standing document addressed to prepare the personnel to operate with the HASI Experiment, a description of the HASI Experiment functioning and internal/external interfaces is reported together with practical details and guidelines to handle, prepare for integration and integrate the HASI Experiment into the HUYGENS Probe system.

In the chapter dedicated to the HASI software a description of all the functions of the installed software is reported while a chapter is dedicated to software maintenance procedures (e.g. to load software patching).

1.2 Documents

The following documents form part of, or must be read in conjunction with this manual. The relevant issues and revisions shall be these in effect on the emission of this document.

1.2.1 Applicable Documents

AD(1)	HUYGENS EID part Issue 1 Rev. 5 - May 96	
AD(2)	HASI Experiment EID part B Issue 2 - March 95	
AD(3)	HASI Experiment IDS Issue 3 - May 96	
AD(4)	HUYGENS EID part C	
AD(5)	HASI-SP-OG-004 Issue 7 Oct. 95	HASI Software User Requirements Document
AD(6)	PY-HASI-UKC-AD-004	ACC FS Acceptance Data Package
AD(7)	SO/97-243/RG/SV	DBS FS Acceptance Data Package
AD(8)	HASI-ADP-FS-UPD-001	STUB FS Acceptance Data Package
AD(9)	HASI-PWA-FS-DOC	PWA-D FS Acceptance Data Package
AD(10)	HASI-FMI-FSM-DOC-009 Iss. 1 + Addendum	PPI FS Acceptance Data Package
AD(11)	PWA-DP-1136-02-CRS	PWA-A FS Acceptance Data Package
AD(12)	HASI/PWA-ADP-LPCE-300 Iss. 1	HASI-I FS Acceptance Data Package
AD(13)	HASI-LB-OG-007	HASI DPU FS Acceptance Data Package

1.2.2 Reference Documents

RD(1)	PY-HASI-UKC-AD-003	ACC FM Acceptance Data Package
RD(2)	SO/95-3999/RG/SV	DBS FM Acceptance Data Package
RD(3)	HASI-ADP-FM-UPD-001	STUB FM Acceptance Data Package
RD(4)	HASI-PWA-FM-DOC-001 Iss. 1	PWA-D FM Acceptance Data Package
RD(5)	HASI-FMI-DOC-009 Iss. 1 + Addendum	PPI FM Acceptance Data Package
RD(6)	HASI-PWA-FM-DOC-014 Iss. 1	PWA-A FM Acceptance Data Package
RD(7)	HASI/PWA-ADP-LPCE-200 Iss. 1	HASI-I FM Acceptance Data Package
RD(8)	-----	RAE FM Acceptance Data Package
RD(9)	HASI-AN-OG-001 Iss. 5 June 96	HASI FMECA
RD(10)	HASI-SP-UKC-001 Iss. 2 Rev. 6	ACC Specification
RD(11)	HASI-RP-OG-020 Iss. 1 Jan 95	EPDH Design Report
RD(12)	HASI-RP-OG-047 Iss. 1 June 96	HASI DPU Subsystem PFM Summary Report
RD(13)	HASI-PL-OG-007 Iss. 1 Jan. 95	HASI DPU Subsystem Assembly, Integration and Test Plan
RD(14)	HASI-RP-OG-048 Iss. 1 June 96	HASI Experiment FM Summary Report
RD(15)	HASI-FMI-SYS-DOC-004 Iss. 1 June 93	PPI specification
RD(16)	HASI-RP-OG-021 Iss. 1 Jan 95	FPGA 48130R108180 Design Report
RD(17)	HASI-RP-OG-022 Iss. 1 Feb. 95	FPGA 48130R108170 Design Report
RD(18)	HASI-IDP-DOC-04 Iss. 2.1 Feb. 96	EGSE EM/FM User Manual

1.3 Abbreviations and Acronyms

ACC	Accelerometer sensor subsystem
ACU	Acoustic sensor
AC_DC	AC Electric field and DC Electric field experiments
AC_DC_AU	AC Electric field, DC Electric field and Acoustic experiments
AD	Applicable Document
ADC	Analog to Digital Converter
ADU	Analog to Digital Converter Unit.
ADP	Acceptance Data Package
AIV, AIT	Assembly Integration and Verification Activities
ASI	Agenzia Spaziale Italiana
BCP	Broadcast Pulse
BOB, BoB	Breakout Box
BOX-TEM	DPU temperature TM packets (TM format #7)
C1, C2	TEM 1 (TEM 2) Coarse sensor TM packets (TM formats #98 and #102)
CDMS,U	Control and Data Management System, Unit
CO#1	Cruise Checkout Scenario 1 (Refer to AD(1))
CORRUPTED	PWA Corrupted TM packets (TM format #129)
CPU	Central Processing Unit
CRC	Cyclic Redundancy Code
CS1, CS2	Closure Support 1 and 2 (STUB s/s)
CUT	Compute Unit Time (Probe CDMS) refer to AD(1)
DBS	Deployable Boom Subsystem
DB	PWA Data Block
DDBL	Descent Data Broadcast List
DMA	Direct Memory Access device
DPU	Data Processing Unit Subsystem
BOXTEM	DPU temperature TM packet (TM format #7)
DSP	Digital Signal Processor
DVM,DVU	Development Model, Unit
DWG	Drawing
EEPROM	Electrical Erasable PROM
EGSE	Electrical Ground Support Equipment
elec.	electronics
EM, EU	Engineering Model (Unit)
EMC	Electromagnetic Compatibility (Interference)
EOC	End of Conversion
EPDH	Experiment Power Data Handling
ESA	European Space Agency
ESD	Electrostatic Discharge
ESOC	European Space Operations Center
ETOL	European Test Operation Language
EVENT-LOG	Health Check EVENT LOG TM packets (TM format #3)
F1, F2	TEM 1 (TEM 2) Fine sensor TM packets (TM formats #96 and #100)
FM, FU	Flight Model (Unit)
FMECA	Failure Mode Effect Analysis
FMI	Finnish Meteorological Institute
FS, FU	Flight Spare (Unit) model

Fvalue(s)	Data (Frequency) which is contained in the PPI HCs session TM packets
GSE	Ground Support Equipment
GND	Signal ground
HASI-I	HASI Interface boxes
HASI	HUYGENS Atmospheric Structure Instrument
HASI-S/W	HASI DPU Software (main processor)
HC2S	HASI Health Check at 2 sec rate TM packets (TM forma #5)
H/K	Housekeeping
HKD1, HKD2	ACC Temp1 (Temp2) TM packets (TM format #38 and #39)
HKV	PPI Housekeeping voltages TM packets (TM format #72)
H/W	Hardware
HMT	HASI (internal) Mission Time
IAA	Instituto de Astrofisica Andalusia
IAR	Instituto Astronomico Roma
IDS	Interface Data Sheets
ID1, ID2, ID3	Xpiezo (Ypiezo or Zpiezo) Impact trace TM packets (TM formats #48 to #50)
I/F,i/f	Interface
I/O	Input/Output
ImpactFun	Impact Detection Function (uploadable parameter)
I/P	Input
IWF	Institut fur Weltraumforschung
IWS	Instrument Work Station (HASI EGSE)
KP	Kiel Probe assembly (STUB s/s)
LEFT	Long Experiment Functional Test
LISN	Line Impedance Simulation Network
LPCE	Lab. de Phisique et Chimique de l'Environment
MB	Motherboard
MCA	Magnetic Coil Actuator device
MI	Mutual Impedance (experiment)
MI-Rx	MI receiver sensor
MI-Tx	MI transmitter sensor
ML	Memory Load lines
MLC	Memory Load Command
MOI	Moment Of Inertia
MEMORY DUMP	Memory dump TM packet (TM format #161)
ML ECHO	Memory load echo TM packet (TM format #162)
µP	HASI 80C86 Main Processor
NA	Not Applicable
NMI	Not Masked Interrupt
OG	Officine Galileo
O/P	OutPut
OP	Operative Phase
OS	HASI Operating System PSOS® Integrated System
0xXXH	Hexadecimal notation of a byte content
0xXXXXH	Hexadecimal notation of a word content
PA	Product Assurance

PCDS, U	Power Control and Distribution System, Unit
PCB	Printed Circuit Board
PEC	HASI TM Packet Error Control (XOR)
PFM	ProtoFlight Model
PI	Principal Investigator
PIFS	Probe InterFace Simulator
PPI	Pressure Profile Instrument electronics module (DPU s/s)
PPI-N#A	Low Pressure Normal Session TM packets (TM format #64)
PPI-N#B	Medium Pressure Normal Session TM packets (TM format #65)
PPI-N#C	High Pressure Normal Session TM packets (TM format #66)
PPI-HC#G	G type Health Check session TM packets (TM format #70)
PPI-HC#H	H type Health Check session TM packets (TM format #71)
PRE	PREssure sensors
Predicted T0	Mission Time to detect the T0 transition when HASI is in back-up sub-mode
PRL	Probe Relay Link
PROM	Programmable Read-Only-Memory device
P/S	Power Supply
PT1, PT2	Pressure Tube 1 and 2 (STUB s/s)
PV	Processor Valid
PWA	Permittivity, Wave and Altimetry package
PWA-A	PWA Analogue module (DPU s/s/)
PWA-D	PWA Digital module (DPU s/s)
PWA-S/W	PWA software (embedded into the DSP)
PWA-TM	PWA science mode TM packets (TM formats #131 to #135)
PWA-TST	PWA test mode TM packets (TM format #130)
QFSM,QU	Qualification Flight Spare Model (Unit)
QFS	Qualification and Flight Spare Model
QfA, QfB, QfC	
QFT	Impact Detection filter Parameters
RAE	Radar Altimeter (Proximity sensors) Extension elec. board (DPU s/s)
RD	Reference Document
REE	Radiated Electric Field Emission
RP, REL	RELaxation Probe sensor
SB	PWA Status Block
SCOE	Special Check Out Equipment
SCDS.E	Xservo TM packets in ENTRY state (TM format #32)
SCDS.D	Xservo TM packets in DESCENT 1st and 2nd state (TM format #33)
SCDS.R	Xservo TM packets in DESCENT 3rd and SURFACE state (TM format #34)
SCDP.X	X piezo TM packets (TM format #35)
SCDP.Y	Y piezo TM packets (TM format #36)
SCDP.Z	Z piezo TM packets (TM format #37)
SEFT	Short Experiment Functional Test
SEE, SEL, SEU	Single Event Effect, Latch-up and Upset
SOI	Saturn Orbit Insertion
S/S, s/s	Subsystem
DPU START-UP	MEMORY START-UP TEST REPORT TM packets (TM format #0)
STD2.XS	Xservo statistic TM packets (TM format #40)
STD2.XP	Xpiezo statistic TM packets (TM format #41)
STD2.YP	Ypiezo statistic TM packets (TM format #42)
STD2.ZP	Zpiezo statistic TM packets (TM format #43)
STM	Structural Thermal Model
STUB	STUB subsystem

S/W	Software
SW	Status Word
T0	Mission Time for end of Probe Entry phase (descent device deployment begins)
TaccSample	Mission time when HASI starts to acquire ACC sensors
(Td1, Td1w)	Mission time window for the first Boom deploy attempt
(Td2, Teoff)	Mission time window for the second Boom deploy attempt
Tdata	Mission time when HASI starts to acquire TEM and PRE sensors
TdataH	Mission time when HASI starts to acquire ACC sensors
Thigh	Mission time when HASI change from MEDIUM to HIGH Normal Session
Thasi	Mission time when HASI is switched-ON during Titan Descent (before T0 transition)
Tmid	Mission time when HASI change from LOW to MEDIUM Normal Session
Tradar	Mission time when HASI starts to acquire Proximity sensors
Tproximity	Mission Time to start the Impact state when HASI in Back-up sub-mode
TBD	To Be Defined
TBS	To Be Supplied
TBW	To Be Written (only FS model missing information)
TCECHO	TC echo TM packet (TM format #160)
TC	Memory Load Telecommand
TEM	TEMperature sensors (STUB s/s)
Temp 1	Temperature sensor located inside of the Xservo sensor (ACC s/s)
Temp 2	Temperature sensor located inside on the ACC mounting block (ACC s/s)
TINI	Science item acquisition starting time
TM	Telemetry
UFT	Univerisita' di Fisica Tecnica - Roma
URD	HASI User Software Requirement Document
URF	Unit Reference Frame
UPD	Universita' Padova - Dipartimento Ingegneria Meccanica
UKC	University of Kent Canterbury
Xservo	X axis Servo accelerometer sensor (ACC s/s)
Xpiezo	X axis Piezo accelerometer sensor (ACC s/s)
Ypiezo	Y axis Piezo accelerometer sensor (ACC s/s)
Zpiezo	Z axis Piezo accelerometer sensor (ACC s/s)
Yvalue	Data which is contained in the PPI NORMAL session TM packets

Note: The **'TM format #n'** refers to the packet identification reported into the table in the ANNEX 1 pages 6, 7 and 8 of the AD(5).

2 HASI Subsystems description

2.1 ACC subsystem

2.1.1 ACC description

The ACC s/s (Refer to figure bb) FM and FS models contain one servo accelerometer (SUNDTRAND QA 2000-30) with switchable range (by means of its conditioning circuitry) sensitive to acceleration in the X axis (the Probe spin Axis) and three piezo-resistive accelerometers (ENDEVCO 7264A-2000T) each sensitive to acceleration in one of the X, Y or Z axes of the Probe (**Important Note**: <u>both the Y and Z axes in the Accelerometer reference system are rotated of 90 degrees with respect to the probe system axes</u>).

Two AD 590 temperature sensors, one situated inside the servo accelerometer case (Temp 1) and one attached to the aluminium alloy accelerometer mounting block (Temp 2), are used for calibration and compensation. Since both the temperature sensors are effectively in good thermal contact one with the other (and the acceleration sensors), a high degree of redundancy exists in the temperature measurement system. The X-axis servo accelerometer's output is conditioned and amplified by two non inverting amplifiers, one with a gain of 1 and the other with a nominal gain of 10, to provide the X-axis servo channel outputs. As well as these two channels, the range of the servo is switchable between a high resolution and a low resolution range. This range switching is achieved by switching the output of the servo accelerometer (a current) between two load resistors by using a single analogue switch. The range change capability is remote controlled by DPU (via a digital command).
For detailed description refer to RD(1) and the RD(10).

2.1.2 ACC mechanical I/Fs

The ACC will be attached to the experiment platform via four **M3 bolts**. The bolts will be torque by using a long Allen key passed down the ACC box corner holes.
In the following table the measured mechanical characteristics of the two models of the ACC sensor are reported. The ACC box CoG is measured wrt the ACC reference hole with ±5 mm accuracy.

Table A: ACC subsystem mechanical characteristics

Model	FM	FS
ACC reference system X	32 mm	As per ADP
ACC reference system Y	27 mm	As per ADP
ACC reference system Z	- 34 mm	As per ADP
ACC measured mass	297.53 grams	As per ADP

Since the ACC Servo sensor is required to have its seismic mass in the X axis positioned as near to the Probe's entry CoG as possible (displacement in any direction shall be not greater than 3 mm sphere radius), shimming during ACC sensor mounting on the Probe could be needed.

In the next table the displacement of the ACC servo sensor seisming mass is reported (with respect to the ACC base). These values, together with the Probe (in entry configuration) measured CoG, shall be used for the calculation of the shimming to be used when mounting each ACC on the Probe. Shimming is required just on the X axis, but the offsets/displacements between the ACC servo seismic mass and the Probe CoG (in entry configuration) is required to be known to an accuracy of, preferably, better than 10% (e.g. 0.3 mm accuracy in a 3 mm offset) by the ACC experimenters also for the Y and Z axes (to better characterise the Probe oscillation on Titan descent).

Table B: ACC Xservo seismic mass position

Model	FM	FS
Position along X axis	21 mm	21 mm
Position along Y axis	centred	centred
Position along Z axis	centred	centred

Installation of the ACC on the Probe is required to an accuracy of better than ± 0,16° in two angles of elevation relative to mount platform.

2.1.3 ACC power input characteristic

The ACC input voltages requirements are ± 13.5V (absolute minimum) to ± 18V. The power consumption is mainly driven by the servo accelerometer; the power is required by the sensor to maintain its inertial mass at the equilibrium which depends upon the acceleration it undergoes.
In the HASI experiment, the ACC is powered via DPU and the power voltage rails are ±14V ±3%.
In normal condition (i.e. when the servo accelerometer undergoes to the Earth's surface gravitational acceleration) the total power consumption (on both lines) is 1.9 ±5% [W].
The peak power can happen only when the ACC experiences the shock (if powered) or at the Probe Entry.

2.1.4 ACC grounding

The ACC signal ground is insulated from the box chassis. The servo accelerometer has a capacitance (≈ 46 nF) between signal ground and its housing (i.e. the ACC box, since the servo accelerometer housing is screwed to chassis).

2.1.5 ACC signal outputs characteristic

The ACC produces voltage outputs from its internal signal conditioning circuits and sensors. In nominal condition the output voltages range is ±10 V while, if the Op-Amp output is saturated, it can reach as maximum value the power supply voltages.
A short functional check of the ACC (in stand-alone) can be carried out measuring the output voltages when ACC is powered and the X axis of ACC box is perpendicular to the horizontal mounting plane. Referring to the pin-out of the ACC connector J01 (see AD(3)), in the above situation the following ranges are applicable:

Table C: ACC outputs

Output line	FM	FS
SERVO HIGH	+5.6 V ± 5%	As per ADP
SERVO LOW	+0.56 V ± 5%	As per ADP
PIEZO X	+4.2 V ± 10%	As per ADP
PIEZO Y	-1.95 V ± 10%	As per ADP
PIEZO Z	+4.6 V ± 10%	As per ADP
TEMP 1	+2.1 V ± 5%(*)	As per ADP
TEMP 2	+2.1 V ± 5%(*)	As per ADP

(*) if the ambient temp is 22°C. ±10%.

2.2 DPU subsystem

2.2.1 DPU description

The DPU shown in figure cc is an electronics box containing seven electronics modules. They act the following functions:

- *DC/DC converter* to provide all the DC power supply voltages required inside the DPU and for the whole HASI experiment (i.e. the units and *sub-systems externally connected to the DPU itself).*
- *Interface to CDMS system to transfer the acquired data and to accept telecommands.*
- *Data analogue and digital conditioning to provide proper interface to the sensors signals (i.e. TEMperature, Accelerometer, PREssure and PWA sensors).*
- *Analog to Digital Converter to convert signals coming from analogue sensors and internal/external housekeeping.*
- *Reading interfaces to read all the data at the required rate.*
- *Real time processing of the PWA sensors (including Probe Proximity sensors).*
- *Booms release command issuer.*
- *Reconfigurable on-board computer to handle all the above mentioned activities.*

DPU external aspect is an unique, solid box parallelepiped shaped. In reality the DPU is composed by seven separated modules interconnected together by a Motherboard PCB:

- *one PPI module comprising the RAE daughter-board and a wall Pressure connector;*
- *one PWA-A module;*
- *one PWA-D module;*
- *one Experiment Power and Data Handling comprising:*
    - *one A/D converter module;*
    - *one CDMU i/f module;*
    - *one CPU module;*
    - *one DC/DC converter module.*

2.2.1.1 CPU module

The CPU module is the hearth of the HASI itself. Its architecture is centred around an microprocessor system comprising the 16 bits 80C86 Central Processing Unit, 16K words of programmable read-only-memory (PROM) and 32 K words of read/write random access memory (RAM). The RAM is located into the CDMU I/f module. The system is clocked at 4.5 [MHz]. The 80C86 operates in 'minimum' mode, so that it can address at least 1 Mbytes of the memory and 64 Kbytes of the Input/Output. The microprocessor uses a time multiplexed line to multiplex the memory I/O address and data bus. Three octal latches controlled by Address Latch Enable signal are used to latch the addresses during the normal operations. Both word and byte accesses can be performed in memory or the I/O spaces. The module includes the following main functions:

- *Clock generator;*
- *Interrupt Controller;*
- *PROM memory;*
- *EEPROM memory;*
- *NMI function;*
- *RESET function;*

- HOLD/HOLDA function;
- Watch-dog and ready logic;
- Two Programmable timers;
- Eight bits parallel port (including handshaking lines) for PWA interface;
- Bus i/f to the other modules.

For detailed description refer to the RD(11) sect 4.1.

2.2.1.1.1 EPDH Memory and I/O Maps

Refer to the AD(5) sect. 3.2.1.2 and 3.2.1.3.

2.2.1.1.2 EEPROM memory

An 8Kbytes EEPROM memory (28C64 device manufactured by SEEQ) area is provided to store software patches and parameters. The use of the device is under control of the HASI-S/W, except for the current limiter function that protects the device and HASI from the EEPROM latch-up. The EEPROM switch status and its current limiter status are read by the HASI-S/W. The device is normally switched-OFF, except for each HASI power-ON and during the Memory Load and Dump commands (refer to sect 6).

2.2.1.1.3 Watch-dog

The circuit consists a binary counter, clocked by a square wave signal with a 112 µsec period. It generates a Reset signal to the EPDH modules every 0.46 sec. To prevent this, the HASI-S/W must reset in time the counter. In case of timeout, a bit in a H/W register is set to inform the software reset procedure whether the reset was generated by Power-On or by a fault condition.

2.2.1.1.4 READY logic provision

The Ready control logic is composed by a binary counter clocked at 4.5 [MHz]. All the EPDH memory and peripheral devices, when they are addressed either by the µP or the DMA, generate a signal (i.e. the READY) that resets the Ready control logic. An hardware failure (either permanent or occasional) of the address bus or the address decoding logic is detected using the same method. In case of timeout (e.g. device answer is issued after 8 µsec), the Ready control logic generates an Not Maskerable Interrupt (NMI) request to the µP and forces the Ready to be active. Then the µP starts the NMI interrupt routine to recover the situation. The HASI-S/W writes in the RAM a warning message (i.e. 'NMI INTR') and then it jumps to the bootstrap address location. The warning message is late copied into the DPU START-UP packet.

2.2.1.1.5 PWA interface

An eight bits bi-directional parallel port, shown in the figure ii provides data communication between the main cpu and the PWA-D electronics. The interface timing is fully managed by HASI-SW (data throughput is normally 1 msec for each data). The PWA port is normally in three-stated and becomes active only during read or write operations. Four handshake signals are provided in order to control the data flow. Furthermore the interface is protected by un-foreseen data transferring from PWA to the main processor (as experienced during the DPU PFM qualification test campaign).

2.2.1.2 CDMU i/f module

The Command Data Management System i/f module implements all the communication functions with the two CDMU units. The module includes the Direct Memory Access Controller, the RAM memory, the MCA and Protected power monitoring functions, the PPI drivers signal and the MCA activation command. The 80% of the CDMS functions are implemented in two programmable logic device (ACT 1020 type).

2.2.1.2.1 Direct Memory Access controller

The 82C37A DMA allows the external devices to transfer data directly to or from system memory (i.e. RAM). The device, which has four independent maskable channels, is the main component of the CDMS interface (Telemetry Packet and Memory Load) and the ACC data acquisition system.

The four DMA channels perform in the following functions:

- Memory to I/O (word transfer): CDMU A & B interfaces
  - channel 0: Packet Telemetry i/f - line A
  - channel 1: Packet Telemetry i/f - line B.
- I/O to memory (word transfer): ML interface
  - channel 2: Memory Load i/f line A or B.
- I/O to memory (word transfer): ACC data acquisition
  - channel 3: ACC channel selecting and ADC data storing.

During CDMU (both TM and ML interfaces) data transfers (using 0, 1 and 2 DMA channels), the data exchange remains internally to the CDMS module so that the external busses (data/address/control lines) to the module are disabled. In the case of ACC data transfers, since the data exchange is between the CDMS module and the AD module, only the address/control lines busses are disabled.

2.2.1.2.2 MCAs interface

The MCA devices are the initiator of the boom deployment. A distinguished MCA is foreseen for each boom device (refer to sect. 2.4.1). The booms are located outside the Probe. When they are activated (i.e. the current flows in the MCA), the retaining pin is sucked and the boom release starts. The MCA activation is therefore a critical function. The elec. design provides a dedicated protection mechanism in order to avoid un-wanted booms opening. The **MCA command elec**. is separated from the **MCA power drivers**. The power drivers are located in the DC/DC conv. module (refer to sect. 2.2.1.4.4) and they are supplied by a insulated power supply. Each power driver is commanded by distinguished command signal. A optocoupler insulates the command logic from the drivers. The figure jj shows **the MCA command electronics**. Two separate registers are provided to issue the MCA commands:

- the **MCA control register** (shared between other services) which acts the following functions: ‘MCA selection’, ‘Enable/Disable’ of the **MCA command logic** and the ‘Command level (HIGH/LOW)’;
- the **MCA activation register** which generates the start of the MCA pulse when the MCA command logic is enabled and the command level is HIGH.

Both registers are reset at Power-On or after watch-dog timeout.
The following cycle shall be sequentially performed in order to execute an MCA1 (MCA2) single activation:

- MCA1 (MCA2) selection; Enable the MCA command logic; MCA Command level sets to HIGH (**MCA control register**).
- Assert the **MCA activation register** ; then the relevant MCA is activated.
- Wait for the pulse duration.
- Switch-OFF the pulse (i.e. command level is set to LOW) and Disable the **MCA command logic**.

NOTE: without the write in both registers the MCA activation cannot happen.

The reset of the registers and the double write guarantee that the MCA power drivers are switched OFF even if the HASI-S/W crashes. In this failure case, it can happen one the two possibilities:

- **No command pulse**; the activation cycle (double write) provides a very low probability to have a command pulse during a software crash.
- **Command pulse lasts no more then 0.4 sec**; after a watch-dog timeout the registers are reset and consequently the active command is OFF.

A further feature of the **MCA command logic** is to lock the possibility of both the MCA commands are active at the same time.
The **MCA power drivers** (and the MCA) **are not designed** to be maintained switched-ON for a period greater then 1 sec (0.5 sec, in the case of MCA). In case of failure both the MCA driver and the MCA itself over heat and they may be permanently damaged. In the nominal condition or during tests (i.e. simulated Titan Descent), the HASI-S/W assures that the MCA driver remains active for a period less then 70 msec (worst case estimated value). This period is sufficient to initiate the boom release. In order to initialise the **MCA Control register**, a software patch has been prepared and loaded in the EEPROM. It is recommended to remain installed till the TITAN mission.
The status of the MCA commands (i.e. optocoupler outputs) as well as the presence of the Protected Power are monitored by the HASI-S/W (refer to following sections 2.2.1.4.4, 3.7.1, 3.8.5 and 4). **Note that the two MCA command status are active only when the Protected power is present**.

Remark : if the two MCA command status (reported in the EVENT LOG packets) are ON, it does not means that the MCAs have been successfully activated (i.e. the booms are deployed). This information must be used in combination of the Boom μ-switches status information given (refer to 2.4.1).

2.2.1.3 A/D module

The A/D module provides the analog processing/conditioning and data acquisition for the ACC and TEM sensors and the DPU internal H/K signals (i.e. the DPU temperature, the PPI housekeeping voltages and the EPDH power supply voltages). Two separate analog to digital converter chains (each based on 12-bit AD converter AD574) are foreseen. One dedicated to the TEM & housekeeping conversion and the other to the ACC sensors measurements. The ACC analog to digital is triggered by a 3.2 KHz clock (internally generated to the CPU module) while the data transfer and the channel selection is performed using a logic controlled by DMA. The TEM ADC and the multiplexer selection are under HASI-S/W control. This solution offers high TEM measure reconfigurability (in term of the measurement sequence and timing) and high measure reliability (two separate ADCs respect to only one). The module includes:

- the ACC analogue front-end which is composed by a seven low noise differential amplifiers (one for each ACC channel), a seven low pass filters (100 Hz cut-off frequency) and 8 way multiplexer (the least channel is grounded by EPDH analogue signal ground).
- the Xservo range change driver;
- the TEM current generators (25 mA output current);
- the TEM analogue front-end which is constituted by a passive networks plus a clamping diodes in order to reduce the ESD sensitivity of the multiplexer inputs and to attenuate the high frequency noise induced by the sensors and the cabling;
- the TEM REFERENCE resistors; they are two resistors RBR 56 type one for each TEM measurement range. The values of these resistors are reported in the sect. 3.8.3.3.1.
- the TEM & REFERENCE multiplexer (16 ways differential);
- the TEM low noise instrumentation amplifiers (one for each range);
- the TEM & H/K multiplexer.

For detailed description refer to RD(11).

2.2.1.4 DC/DC converter module

The DC/DC converter provides all the voltages for the DPU internal modules (i.e. EPDH, PWA-A, PWA-D, RAE and PPI) and for the other HASI s/s (ACC and DBS). It also contains the power driver for the MCA1 and MCA2. It consists of a rigid-flexible PCB which rigid parts are mounted one over the other. The primary circuit is based on a fixed frequency pulse width modulator which controls the pre-regulated voltage. The pre-regulated voltage feeds the chopper section which drives the primary windings of the transformer. From the secondary winding, by proper winding ratio, all the secondary voltages are obtained. The secondary voltages are then rectified and properly filtered. Only the +5V(DIG) uses a linear regulator. The secondary voltage outputs are:

- +5Vdc (Digital power supply for EPDH and PWA digital elec.);
- ±14Vdc (ACC and EPDH analogue power supplies);
- +12Vdc (PPI analogue power supply);
- ±5Vdc (PWA analogue power supplies);
- ±15Vdc (PWA analogue power supplies).

The ACC and DBS power supply voltages measured in different environmental conditions are reported into sect. 3.2.3 of the RD(12).

2.2.1.4.1 DC/DC converter electrical characteristics

The main features of the DC/DC converter are listed in the following Table.

Table D: DC/DC conv. electrical characteristics

	VALUES
Input voltage (MAIN and REDUNDANT)	26.5V to 29.3V
Current Limiter	1.5 A ±0.1 A (1)
Under-voltage protection	13.5 V ±1V
Minimum start up voltage	21 V ±1.5 V
Insulation characteristic between primary and secondary power lines	better than 50 nF // 1 MOhm
Main oscillator frequency	120 KHz ± 20%
Typical efficiency at 28V, 20°C and nominal Load	70%
Operating temperature range	-30°C / +60°C

Note: (1) These values apply when a voltage generator supplies the HASI.

2.2.1.4.2 Input Filter

Referring to the input filter electrical scheme reported in figure kk, the power lines (main and redundant) coming from the DPU Power connector J08, are connected to CR44 and CR43 respectively. This allows the DC/DC converter to work with the redundant bus when the nominal bus fails. The network L16, L17, L15, L18, L32, L33, C41 and C53 realises a filter which reduce both the differential and common mode noise coming from the power lines. The C56 and R56 provide a further reduction of common mode noise afflicting the primary circuit. L17 and L18 limit the drawn current transition (di/dt) to a value below 10^6 A/sec.

2.2.1.4.3 Current Limiter

When the HASI is supplied by a laboratory power supply, the primary current is limited to 1.5 A by a dedicated current limiting internal circuit. This current limiter does not work when the HASI is powered by the PCDU being the PCDU already limiting the HASI current to a lower value (0.85 A). The current limiter value has been measured in two different configuration:

- DPU PFM level using external s/s simulators (refer to RD(12));
- HASI level (refer to sect. 3.2 of the RD(14)).

Both the values indicate that the current limiter is in the designed range.

2.2.1.4.4 MCA power driver

Referring to the scheme reported in figure ll, the MCA power driver acts as a current limiter in series with a elec. switch (one for each MCA). They are supplied via DPU J08 connector, by the Protected power (Nominal and Redundant) that is energised and controlled by the PCDU. This power is electrically separated from the Main power lines and from the HASI secondary lines. Each switch is activated by a digital command issued by the HASI-S/W (refer to the sections 2.2.1.2.2 and 3.7.1) an optocoupler (U7) provides the required insulation between the driver and the MCA command logic (see sect. 2.2.1.2.2).
The current, flowing through R26, causes a voltage drop which is compared with a reference voltage VREF by dual transistor U4 or U9 depending on which MCA has to be activated. The resulting output at the collector of U4-B (U9-B) controls the gate of MOS-FET Q11 (Q10), limiting the flowing current at I_{LIM} = 2.4 A (nominal value).
The command level of the MCA1 and MCA2 elec. switches (i.e. the output voltage of the U7) and the presence of the Protected power voltage are read by HASI-S/W via optocoupler U9. Since the optocoupler U7 is powered by the Protected power voltage, the status of the commands level are significant only when this power is present.

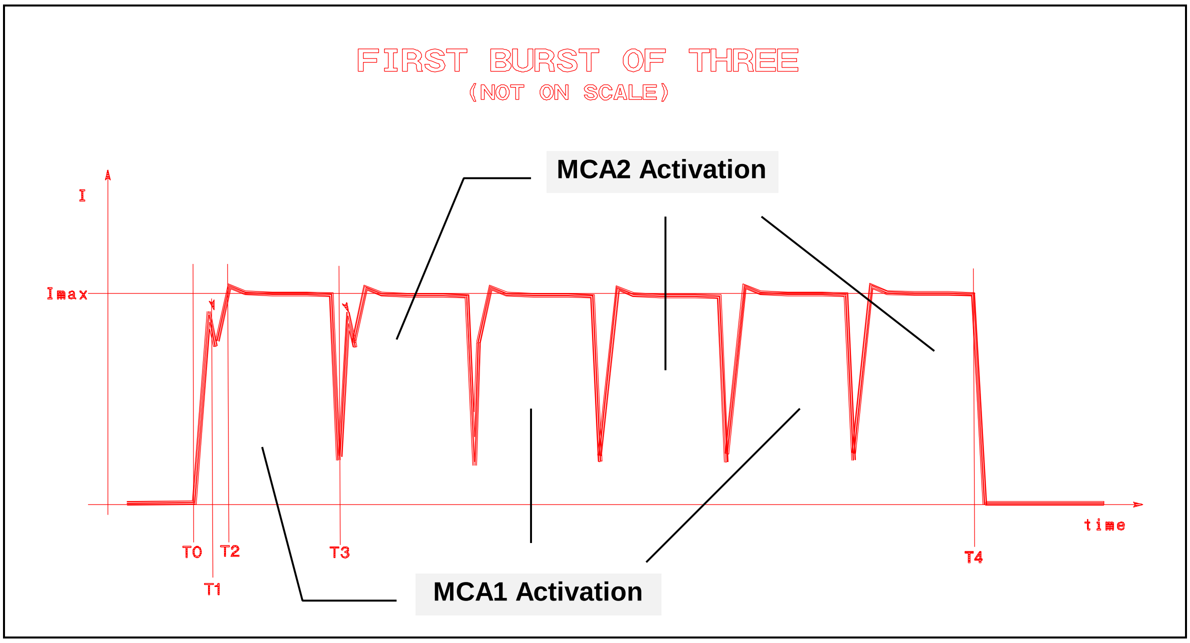
The MCA driver electrical characteristics are reported in the following table.

Table E: MCA power driver electrical characteristics

	VALUES
Input voltage (MAIN and REDUNDANT)	26V to 31V
Current Limiter	2.4 A ±0.1A
Drawn current transitions (Di/dt)	< 4000 A/sec [(1)]
Insulation characteristic between primary and secondary power lines	better than 50 nF // 1MOhm
Operating temperature range	-30°C / +60°C

Note: (1) With MCA device as load.

Figure A: MCA activation sequence



Each MCA is activated by a sequence of the nine pulses (refer to sect. 3.7.1); therefore each sequence is composed by 18 pulses. The above figure shows the first three pulses of each MCA activation (the MCA1 activation pulses are mixed with the MCA2 activation pulses). The gap between two consecutive pulses is about 20 msec, even if is not shown. In the nominal condition the first (second) pulse initiates of the Boom1 (Boom2) release: the current rises up to the I_{max} limit (2.4 A nominal), after few milliseconds decreases and then it increases rapidly to the I_{max}. This phenomena is characteristic of the MCA activation. The electrical characteristics of the MCA activation current pulse are reported in the sect. 3.2.8 of the RD(12) (tests performed at DPU s/s level) and in the sect. 3.2 of the RD(14) (tests performed at HASI level). The MCAs sequence timing is managed by software (refer to sect. 3.7.1).

2.2.1.5 PWA H/W description

Refer to RD(6) (User document section).

2.2.1.6 PPI description

The PPI board includes the following elements:

- DPU pressure inlet connector wall fitting;
- Tubing and bellows to carry the pressure from the pressure inlet to the Plenum chamber;
- Plenum Chamber which distributes the pressure to the sensors;
- Pressure and Temperature sensor Heads;
- Constant and Reference channels;
- Three Oscillator blocks and a relevant multiplexer;
- Oscillator block and multiplexer power supply conditioning and filtering.

2.2.1.6.1 Pressure/Temperature/Constant/Reference sensor heads

In the PPI are present three sensors types: Pressure, Temperature, Reference and Constant.

The Pressure transducers are the variant of the silicon capacitive absolute pressure sensor (Barocap) produced by the Vaisala Co. The varying ambient pressure bends a thin silicon diaphragm causing changes in the sensor head capacitance. Eight different pressure heads are mounted in the module.

The PPI temperature is measured by thermocap (Temperature) sensors. The technology of these sensors is similar to the one of the Barocap. Three sensors are present in the PPI.

Each Constant sensor head is an high stability capacitor (calibrated during PPI calibration). It provides fixed capacitance. Seven constant capacitors are present into PPI. They are mainly used to check the stability and performance of the whole measurement system (including reading elec. located in the CPU module).

The Reference sensor heads are high stability capacitor. They provides fixed capacitance. Six Reference are present into PPI. They are used in the pressure measurement in combination with the other sensors (Yvalue formula, refer to sect. 3.8.1) in order to compress the pressure data.

The sensors are grouped in three blocks each composed of eight channels. The complete list of blocks and channels with the correspondence to their functions is shown in the following table (FM and FS are identical). The table reports the identification number used by the HASI-S/W to address each channel.

Table F: Pressure sensors layout

BLOCK	CHANNEL	CHANNEL # WRT HASI-S/W	SENSOR TYPE
1	1	0	Medium Pressure
	2	1	Reference
	3	2	Temperature
	4	3	Constant
	5	4	Reference
	6	5	Medium Pressure
	7	6	Constant
	8	7	Medium Pressure
2	1	8	High Pressure
	2	9	Reference
	3	10	Temperature
	4	11	Constant
	5	12	Reference
	6	13	Constant
	7	14	High Pressure
	8	15	High Pressure
3	1	16	Constant
	2	17	Reference
	3	18	Temperature
	4	19	Constant
	5	20	Reference
	6	21	Constant
	7	22	Low Pressure
	8	23	Low Pressure

The Block 1 Channel 6 and Block 2 Channel 1 are not connected to the Plenum chamber. They measure the housekeeping pressure internal to the DPU (i.e. the pressure internal to the Probe during the TITAN descent). The other six pressure sensors are divided in three groups (each composed by two sensors). The first group (High pressure) is capable to measure in the range 0..2000 mbar (i.e. the whole pressure profile of Titan) and they are more sensitive and stable in the HIGH part of this range. The second group (Low pressure) is more sensitive and stable in the LOW part of the Titan pressure range (i.e. 0..1200 mbar). The last group is constituted by the Medium Pressure heads that behave like the HIGH PRESSURE heads except that the working range is limited to approx. 1400 mbar. They are mainly used as to check the long term stability of the PPI.

The Low pressure heads will be permanently damaged if exposed to a pressure greater than 1200 mBar. This pressure shall never be exceeded during ground operations (e.g. Probe transportation or purging.

NOTE A: LOW PRESSURE SENSORS WARNING

The variable capacitances and the constant capacitances (relevant to the Constant and Reference channels) are transformed in a frequency variation by means of a Stable Oscillator. Each sensor block has a dedicated Oscillator. The Oscillator outputs are multiplexed. The channel selection in each block is performed by the HASI-S/W using two digital signals common to the tree blocks: the Reset and the Step. The software selects firstly, via RESET signal, the first channel in the block and secondly the selected channel via STEP pulses. The actual procedure and the relevant timing are described in sect. 3.2.2.9 of the AD(5). The pressure and temperature measurements consist of three measures: the frequency period of the selected sensor head and the frequency periods of the two Reference channels relevant to the sensor. Then the three measures are combined by means of the Yvalue formula (refer to sect. 3.8.1). The period measurement elec. in located in the CPU module. Note that each sensor block contains a different couple of the Reference channel.
The HASI-S/W monitors the oscillators and multiplexer supply voltage reading the PPI-HK-0 H/K signal and the PPI power supply voltage reading the PPI-HK-1 H/K signal. These signals are range checked and reported in the HC2S packets (refer to sect 3.8.5). Furthermore the measured values are long period averaged and then transmitted via HKV packet (refer to sect. 5.2).

2.2.2 DPU mechanical I/fs

The DPU will be attached to the experiment platform via four M4 bolts. The physical characteristics are reported in the sect 3.1 of the RD(12).

2.2.3 DPU External interfaces

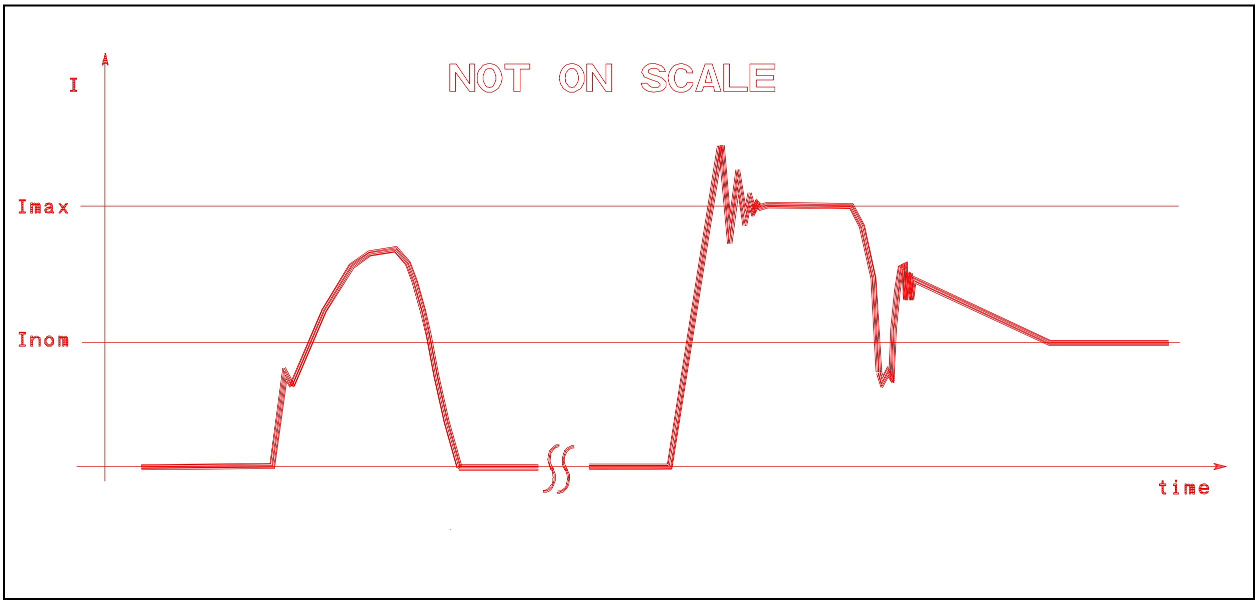
2.2.3.1 DPU i/f to PCDU (Power input characteristics)

2.2.3.1.1 DPU behaviour at power on

The DPU power-on is divided in two phases: the DPU start-up (except to PWA experiment) and the PWA start-up. There are two options for the PWA Start-up since on board of the PWA-D there is a current limiter which observes the current drawn by the DSP. When the current is greater then a threshold (that normally is happen after latch up of this device), the current limiter disconnects from the DC/DC conv. power lines the whole PWA instrument (i.e. RAE, HASI-I, PWA-D and PWA-A elec.) at exception of the digital interface with the µP which is always powered. In the mean while, the power lines are connected to a resistors load in order to maintain the un-switched DC/DC conv. power lines in the nominal range. After 20 sec. the power is reconnected to the whole PWA instrument. The two options for the HASI start-up are therefore as follows:

1. **HASI normal power** in which the PWA current limiter does not operate. In this condition the in-rush current shape is reported in the hereafter figure b.

Figure B: HASI In-rush current



The electrical characteristics have been measured in different configuration and environmental conditions and they are reported in the RD(12) (DPU plus external s/s simulators powered by a commercial power supply) and RD(14) (whole HASI powered with commercial and PCDU current limiter simulator).

2. **DSP latchup** in which the PWA current limiter switches off the PWA during Power On. A second in-rush current at new PWA power ON (delayed with respect to the initial) will happen. Up to now this condition is never been experienced.

2.2.3.2 HASI (DPU) i/f to CDMS

The interface elec. to the Probe CDMS and the relevant digital logic are fully located in the CDMS module of the DPU. The typical line receiver (refer to AD(3) for the detailed elec. dwg) is based on half RH-119 comparator. The primary electrical characteristics are:

- the hysteresis is not symmetrical respect to the signal ground (i.e. Box chassis);
- the output is in HIGH state when the source is OFF.

The HASI driver (refer to AD(3) for the detailed elec. dwg) is composed by two couples of the elec. buffers for each line: two 54HCTS244 gates for the positive line and two 54HCTS240 gates for the negative line. Furthermore four equal value resistors provide the output line interface. Both the interface are fully in compliance with the EID-A requirements (refer to AD(1)).

The block diagrams and the relevant descriptions of the digital logic which implement the different types of the CDMS interface functions are described in RD(11). The main features are hereafter summarised:

- the digital elec. functions are fully integrated in two FPGA Actel devices (refer to RD(16) and RD(17));
- the channel A line drivers are separated from the channel B;
- <u>Status word</u>: the channel A and B (including receivers and drivers) are fully redundant. The Status Word clock is common to the packet TM interface. The same data are transmitted on both channels (H/W implemented);
- <u>Packet TM</u>: the channel A and B (including receivers and drivers) are fully redundant. Both channels are independent. The packet TM clock is common to the Status Word;
- <u>ML and BCP</u>: the channel A and B receivers are fully redundant. The digital elec. is single and a multiplexer (commanded by HASI-S/W) switches between the two CDMU channels;
- <u>PV</u>: the Processor Valid status is read by HASI-S/W.

2.2.3.3 HASI (DPU) i/f to Proximity sensors

The RAE elec. is small size piggy back screwed to the PPI. It provides the interface with the Probe Proximity sensor. The RAE is completely shielded in order to increase the PPI elec. noise rejection against the RAE induced REE. The front end to the Proximity sensor analog signal (Radar signal) is an AC coupled differential amplifier (refer to AD(3) for the detailed elec. dwg). The 200 KHhz ±7.5 KHz signal output is afterwards downconverted by a mixer to a centre frequency of 10 KHz. After a filter bench, the signal is linked to the analog multiplexer located in the PWA-A. The Proximity sensor digital signal (Blanking pulse) front end is an differential line receiver based on a comparator which converts the blanking pulse to a TTL level output signal. This level is directly connected to the PWA-D. Both analogue and digital chains are fully redundant (i.e. one for each Proximity sensor) and they are in compliance with the EID-A requirements (see AD(1)).

2.2.3.4 DPU (HASI) grounding

2.2.3.4.1 Normal power lines

The normal power lines (Nominal, Redundant and their returns) are insulated from the box housing (HASI bonding stud which is located on rear panel of DPU). A galvanic insulation is provided by the DC/DC converter between the input power and the secondary power lines.

The EPDH analogue power supplies return, the DPU digital supply return and the PWA analogue power supplies return are DC separated at the output of the DC(DC conv. The PPI power supply is derived from the EPDH analogue power supply and then its return is common to the EPDH analogue. Note that the PWA analogue power lines returns (±5Vdc and ±15Vdc) have been joined at the secondary of the DC/DC conv. transformer after the DC/DC conv. trimming. Furthermore, the all power lines returns are AC coupled (via a capacitors) to the chassis (box housing) internally to the DC/DC conv. in order to reduce the common mode noise (injected by the DC/DC conv. itself) on the secondary output voltages.

The EPDH analogue and DPU digital power supplies returns are connected together in one point (EPDH star point) close as possible to the TEM ADC (i.e. into the AD module). The PWA analogue power return is connected to the PWA start point which is located in the PWA-A close as possible to the AD conv. The power supply returns of each PWA analogue circuitry (e.g. MI#1 amplifier, HASI-I1 MI amplifier, etc.) are connected separately to the PWA star point.

The two start points are then linked separately to the HASI feedthrough (located on the rear panel of the DPU). An external removable jumper grounds the HASI feedthrough to the HASI Bonding Stud.

2.2.3.4.2 Protected power lines

The protected power lines (Nominal, Redundant and their returns) are insulated from the Normal power lines and from the box housing. The insulation between the secondary power lines is ensured with opto-couplers.

2.3 STUB subsystem

2.3.1 STUB description

The STUB shown in figure dd consists of several loose items:

- a metallic STEM (made of Aluminium Alloy) that supports two TEMperature sensors (screwed to it via a metallic cap), the Kiel Probe assembly (screwed to it via four bolts) and a pressure tube (PT1) that is connected to the KP on one side and is free on the other. The STEM opening, on the attachment flange side, is closed with two screwed supports (CS1 and CS2). The TEM cable and PT1 tube come out from two holes in the closure supports. An Acoustic sensor (together with its cable) is screwed to the STEM attachment flange.

- a pressure tube PT2 that joins PT1 to the DPU wall fitting pressure connector, when the STUB and the DPU are integrated in the Probe.

- two sealing gaskets that will be mounted one on the DPU side and the other on PT2/PT1 joint.

- two Pressure Supports for PT2 that will be screwed to the Experiment platform (when STUB is integrated in the Probe).

2.3.1.1 TEM sensors

Each TEM sensor has two sensor heads (Fine and Coarse). Both sensor heads are constructed on a hollow tubular frame (made of Pt-Rh material). The Fine sensor is Pt wire wound around the central part of the tubular frame while the Coarse sensor wire (also made of Pt) runs along part of the frame at the furthest end from the STUB stem. The sensor elements are electrically connected to the base of the TEM frame by insulated leads (made of Pt) which pass inside the hollow tubes of the frame. At the base of the TEM frame, these leads are soldered (in a potting boot) to the twisted copper wires (AWG 28) which run to the DPU. For each sensor head there are four lead wires: one pair for injecting current and the other for measuring the voltage across the sensor.
The TEM sensor is designed to operate in temperature range between -210 °C and +60 °C.

2.3.1.2 ACU sensor

The Acoustic sensor is shielded against electric field and is designed to operate in a temperature range between -210 °C and +60 °C. The sensor uses the principle of bridge: the pressure fluctuation causes a variation of the resistance.

2.3.2 STUB mechanical I/fs

The STUB STEM flange is attached to the Probe ring via 16 M3 screws. No specials tools are required to integrate it on the Probe platform ring. The closure supports and the items sticking out from the STUB are thermally sealed using Staycast glue. Each pressure support is screwed to the Experiment Platform via two M3. These screws are not provided by HASI experiment. The whole mass of the STUB FM is 0.410 Kg.

2.3.3 STUB power input characteristic

2.3.3.1 TEM sensors

The TEM measurement is performed by the DPU injecting into the sensor a current pulse (to reduce the joule effect in the sensor) and measuring the voltage across it. The current pulse has a trapezoidal shape (to reduce rise and fall time) and its nominal characteristics are summarised in the following:

- Peak current: 25 [mA];
- Duration: 50 [msec];
  70 [msec] (Maximum);
- Rise and Fall time: 0.5 [msec];
- Repetition rate: 1 sensor head measure every 5 [sec];
- Overall repetition rate: 1 pulse every 1.25 [sec].

The TEM sensors power consumption is negligible. The TEM interface signals have been measured in the different environmental conditions during the DPU PFM test campaign and they are reported in the sect. 3.2.6 of the RD(12).

2.3.3.2 ACU sensor

The ACU sensor input voltages requirements are +15V ±5%. The sensor is powered via PWA-A circuitry through J10 connector. The ACU power consumption is negligible.

2.3.4 STUB sensors grounding

Both the ACU and the TEM sensors are insulated from the STUB chassis.
The ACU cable is composed by a four shielded wires; the shield is connected to the PWA analog signal ground via connector pin and it is open on the ACU side. The TEM cable consists of eight pairs of twisted wires. Inside the STUB, the TEM wires are wounded around the PT1. To reduce risks during vibration, they are glued to PT1 and to the Closure supports.
Both TEM and ACU cables are overall shielded and then they are protected with an electrically insulated sleeving. In order to guarantee the Probe faraday cage till the DPU, the overall shields are grounded to the Closure supports backshell (360° closed) on the STUB side and to the connector backshell (360° closed) on the DPU side.

2.3.5 STUB output signal characteristic

2.3.5.1 TEM sensor

The TEM sensor is a resistance variable with the temperature; in the range -200°C to +60°C, the resistance changes between 2 to and 20 Ohms. At ambient temperature the TEM resistance is about 16 Ohms ±5%. The voltage across each sensor head has the range 0.05V to 0.5V.

2.3.5.2 ACU sensor

The ACU sensor output voltages (when it is subjected to the environment noise) is in the range of ± 10 Volt.

2.4 DBS subsystem

2.4.1 DBS description

The DBS shown in figure ee is composed by four loose parts:

- Two HINGE bracket assemblies (B1 and B2), one of BOOM#1 (refer to figure ff) and the second of BOOM#2. Each assembly consists of one boom STEM which supports three electrodes, one bracket supporting the HINGE, the electrodes harnesses and the HASI-I box (refer to figure gg).

- Two RELEASE Mechanism bracket assemblies (A1 and A2), one of BOOM#1 and the second of BOOM#2. Each assembly (refer to figure hh) consists of one MCA device, one micro-switch, the U-shaped retaining cavity and the harness for the MCA and micro-switch.

Since the two BOOMs are each one the mirror image of the other, they are not interchangeable!! **NOTE B: DBS CONFIGURATION**

2.4.1.1 Boom Stem and Electrodes

The boom STEMs are made of fiber glass material, each holding the MI-Tx, MI-Rx and RELaxation electrodes. The REL sensor is an metallic disk which is fixed to the short stem located in the middle of the boom. The other two sensors are each metallic loops, but with different dimensions: the MI-Rx is larger then the MI-Tx. The MI-Tx is located in the opposite side of the REL electrode while the MI-Rx is fixed to the end of the boom. The MI-Tx and MI-Rx electrodes are AC coupled to the cables through a capacitive coupler (made of a PCB board mounted inside the boom stem). A thin wire (inside the boom stem) links the lead-wires (electrodes wiring external to the boom stem) to the capacitive coupler (0.2 pF). The MI-Rx coupler is linked by a triax cable without connectors to the HASI-I MI circuit. The MI-Tx coupler is linked by a coax cable to an SMA connector which is plugged into a jacket connector fixed in the HASI-B bracket. Then, via the Probe system harness, it is connected to the PWA-A (DPU s/s). A txiax cable directly links the RELaxation electrode to the HASI-I RP circuit.
The purpose the capacitive couplers is to introduce an impedance in the measuring circuit, much higher than the impedance of the electrode itself in the TITAN atmosphere, to deduce the mutual impedance from a simple voltage measurement.
The electrodes cables boundle comes out from the Boom stem through a small hole located close to the stem base and then is routed to the HINGE bracket plate. The boundle is not overall shielded. It passes internally to the Probe ring (when the DBS is integrated in the Probe) through a 360° shielded feedthrough which provides an air-tight seal for the external cabling. The feedthrough splits the boundle in three overall shielded cables: one is routed to the HASI-B bracket and the other separately to the HASI-I box.

All the PWA sensors and the relevant electronics are sensitive to **ESD.** **NOTE C: DBS ESD SENSITIVITY WARNING**

2.4.1.2 Hinge

The HINGE is the pivot for the deployment of the boom stem. The hinge contains a spring which deploys the boom when the retaining latch, in the Release Mechanism bracket, is released by the MCA activation. After deployment, the stem is maintained in deployment position by a Locking pin.

2.4.1.3 HASI-I box

Both the HASI-I boxes are identical. Two feedthroughs, located in one box side, allow the link between the electrodes cables and the internal electronics. Each HASI-I contains two DC coupled amplifiers and a relay for the RP experiment. With the relay switch, the RP sensor can be charged to +5Vdc, -5Vdc, GND or floating. The relay switching is under control of the PWA-S/W (refer to annex 2: pwa flight software) and it depends on which PWA experiment is running. The relay driver is in the PWA-A module (DPU s/s). The RP and MI-Rx electrodes preamplifiers are based on high impedance Operational Amplifier (AD549). The MI-Rx electrode and the relevant elec. have a band pass characteristic between 10 Hz to 10 KHz and an attenuation of -15 dB. The two HASI-I boxes are connected to the PWA-A via Probe system harness.

2.4.1.4 Release Mechanism bracket

The boom stem is normally held in the U-shaped retaining cavity by the Release mechanism (LATCH). When the MCA is activated (i.e. the DPU generates the current pulse), the retaining pin (MCA shaft) of the Latch leaves it free to move away from the cavity (helped by its spring). At this point the Boom stem is also free and by an the initial push given by a spring at the base of the retaining cavity it begins the opening. The force given by the hinge spring completes the deployment. The successful ejection of the stem is detected by an μ-switch which changes status. This status is read directly by the CDMS system ant the relevant report is part of the Probe system telemetry.

The MCA is an metallic body screwed to the RELEASE mechanism bracket. The μ-switch is also screwed on the bracket and it is located in proper position in order to detect the Boom opening. The μ-switch and the MCA bodies are shielded by a metal cage made of aluminium alloy. A single overall shielded cable connects both the MCA and the μ-switch leads to the jacket connector fixed on the HASI-B bracket. The cable passes via an air-tight 360° shielded feedthrough inside the Probe (when the DBS is installed in the Probe).

> Note that the micro-switches are not able to detect if the Booms are completely deployed (i.e. the two booms are in locked position).
>
> **NOTE D : DBS Micro-switches position**

2.4.2 DBS mechanical I/fs

Each HINGE bracket is attached to the Probe ring with 12 M3 screws. Each RELEASE Mechanism bracket is attached to the Probe ring with 10 M3 screws. Each HASI-I box is screwed by two M3 screws to the Probe Experiment platform.

2.4.3 DBS input power characteristic

2.4.3.1 Magnetic Coil Actuator

To operate the MCA devices, it is necessary to supply the pins 1 and 6 of P01 connectors (on the HASI-B# bracket) with a signal not exceeding the following characteristics:

- Voltage 26.5 ÷ 28 Volts
- Current 3 Amp (Maximum)
- Maximum Pulse duration 1 sec (one shoot)
- Maximum Number of Pulses 2
- Distance between two consecutive pulses ≥ 5 sec.

> If the pulse applied to the MCA through the P01 connector does not comply with these limits, the MCA itself is damaged for overheating.
>
> **NOTE E: MCA pulse warning**

2.4.3.2 Micro-switch

The input signal of the micro-switch devices, to be used to monitor the status, shall not exceed the following characteristics:

- 28 VDC (maximum voltage)
- 0.2 A (derated current value).

2.4.3.3 HASI-I box

The HASI-I box input voltages requirements are for the:

- Analog circuitry: ±13V (absolute minimum, for voltage output dynamics) to ±18V
- Relay: 5V ±10%.

The mean power consumption of each HASI-I is about 33 mW, while the peak power (i.e. when the relay is activated) is about 0.533W. The relay activation lasts 1 sec and it cycles every 64 sec driven by the PWA experiment manager (refer to annex 2: pwa flight software for details).

2.4.4 DBS sensors and electronics grounding

Each HASI-I electronics is floating respect to its box housing. The following sections summarise the grounding concept of each item consisting of the DBS (refer to page 10 of the AD(3)).

2.4.4.1 MI-Rx and RP electrodes grounding

The MI-Rx and RELaxation electrodes together with their cables are electrically insulated from the HINGE bracket structure. The outer screen of the two triax cables are grounded internally to the HASI-I box, while they are free on the electrode side.

2.4.4.2 MI-Tx electrodes

The MI-Tx electrode is electrically insulated from the HINGE structure. The coaxial cable shield is connected to the SMA outer contact and then is grounded to the HASI-B bracket when the connector is plugged in.

2.4.4.3 Electrodes cables

The MI-Rx, MI-Tx and RELaxation cables are only overall shielded internally to the Probe with a braid screen. The screen starts from the HINGE feedthrough where is divided into three different parts: two of them are routed separately to the HASI-I box feedthroughs (i.e. MI-Rx and RELaxation cables) and the last goes to the connector located on the HASI-B bracket (SMA type). All the screens are electrically insulated from the chassis (i.e. they are dressed with a sleeving), but they are grounded in both side in order to extend the Probe faraday cage up to HASI units:

- to the HINGE bracket through the HINGE feedthrough;
- to the HASI-I box through the HASI-I wall feedthroughs;
- to the HASI-B bracket through the outer contact of the SMA connector.

2.4.4.4 MCA and Micro-switch

The MCA and Micro-switch signals are insulated from the RELEASE Mechanism bracket. The cable is overall shielded. Externally to the Probe, the overall shield is grounded to the MCA and micro-switch caps and to the mounting flange of the RELEASE Mechanism bracket (before to pass inside the Probe). Internally to the Probe, the overall shield is grounded to the mounting flange of the RELEASE Mechanism bracket (360 closed metallic feedthrough) and to the HASI-B bracket via connector backshell.

2.4.5 DBS output signal characteristic

2.4.5.1 MCA

The MCA device coil resistance can be measured between pin 1 and pin 6 of P01 connector (HASI-B bracket) and its value is 7.8 Ohms ± 20%. Each device is activated by DPU with three bursts each made of three pulses; this activation sequence is repeated twice (refer to sect 3.7.1). The electrical characteristics of each pulse are reported in the sect. 3.2.8 of the RD(12).

2.4.5.2 Micro-switch

The µ-switch status can be read through connector P01 (on the HASI-B# bracket) pins 4 to 8.

- A resistance through these pins lower than 100 ohm means that the relevant BOOM is in STOWED configuration,
- a resistance higher than 10 MOhm means that the relevant BOOM is in DEPLOYED configuration.

2.4.5.3 HASI-I box

2.4.5.3.1 RELaxation contact

In the measurement of the RELaxation time constant, the two RELaxation electrodes are set to ±5V during 1 sec and then disconnected from DC voltage source and connected to the PWA electrometer which registrates the RELaxation of the electrode potential towards the equilibrium during 63 sec.
During the detection of a DC electric field in the vicinity of the spacecraft the RELaxation electrodes are set to 0 VDC during 1 sec and then connected to the PWA electrometer. The voltages measured will be representative of DC electric field close to the spacecraft.

2.4.5.3.2 RELaxation output

The output of the RELaxation electrode amplifiers depend on which voltage has been charged the electrode. The maximum voltage output is ±15.5 VDC, when the amplifier is saturated.

2.4.5.3.3 **MI-Rx** Electrode output

The output of the RX Electrode amplifiers depend on which voltage has been received by the electrode. The maximum voltage output is ±15.5 VDC, when the amplifier is saturated.

2.4.6 DBS input signal characteristic

2.4.6.1 MI-Tx Electrode

The input signal voltage to the SMA connector (on DBS side) depends on the Mutual Impedance measurement sequence driven by HASI software. In-fact a sine wave is generated and different voltages can be selected (20V, 2V or 0.2V).

3 HASI SOFTWARE DESCRIPTION

3.1 START-UP MODE DESCRIPTION

After bootstrap (caused by power-on and by NMI interrupt recovery routine execution and by reset due to or a watch-dog or a TC 'Soft Reset'), the microprocessor begins its start-up activities that consist in the following:

- Hardware devices warm-up: duration ≈ 300 msec
- Update the HASI-SW from 0x0000H to 0x8000H meaning that the HASI-S/W has started its START-UP activities;
- LOOK UP of possible reset causes (power-on or watch-dog or NMI) and reports them into the DPU START-UP packet (i.e. 'RESET-FLAG' field).
- Clear and initialise all the hardware interfaces.
- Copy the PROM DEFAULT values to RAM.
- **EEPROM test** which is composed by two steps: first EEPROM Override and then the EEPROM Parameters loading.

PROCEDURE A: EEPROM OVERRIDE

- ❍ the presence of the DDBL on both lines is verified:
- ❍ IF the received DDBLs are corrupted or no DDBL is received for 14 seconds the EEPROM Parameters are checked (i.e. goto EEPROM Parameters Loading);
- ❍ ELSE IF the received DDBL shows TITAN DESCENT flag and SPIN rate = 0xFFH, the EEPROM Parameters are checked (goto EEPROM Parameters loading);
- ❍ ELSE IF three DDBLs show FLIGHT or GROUND CHECKOUT flag with SPIN rate = 0xFF the EEPROM content is **NOT loaded in the RAM**. The EEPROM test finishes and an Event is recorded into the EVENT LOG packet (**EEPROM LOCKED** message).
- ❍ ELSE the EEPROM Parameters are checked (goto EEPROM Parameters loading).

PROCEDURE B: EEPROM PARAMETERS LOADING

- the EEPROM is switched-ON and the 'EEPROM SWITCHED-ON' message is recorded into the EVENT LOG packet.
- the EEPROM is scanned to search code (software patch) or parameters 'UPDATE BLOCKS' and to execute an integrity check (CRC verification) on each of them:
    - IF the integrity check is OK the parameter is loaded in the processor RAM and the result is also reported in the DPU START-U packet,
    - ELSE the parameter is not loaded in the processor RAM and the SW bit #13 will notify the failure which will be also reported in the DPU START-UP packet.
- the EEPROM is switched-OFF and the following messages are both recorded into the EVENT LOG packet: 'EEPROM SWITCHED-OFF' and 'EEPROM LATCH-UP'.

- Set the ACC range to HIGH resolution
- Check the ACC sampling rate. In case of incorrectness, an Event is recorded into a EVENT LOG packet
- **DDBL start-up test and HASI Operative mode**:
    - The DDBLs coming from both channels are examined, to decide which CDMU line shall be selected and which operative mode HASI shall enter after the START-UP. The test starts selecting the channel which is not determined by the CDMS Processor Valid signal as 'VALID'.
        - The test is executed according to the following criteria:
            - BCP time-out not occurred;
            - Packet ID validity (CDMU-A and B) (refer also to figure g);
            - Packet Sequence count congruity (the new sequence count shall be greater then the old one);
            - CRC correctness;
            - DDBL time-out (4 sec) not occurred;
        - Then the line determined by the CDMS Processor Valid signal as VALID is checked according to the same criteria. If any of these checks fail the DDBL reception on that line is considered 'RECEPTION NOT OK'.

In case the line selected by the Processor Valid results NOT OK the other line is checked a second time prior final selection.

NOTE F: START-UP DDBL test

- The **operative mode** is performed once at START-UP and it is determined according to the following matrix:

Table G: DDBL Start-up test: Operative mode selection matrix

DDBL B flag / DDBL A flag	ENTRY/DESCENT	CHECKOUT	RECEPTION NOT OK
ENTRY/DESCENT	TITAN DESCENT	TITAN DESCENT	TITAN DESCENT
CHECKOUT	TITAN DESCENT	CHECKOUT	CHECKOUT
RECEPTION NOT OK	TITAN DESCENT	CHECKOUT	TITAN DESCENT(*)

Remark: (*) in case of DDBL or BCP absence the HASI-S/W enters a BACKUP in which the mission program is kept on autonomously and it is driven by the Internal clock (refer to sect 3.7.2).

- **Conclusion**: the current CDMU channel is the one indicated by the Processor valid signal if any DDBLs errors are not detected in that channel; otherwise the channel not affected by 'RECEPTION NOT OK' is selected. In case of both Channel A and B results as 'RECEPTION NOT OK', HASI enters in BACK-UP mode (i.e. the mission is driven by the Internal clock) in which the DDBL test will be periodically repeated (refer to sections from 3.7.2 to 3.7.4).

- Initialise the internal HASI mission time (HMT); there are two cases:

HASI NOMINAL in which the HMT is initialised with the DDBL time; the HMT is then incremented every BCP reception (i.e. each 125 msec) and reloaded after DDBL reception with the DDBL time.

HASI BACKUP in which the HMT is initialised with the internal clock and then incremented every BCP reception (each 125 msec). In case of BCP absence, the HMT is incremented by the HASI provided BCP in which the reception is simulated every about 180 msec (refer to sect 3.7.2).

- Update the Status Word according to the **start-up** tests results

In the nominal case (DDBLs from both CDMU are correctly received), the START-UP activities last at minimum 20 sec: 14 sec for the EEPROM check plus 6 sec for the START-UP test and HASI operative mode selection.
The following table shows the approximate duration relevant to the different cases according to the results of the EEPROM and DDBL start-up tests:

Table H: START-UP mode duration

DDBL A & B OK	Valid DDBL OK Not Valid DDBL NOK	Valid DDBL NOK Not Valid DDBL OK	Valid DDBL NOK Not Valid DDBL NOK
20 sec	80 sec	140 sec	200 sec

The 'Valid DDBL' refers to the DDBL coming from the CDMU selected by the Processor Valid status.
A longer period may be required in order to load EEPROM parameters (3.28 msec for the CRC calculation of each EEPROM parameter word plus about 20 msec for each parameter updating).

3.1.1 START-UP MODE REPORT

The HASI START-UP activities are summarised in the Status Word (refer to sect. 4.1.1) and in the following TM packets: DPU START-UP, EVENT LOG and HC2S (only in the first field). In the nominal mission, even if they are created first, they **are not transmitted** until one of the following condition is satisfied:

- The DPU START-UP packet type is generated at each HASI power-on or reset. The number of the DPU START-UP packets depends how many parameters (variables or tables or software patch) have been loaded into RAM from EEPROM memory: greater than 10 parameters implies more than one packet. The DPU START-UP packets remain stored in RAM till **Tdata** (i.e. T0+1min). Then they are transmitted via telemetry to ground. When no parameters nor software patch have to be loaded into RAM from EEPROM, only a packet is produced and it contains the 'RESET-FLAG' message in the first field. Otherwise this packet contains a 'PAR-LOAD-REPORT' for each EEPROM parameter loaded into RAM. When the power-on or reset happen after **Tdata**, HASI produces several DPU START-UP one for each message: the first contains the 'RESET-FLAG' message while the other contain one 'PAR-LOAD-REPORT' message each. In this case the total number of packets depends on the number of EEPROM parameter loaded into RAM.
- The EVENT LOG packet is stored in RAM till the packet is completed (i.e. it must be generated more than 16 events) then is transmitted. If is not complete, the EVENT LOG is transmitted if the deactivation flag in the DDBL is set (only CHECKOUT mode) or when HASI reaches the IMPACT state.
- The HC2S packet is stored in RAM till the packet is completed (i.e. 112 sec after the START-UP completion).

The nominal HASI START-UP report is shown in the following figures: the first reports the DPU START-UP content, the second the EVENT LOG and the last the HC2S as they are displayed on the IWS monitor (refer to RD(18)).

Figure C: START-UP report - DPU START-UP packet

```
%M 21:06:07 -0:17:46.000 A#01145ci DPU START-UP
%E 21:06:07 -0:17:46.000 Reset flag "~P B++@ +_" received.
%E 21:06:07 -0:17:46.000 PAR PROGR #255 LOADED
```

The first field in each line indicates the window where the message is displayed in the IWS monitor: **%M** indicates 'Message window', **%E** the 'Event window' and **%W** the 'Warning window'. The two time values, in each line, correspond respectively to the IWS time when it receives the packet and to the packet Mission Time (i.e. the HMT time of the first field in the packet; refer to sect 3.6.2 and 5) The time "-0:17:46.000", where the '-' marks the time before T0, is the HASI nominal power-ON time (**Thasi**). The HASI mission time is initialised with DDBL time after START-UP mode completion; therefore the DPU START-UP packets data and all the data created during START-UP are marked with this time, even if the HASI is switched-ON after **Thasi**. Nevertheless, this time could be modified by parameter uploading in EEPROM. The other information are relevant to the packet header:

- the TM channel (A, it means CDMU-A);

- the packet sequence count (#01145)
- the flag **'i'** indicating that packet is not full (refer to sect 5);
- the flag **'c'** indicating that the packet is a copy (refer to sect 5);
- the packet format (DPU START-UP).

and to its content:

- "**P B++@ +_"** means the START-UP was caused by a Power-ON.
- "**PAR PROGR #255 LOADED**" means that the parameter #255 (i.e. the 'MCA control register' patch, refer to AD(3) page 6N) was successfully loaded in RAM. Note that the IWS software does not display the complete content of the 'PAR-LOAD-REPORT' field; in fact the RAM parameter address, the size and the CRC are not shown in the line, but they still available into the packet.

Figure D: START-UP report - EVENT LOG packet

```
%M 23:18:39 -0:17:46.000 A#05807i DPU HK EVENT LOG

-0:17:46.000  DDBL time wrong           -|
-0:17:46.000  EEPROM SWITCHED ON          |
-0:17:46.000  EEPROM SWITCHED OFF        START-UP
-0:17:46.000  EEPROM LATCH-UP             |
-0:17:47.375  DDBL time wrong           -|
-0:24:18.500  ACC range set COARSE
-0:28:59.875  T0
-0:28:59.875  DDBL time wrong
```

figure d reports (till the **'ACC range set COARSE'** message) a nominal events sequence from HASI START-UP to T0 transition. The recorded sequence has been taken during one CO#1 mission simulation performed at DASA (during Probe system AIV) in which the HASI power-On was 5 min before T0:

- The first **'DDBL time wrong'** message is related to the DDBL check performed during **EEPROM test**: the received DDBL time is not monotone respect to the START-UP Mission time. In other words the difference between the START-UP Mission time and the actual DDBL time is greater then 2 sec. The message is time tag with the START-UP HMT (i.e. -0:17:46.000, where '-' is T<T0). Note: the HASI Mission time is initialised with the received DDBL time at the end of the START-UP only.
- The messages sequence **'EEPROM SWITCHED-ON'**, **'EEPROM SWITCHED-OFF'** and **'EEPROM LATCH-UP'** identifies that the **EEPROM loading** is performed and it is correctly finished. Note: if the 'LATCH-UP' message happens before the 'SWITCHED-OFF', the EEPROM has been autonomously switched OFF by the current limiter and **EEPROM loading** may be not correctly executed.
- The last **'DDBL time wrong'** message is related to **the DDBL test during START-UP**: the received DDBL time is not monotone respect to the current HMT (i.e. -0:17:46.000, where '-' is T<T0). The Mission time is now initialised with the received DDBL time.

The **‘ACC range set COARSE’** message means that the FINE range Xservo Low gain at the time -0:24:18.500 was saturated (refer to sect 3.8.5) and therefore the HASI-S/W set the range to COARSE.
The **‘T0’** and **‘DDBL time wrong’** messages are the result of the T0 transition in the DDBL information. The two events are time tag with the HMT before the T0 transition; in this case T0 is happened at -0:29:00.000 DDBL time.

Figure E: START-UP report - HC2S packet

```
%M 21:02:03 -0:24:19.000 A#00326c DPU HC RATE 2 sec

%W 21:02:03 -0:24:19.000 -0:24:19.000 DPU HC OK
%W 21:02:03 -0:24:19.000 -0:24:19.000 PPI HKV1 HC OK
%W 21:02:03 -0:24:19.000 -0:24:19.000 PPI HKV2 HC OK
%W 21:02:03 -0:24:19.000 -0:24:19.000 PPI Time-out OK
%W 21:02:03 -0:24:19.000 -0:24:19.000 ADC2 Converter HC OK
%W 21:02:03 -0:24:19.000 -0:24:19.000 DDBL Line Failure OK
%W 21:02:03 -0:24:19.000 -0:24:19.000 BCP Line Failure OK
%E 21:02:03 -0:24:19.000 -0:24:19.000 MCA 2 Status OFF
%E 21:02:03 -0:24:19.000 -0:24:19.000 MCA 1 Status OFF
%W 21:02:03 -0:24:19.000 -0:24:19.000 PWA Data Link HC OK
%E 21:02:03 -0:24:19.000 -0:24:19.000 PWA Status HC science
```

The Nominal HASI HC2S packet content is shown in the figure e. The first line identifies the TM packet (HC2S format) in which the next information are extracted. The other lines show the IWS processed information extracted from this packet. Each line reports three time values that correspond to:

- the IWS time when the packet #326 is received;
- the packet time tag (in HMT);
- the HMT related to the next message on each line calculated according to the rule in section 3.6.2.1; in this case, the message reports the first H/K message (i.e. field) in the packet.

Refer to the sect 3.8.5 for detailed information. The not reported information are the following:

- the ACC range is HIGH (i.e. COARSE)
- the Processor Valid status is A;
- the current selected CDMU is A;
- the ENERGISE (Protected Power) is OFF.

3.2 TITAN DESCENT MODE DESCRIPTION

In this mode HASI behaves according to the Mission timelines reported in the following tables. The **NOMINAL Timeline** is when HASI is driven by the BCP pulse and by the DDBL information (time and altitude). The **BACKUP timeline** is when HASI is in BACKUP sub-mode (i.e. both channel A and B DDBLs are not present or they are corrupted) and it is driven by the BCP pulse (if present) or by the HASI provided BCP. The same BACKUP timeline is when HASI is not receiving BCP pulse (HASI BACKUP sub-mode) and one the two DDBL is correctly received; in this case the HASI is driven by the DDBL information and by the HASI provided BCP.

When HASI is in **NOMINAL**, the HASI mission time (HMT) is incremented after every BCP reception and it is loaded with the DDBL time. Therefore, the internal states change using the DDBL information (time and altitude) and the Servo ACCelerometer data (i.e. to detect the Probe Impact). All the states are reported in the Status Word, except the DESCENT 2nd and 3rd states.

When HASI is in **BACKUP** (i.e. in failure case, refer to sect 3.7.2), the HASI mission time (HMT) is substituted by the internal clock and it is incremented after every BCP reception (i.e. every 125 msec). The internal states change using this HMT time and the Servo ACCelerometer data (i.e. to detect the Probe Impact). No altitude reconstruction is performed in BACKUP. No delay time are envisaged respect to the BACKUP Timeline. If any BCP (channel A and B) are received, HASI is still in BACKUP and the HMT is incremented by the HASI provided BCP (one every about 180 msec). In this case, the HASI mission evolves slowly respect to the previous case. All the states are reported in the Status Word, except the DESCENT 2nd and 3rd states.

In case of failure in which the Probe is powered by G-switches, the HASI is powered after T0. If the **DDBL start-up test** is successfully completed, the HASI TITAN mission starts in DESCENT 1st state or in the DESCENT 2nd state (i.e. after about 180 sec after the Power-On). It depends on the duration of the START-UP mode (refer to sect 3.1). Nevertheless, this duration could be modified via parameter uploading in EEPROM. If the **DDBL start-up test** is not successfully completed (i.e. both channel A and B DDBLs are not present or they are corrupted), the HASI TITAN BACKUP mission starts in ENTRY state and it evolves according to the BACKUP Timeline table.

The bold type event name in the 'EVENT NAME' column are the one modified uploading parameters in EEPROM memory.

As soon as the TITAN DESCENT MODE is initiated, no other mode is taken in account by HASI: only a new power-on or reset restarts HASI.

NOTE G: TITAN DESCENT Warning

Table I: NOMINAL MISSION TIMELINE

DDBL TIME or ALTITUDE	EVENT NAME	HASI EVENT DESCRIPTION
17:46	**Thasi** (-5min before Entry)	HASI power-ON **START-UP** mode start
18:06	-----	**TITAN DESCENT** mode start (**ENTRY** state)
21:30	**TaccSample**	ACC sampling start
28:00 00:00	T0 -----	Mortar firing DDBL time reset
00:43	-----	2nd HASI Power on
00:49.655	Teon	Protected power on
01:00	**Tdata** **Td1**	TEM sampling start Low PREssure measurement start 1st BOOM release attempt window start (**DESCENT 1st** state)
01:40	**Td1w**	1st BOOM release attempt window end
02:20	**Td2**	2nd BOOM release attempt widow start
02:30	**TdataH**	Probe relay data link is OK. PWA sampling (mode A) start (**DESCENT 2nd** state)
03:20.645	**Teoff**	2nd BOOM release attempt widow start Protected power off
10:00	Tswitch	Switch HASI TM packet allocation.
32:00	**Tradar**	Proximity sensor sampling (PWA mode C) start (**DESCENT 3rd** state)
1:15:00	**Tmid**	Medium PREssure measurement start
1:45:00	**Thigh**	High PREssure measurement start
7 Km	-----	PWA mode D
1 Km (132 min (*))	-----	ACC TM data stop (**IMPACT** state)
200 m	-----	PWA mode D, with RELaxation experiment stopped
Impact detected by ACC servo (134 min (*))	Timpact	ACC impact trace PWA mode G ACC TM data restart (**SURFACE** state)
+TBD min	Tloss	Loss of Radio Link (END OF MISSION)

(*) DDBL estimated time based on the Nominal Mission profile (refer to AD(4)).

Table J: BACKUP MODE TIMELINE

HASI MISSION TIME	EVENT NAME	HASI EVENT DESCRIPTION
17:46	**Thasi** (-5min before Entry)	HASI power-ON **START-UP** mode start
18:06	-----	**TITAN DESCENT** mode start (**ENTRY** state)
21:30	**TaccSample**	ACC sampling start
28:00	**Predicted-T0**	HASI Mission time reset
00:00	----	
00:43	-----	2nd HASI Power on
00:49.655	Teon	Protected power on
01:00	**Tdata** **Td1**	TEM sampling start Low PREssure measurement start 1st BOOM release attempt widow start (**DESCENT 1st** state)
01:40	**Td1w**	1st BOOM release attempt window stop
02:20	**Td2**	2nd BOOM release attempt start
02:30	**TdataH**	Probe relay data link is OK PWA sampling (mode A) start (**DESCENT 2nd** state)
03:20.645	**Teoff**	2nd BOOM release attempt stop Protected power off
10:00	Tswitch	Switch HASI TM packet allocation
32:00	**Tradar**	Proximity sensor sampling (PWA mode D) start (**DESCENT 3rd** state)
1:15:00	**Tmid**	Medium pressure measurement start
1:45:00	**Thigh**	High pressure measurement start
1:59:00	**Tproximity**	ACC TM data stop (**IMPACT** state)
Impact detected by ACC servo (134 min (*))	Timpact	ACC impact trace. PWA mode G. ACC TM data restart. (**SURFACE** state)
+TBD min	Tloss	Loss of Radio Link (END OF MISSION)

(*) DDBL estimated time based on the Nominal Mission profile (refer to AD(4)).

3.2.1 TITAN DESCENT MODE STATES DESCRIPTION

The figure nn shows the flow chart of the HASI states evolution during the mission. The PWA internal modes are also reported. After Power-On/Reset, the START-UP mode is entered and at the end the HASI Mission time (‘**T**’) is initialised to:

- the current DDBL time (HASI NOMINAL sub-mode);
- the time -0:17:46.000 (where ‘-’ identifies time < T0) when HASI is in BACKUP sub-mode.

Then the HASI Mission time (‘**T**’) is incremented every BCP reception and loaded with the DDBL time information (NOMINAL sub-mode) or it is internally incremented by the HASI-S/W (BACKUP sub-mode, refer to sect. 3.7.2). The **Altitude** is one from the DDBL information, while no altitude reconstruction is performed when the HASI is in BACKUP sub-mode. In this case, the T0 transition and the IMPACT state are triggered using the internal HASI Mission time:

- T0 transition (i.e. Flag_T0 = TRUE) is met when the HMT reaches the predetermined time **PredictedT0** (i.e. 28 min);
- IMPACT state is detected when the HMT time reaches the predetermined time **Tproximity** (119 min T>T0); this time is the predicted time when the altitude passes 1 Km in the Minimum TITAN Descent profile (refer to AD(4)).

Note that in HASI BACKUP and after DESCENT 2nd state, the PWA enters in Mode D with the RP OFF (since the altitude is 0 m) till the HASI passes into SURFACE state.

From **Thasi** to **TaccSample** (**ENTRY** state):

The TM starts about 112 seconds after START-UP mode completion. The TM rate is in accordance with the CDMU polling. The reading of the health check and housekeeping parameters starts (e.g. DPU box temp.). After START-UP completion, the PWA starts in Entry mode: no experiments are performed (refer to annex 3: pwa fm users document).

From **TaccSample** to **Tdata** (**ENTRY** state):

After **TaccSample**, HASI starts to sample the ACCelerometer sensors (X servo, X, Y and Z piezo) together with the ACC housekeeping data (Temp 1 & 2) and the HASI health checks. The sampled data are stored in the RAM for later re-transmission (i.e. after DESCENT 2nd state) as original and in the mean while are also transmitted as copy. The PWA continues in Entry mode.

From **Tdata** to **TdataH** (**DESCENT 1st** state):

At Tdata, HASI starts to read the PREssure and TEMperature sensors, while the ACC are differently sampled. Till TdataH, all the HASI data remains stored in the memory. Moreover the first and second BOOM release attempts are executed. The PWA continues in Entry mode.

From **TdataH** to **Tradar** (**DESCENT 2nd** state):

HASI starts to re-transmit the stored data together with the real time acquired data. In-fact HASI-S/W continues to acquire the PREssure, TEMperature and ACCelerometer sensors and housekeepings. After TdataH the PWA starts in mode A and it performs the AC_DC, MI and RP experiments (refer to annex 3: pwa fm users document). From TdataH till the TM queues are empty (about 7.5 minutes after T0), the HASI TM rate is 14 packs for cycle (for each CDMU), after is about 9 packs for cycle (refer to the sect. 3.6.1).

From **Tradar** to **Last Km** (**DESCENT 3rd** state):

HASI continues to acquire and to transmit the PRE, TEM, PWA and ACC sensors data and the housekeepings data. The PWA passes into mode C (Proximity sensor sampling) and it switches to mode D at 7 Km altitude. The AC_DC_AU, MI, RAE and RP experiments are performed (refer to annex 3: pwa fm users document). The PRE measure passes from Low to Medium up to High pressure measurement.

From **Last Km** to Probe **Impact detection** (**IMPACT** state):

When HASI recognises the Last km reading DDBL altitude only. HASI-S/W continues to acquire and to transmit the PRE, PWA and TEM sensors. The PWA continues in mode D. At 200m from the Probe Impact, reading the DDBL altitude, the PWA stops the REL Probe relays (RP experiment). The ACC sensors data are sampled to trigger the Probe Impact event, but data are not telemetred. The TEM changes polling rate also (only TEM-F1 and TEM-F2 are sampled).

From Probe **Impact detection** to **Tloss** (**SURFACE** state):

When HASI recognises the Probe Impact using the Xservo data (refer to 3.8.2.4), the Impact time (in HMT) is recorded in one EVENT LOG message and it is immediately transmitted. Afterwards the ACC trace (Xpiezo, Ypiezo and Zpiezo) is transmitted and then the HASI-S/W restarts to acquire and to transmit the PWA, PRE, TEM and ACC sensors as in DESCENT 3rd state. The PWA passes into mode G. The MI-multifrequecies and AC_DC_AU experiments are performed (refer to annex 3: pwa fm users document).

3.3 CHECK-OUT MODE DESCRIPTION

When in CHECKOUT mode, HASI does not distinguish between GROUND and FLIGHT CHECKOUT. The HASI-S/W behaves exactly as in TITAN mode except for the following:

- the BOOM RELEASE is not performed;
- Telecommands are accepted and executed.

3.4 TC EXECUTION MODE DESCRIPTION

3.4.1 TELECOMMANDS MANAGEMENT

HASI accepts commands in CHECKOUT mode. HASI does not distinguish between GROUND and FLIGHT CHECKOUT.

At BCP rate and after delay of 80 msec, the HASI-S/W examines the ML buffer to check the presence of DDBL and/or TC.. Since the HASI Operating System tick is 10msec, the minimum delay time is 70msec. The maximum delay time is 85msec taking into account the priority of the ML task which performs this check.

Remark: DDBLs and/or TC received in the examination window (from 70 msec to 85 msec after BCP) are lost. Since DDBL dispatching is high priority task in CDMU activity, the DDBL arrives early after BCP. Problems may happen when a TC is sent or more often when TC is sent in the same CUT of one DDBL.

figure f shows the Flow chart of the Memory Load activities. The HASI-S/W checks first if a DDBL is received (ML word counter is equal to 7), second if a TC is received (ML word counter is equal to 63) and then if the ML buffer contains a different number of words. In this case, the HASI S/W verifies if a sequence of DDBL plus TC or TC plus DDBL is received. In the other case (ML word counter greater or less than 71), the ML buffer data are discarded and then DDBL or TC would be lost.

The following summary cases could happen:

- **CASE 1**: both DDBL and TC are accepted;
- **CASE 2**: only DDBL is discarded (very rare condition);
- **CASE 3**: only TC is discarded;
- **CASE 4**: both TC and DDBL are discarded;
- **CASE 5**: both TC and DDBL are correctly received, but HASI-S/W does not dispatch the SB to the PWA within 2.1 sec (refer to sect 3.8.4.2 and 3.8.4.5).

In the second and fourth cases, HASI switches over to the not selected CDMU channel. If the DDBL information is corrected (refer to the DDBL test section 3.1), it selects definitively the new CDMU channel otherwise it switches back to the original CDMU. This CDMU switching sequence is reported in the:

EVENT LOG packet by means of the following events: '**TC RX incorrect'** and **DDBL NOK line A or B**, and
HC2S packets by means of the following bits: **DDBL line failure** and **Current CDMU selection**.

3.4.2 TC LAYOUT CHECK

When a TC is recognised, the following checks will be executed to establish its correctness (refer to figure g):

- TC PID congruence according to the selected CDMU (A or B);
- TC sequence count ≥ sequence count of last TC received (it starts from 0);
- TC length as specified (a TC is composed by 63 words);
- TC CRC correctness.

If any of these conditions is satisfied, the TC is considered wrong and it is discarded. A bit is set in the HASI-SW showing LAST TC = WRONG and a **'TC RX incorrect'** message event is reported in the EVENT LOG packet. The LAST TC bit is reset (LAST TC = OK) in the HASI-SW (refer to sect 4) as soon as a new TC is successfully received only. Taking into account the CRC calculation of a single word of 3msec, the TC check takes about 0.2 sec (i.e. it is more then the BCP rate).

The final report is also valid in the HASI-SW bits (i.e. 'Sub-Mode' and 'CDMU correctly used' bits refer to 4).

Note <u>each TC must be sent on both CDMU channels at the same time, because the HASI may change during normal work the selected CDMU channel.</u>

In the last case, the SB is sent to the PWA to late and therefore it is not accepted by the PWA. Therefore PWA goes in time-out. This **PWA time-out event** is reported in the EVENT LOG and in the HC2S (PWA link status bit). This bit may be occasionally shown in the HASI-SW also.

3.4.3 TELECOMMAND CONTENT CHECK

After a correctly received TC, a TC ECHO packet is sent (refer to 5.6). The Echo contains all the <u>Packet Data Field</u> bytes as they are received (refer to 6.1.1). Because the TM packet length, the last byte of the <u>Packet Data Field</u> may be lost (i.e. when the TC is completely filled).

Then the TC content is verified (refer to AD(3)) and if is meaningful, it is executed. When the TC is not in the list of the ones allowed for HASI (refer to the <u>Command Header</u>), the TC is discarded and the '**Unknown TC**' message event is reported in the EVENT LOG packet.

The HASI Telecommands are divided in two main classes according to their impact on the CHECKOUT mode (refer to sect 6.2):

- **SET-UP** TCs that do not require an HASI operative mode change;
- **EXECUTABLE** TCs that require an HASI operative mode change.

The TCs received in TITAN mode are always discarded.

When HASI receives an **EXECUTABLE** TC, the CHECKOUT mode is suspended and the **TC EXECUTION** mode is entered. The TC is executed with higher priority respect to the science acquisition loop. At the end of the TC EXECUTION mode, the HASI returns to CHECKOUT mode and it is ready to receive a new TC. The PWA acquisition loop (task) is the one more frequently affected by the TC EXECUTION. In fact its activity has a period of 2 sec without possibility of the large time delay when it starts (e.g. 0.1 sec, refer to sect 3.8.4.2). The other acquisition loops can be suspended without major data loss. For this reason, it may happen a **PWA time-out** event during the DB reception. This event is reported in the EVENT LOG (PWA time-out message) and into HC2S (PWA link status bit). It may be shown in the HASI-SW also. After DB reception stops, the HASI-S/W sent a **CORRUPTED PWA packet** with data '0x20'. Moreover during a **'MEMORY**

DUMP' TC, in order to have sufficient TM capability, the PWA activity stops and restarts at the end of the TC execution.

3.4.4 TELECOMMAND RULES

The following notes have to be considered as HASI experiment in Flight constraint and their meaning has be to translated in the Flight rules. The use of TC is restricted, during CRUISE CHECKOUT, to special investigation or to load memory patch or modify parameters. The HASI behaviour is checked running a Nominal Checkout mission.

- **HASI can receive only ONE Telecommand for each CDMS cycle (16 sec).**
- **HASI requires to send a TC copy on both CDMU channels (time delay between the two commands is meaningful).**
- **HASI requires each HASI TC to be sent three times.**

NOTE H: HASI TELECOMMAND FLIGHT RULES

Figure F: Memory Load Management FLOW CHART

Figure G: DDBL/TC correctness test

3.5 HASI OPERATIVE MODE/SUB-MODES/STATES SUMMARY

The summary of the HASI possible operative modes and states is hereafter reported. According to the mission events and DDBL information (mission flags, time and altitude information), the HASI-S/W addresses the following observable modes and states:

Table K: HASI Operative mode summary table

MODE	SUB-MODE	STATE
START-UP	NA	NA
TITAN DESCENT	NOMINAL/BACKUP	ENTRY/DESCENT1/DESCENT2 /DESCENT3/IMPACT/SURFACE
CHECKOUT	NOMINAL/BACKUP	ENTRY/DESCENT1/DESCENT2 /DESCENT3/IMPACT/SURFACE
TELECOMMAND EXECUTION	NOMINAL/BACKUP	ENTRY/DESCENT1/DESCENT2 /DESCENT3/IMPACT/SURFACE

The following events cause HASI to change operative mode:

- Power on / reset
- Reset from watch-dog
- NMI interrupt
- DDBL reception error during START-UP
- DDBL phases information at START-UP
- Executable Telecommands
- Reset Telecommand.

The following events cause HASI to change sub-mode inside an operative mode:

- DDBL reception errors
- DDBL time-out
- BCP time-out.

The following events cause HASI to change state inside an operative mode:

- HASI Mission time evolution (Tdata, TdataH and Tradar)
- Altimeter information (if the DDBL is present)
- Impact detection.

The mode changes are specified in the following table; the state changes are detailed in the sect 3.2.1.

Table L: HASI mode transition

Destination Source	START-UP	TITAN DESCENT	CHECKOUT	TC EXECUTION
START-UP	- Power on - H/W reset - NMI interrupt	START-UP DDBL test = DESCENT	START-UP DDBL test = CHECKOUT	---
TITAN DESCENT	- H/W reset - NMI interrupt	---	---	---
CHECKOUT	- H/W reset - NMI interrupt	---	---	Executable Telecommand
TC EXECUTION	- H/W reset - NMI Interrupt - Reset TC	---	End of TC execution	---

3.6 HASI TELEMETRY CHARACTERISTICS

3.6.1 TELEMETRY CAPABILITY

The HASI-S/W provides two independent TM queues: one dedicated to each CDMU channel. The TM packet queues are handled by the internal Operating System which allocates dynamically the memory for the packets. The memory remains allocated until the TM packet is discarded from the queue.
As consequence of the HASI DPU RAM memory size and usage, each TM queue has the capability at maximum to store 130 packets.
In the Nominal TITAN Descent mission, few seconds (about 132) after HASI power ON, although the radio link is not sure, the HASI Telemetry starts (both CDMU-A and CDMU-B). The acquired data, mainly HASI housekeeping and ACC science, are transmitted as 'REDUNDANT' but remain always stored in the memory. In this phase HASI, if polled, is able to provide through telemetry much more packets than the EID-A allocated (14 packets/cycle), even if they contain old acquired data (stored in the memory). This condition remains unchanged until **TdataH**.
Starting from **TdataH** all the stored packets are re-transmitted as 'ORIGINAL' not necessarily in the order of their acquisition. The real time data acquired after **TdataH** are transmitted after the ‘ORIGINAL’ packets transmission is completed. Also in this phase HASI, if polled, is able to provide through telemetry much more packets than the allocated (i.e. 9 packets for CDMU cycle) but only until the TM queues are empty: from this point HASI will provide no more packets for cycle than the allocated amount. In the following condition:

- **Thasi** at DDBL time = 17:46 min (T<T0),
- T0 transition at DDBL time = 28 min,
- CDMU polling rate = 14 packets/cycle,

at about 7.5 minutes after T0, the HASI TM queues are almost empty and HASI delivers only ≈8.99 packets/cycle (average value) which is the current packets production rate. This Packet production rate is maintained till the start of the IMPACT state. During the IMPACT state, since the packet data production is a bit lower, the queues tend to empty out and to be almost empty at the Probe impact. This feature has been designed in order to obtain that most of the HASI packets are already telemetred prior to the Probe Impact (to which HASI could not survive).

The CDMU-B is considered redundant to the CDMU-A. The same packet content will be transmitted both on the CDMU-A TM channel and on the CDMU-B TM channel. Only for the PWA science packets a different redundancy method is applied: the same type of data is sent on both channels such that if both packets arrives to the ground station the data reconstruction has double definition. An sufficient definition in the data reconstruction is obtained also if the packets from one channel are lost. This rules is followed by all the PWA experiments, except for the RP experiment, where the redundancy is performed at sensor level: in channel B is transmitted only the RP data relevant to the BOOM #1 while in channel A is transmitted the RP data relevant to the BOOM #2.

During the ENTRY and DESCENT 1st states (i.e. till **TdataH**), the TM packets in each queue are not ordered respect to the production time (expressed in DDBL time). In-fact as soon as a packet is sent, it is back in the queue and it will be mixed with a real time created packet (i.e. the most recent acquired data). Since each packet is time stamped, the packets will be re-ordered on ground (refer to sect 3.6.2).

In any condition, when a TM queue is full (i.e. 130 packets are stored), the last acquired data (i.e. TM packet) are lost; i.e. no more packets will be queued until a packet is telemetred.

During the system tests at DASA, it has been experienced in CHECKOUT mode a simulated descent (the one with VALID line switches on CDMU-B by time-out) with a not nominal T0 transition. The T0 happened at least 15 minutes after the estimated time of the worst case Titan Descent scenario (refer to section 3.7.6) which has been tested at ground. The same condition will also happen in the flight test. The consequence is that the RAM memory area, allocated for the TM handling, becomes full. This situation is important for the HASI-S/W. The results are that the HASI behaviour is not completely nominal (e.g. it has been experienced that PPI Health Check session packets have a not meaningful timetag value, while the sensors data are completely corrected) although in healthy condition.

Note: in CHECKOUT mode, in order to avoid the RAM becomes full it is sufficient to send a TC (e.g. ‘TEST MODE #0’ TC, refer to 6), after the HASI power-ON. The TM packet store capability will terminate and therefore the RAM will becomes empty.

However, the condition for which the TM queues are full, will be not experienced during TITAN descent since the sensors production rates have been designed in order to avoid it (refer to 3.7.6).

In the following table is reported the TM data rate for each sensors during the DESCENT 2nd and 3rd states.

Table M: HASI TM capabilities summary table

	DESCENT 2nd state		DESCENT 3rd state	
	EID-B (packets/cycle)	**FM/FS** (packets/cycle)	EID-B (packets/cycle)	**FM/FS** (packets/cycle)
PRE	0.5	**0.525**	0.5	**0.525**
TEM	0.5	**0.718**	0.5	**0.718**
ACC	1.5	**1.59**	0.75	**0.753**
PWA	6	**6**	6.75	**6.75**
HOUSEKEEPING	0.2	**0.161**	0.2	**0.161**
Grand Total	8.7	**8.99**	8.7	**8.91**

Note: these values are average value calculated using the following formula:

V = (total number of packets) / (HASI state duration in CDMU cycle)

where: V is expressed in (packets/cycle) and CDMU cycle = 16 sec;
HASI state duration is according to table i.

3.6.1.1 HASI Telemetry in the HUYGENS Probe

The section summarises some information about the HASI telemetry behaviour during the NOMINAL TITAN Descent till IMPACT state. The use of these information allow to understand the HASI telemetry in different configuration (e.g. GROUND or FLIGHT checkout). The TM operation will be analysed within an CDMU cycle.

The HASI TM handling is divided in two phases: before and after DESCENT 2nd state (i.e. DDBL time T0+2.5 min).

Before DESCENT 2nd state and when the first packet is available, the TM queues perform as they are full (i.e. no packets will be discarded from the queues after they will be sent) and therefore the HASI is capable to send packets as required by each CDMU. For example if the CDMU demands

80 packets (CDMU maximum request is 108 packets in 16 sec), HASI will deliver packets according. The time between two consecutive packets is mainly driven by CDMU. In the nominal polling scheme, in case of an Probe experiment does not provide a requested packet, the CDMU checks an other experiment and, if ready, it acquires its packet. Then the CDMU continues with the nominal polling scheme. In this behaviour, HASI TM amount can be not constant in a CDMU cycle. It depends by the TM production of the other Probe Experiment. Before T0, only GCMS and HASI are powered ON. The total amount (108 packets) are shared between the two. When GCMS decreases the TM production, the HASI increases. After T0, according to the EID-A power-ON timeline, the other experiments will be switched ON also. When all the experiments are switched on and they have the expected production (i.e. the one reported in EID-A), HASI decreases up to 14 packets for each cycle. This rate remain constant till the DESCENT 1st state end.

After DESCENT 2nd state (DDBL time > **TdataH**), HASI provides the TM packets discarding the TM queues. Consequently each TM queue becomes empty, since the real time production rate is lower than the polling reading (i.e. ≈9 packets/cycle with respect to the Probe capability of 14 packets/cycle). The time to empty the TM queue depends by the number of packets in the memory (i.e. by the duration of previous states) and by the number of packets read by CDMU. In the ENTRY-NOMINAL case (see sect. 3.7.6 and 3.2) and with the CDMU nominal polling rate (14 packets every 16 seconds), it is expected at about T0+7.5 min.

After T0+2.5min, the HASI production rate (reported in the section 3.6.1) should be considered as AVERAGE value. As soon as a packet is completed, the packet is queued and it is ready to be transmitted. In a CDMU cycle, the HASI produces packets as following rules:

- **PWA**: 6 packets each CDMU cycle till Tradar;
6, 7 or 8 packets each CDMU till mission end;

- **HOUSEKEEPING**, **TEMperature**, **ACCelerometer** and **PREssure**: The production rate is NOT a multiple of a CDMU cycle (e.g. TEM sensors produce 4 packets in 5.625 CDMU cycle);

- **Packet ready NOK**: The HASI average production does not fulfil completely the EID-A allocated polling rate (8.91 packets/cycle with respect to 9 packets/cycle) and it means HASI does not deliver packets as requested in the whole mission;

- **NONE EVENT packet**: The nominal case does not consider some HASI internal events that they may produces packets (e.g. PWA time-out, PPI time-out, DDBL time frozen etc.);

- **NONE ML failure**: The sensors data rates are mainly driven by the Memory Load timing (2 sec of the DDBL timing and 125 msec of the BCP timing);

- **NONE h/w failure**: The expected sensors production rates depend by the failure of the dedicated data acquisition hardware (e.g. in case of time-out in the A/D converter of ACC sensor, the ACC rates decreases).

Up to the switch to the next polling rate table (Experiment Polling Table #1 ends at about T0+10min according to EID-A document), the CDMU reading is faster than the HASI production. Taking into account the above rules and after the queues are empty, it can happen that:

- HASI has ready PWA packets only: the HASI production rate with respect to the CDMU drops to 6 packets;
- HASI has ready PWA plus the other sensors packets: the HASI production rate with respect to CDMU increases up to 13 packets.

After the polling table switches, the CDMU polling rate becomes 9 packets for cycle till the end of the mission. The CDMU reading is closed to the data production and the HASI TM rate becomes more or less constant till the IMPACT state. In fact, according to the HASI data production rate, there are three cases:

- TM queue contains more than 9 packets and the CDMU reads more the expected packets (CDMU polling capability): the HASI TM rate increases while the queue is discarded more faster then expected.
- TM queue contains more than 9 packets and the CDMU reads the expected packets: the HASI TM rate remains constant.
- TM queue contains less than 9 packets or the TM queue was discarded more faster than the expected: for one cycle or more the HASI TM rate decreases up to the minimum (6 or 7 packets).

The PWA science production rate is not symmetrical with respect to the CDMU channel A and B. In one CDMU cycle, the two TM queues will be unbalanced and therefore they will be able to send, if requested, different numbers of packets.

NOTE I: PWA Telemetry

3.6.2 TIME STAMP CAPABILITY

Each sensor science data acquisition loop is synchronised with the Memory Line BCP signal (a pulse every 125 msec) and with the DDBL reception except for the ACCelerometer and the PREssure rough data acquisition. They are continuously sampled at constant rate rates (using internal clock) based upon dedicated "time-tables". For example each ACCelerometer channel is sampled at fixed 400 Hz and recorded in a memory buffer via DMA controller. The software acquisition loop for each channel, driven by different tables, pick-ups data from the buffer and it performs the average.
The HASI software is based on the PSOS operating system multitasks architecture. The main task, internal to the HASI Software, is the Memory Load task. Every BCP, it checks the DDBL/TC presence and it updates the HASI experiment status (i.e. Mission time, Operating modes, internal status and other inf. come from the current DDBL). Then it dispatches the updated Experiment status to the other tasks. Each data acquisition tasks run taking into account a priority list. According to the current Experiment status (mainly the DDBL time) and the user required performance (e.g. each TEM sensor is acquired every 5 sec, i.e. 40 BCP account), each task performs the relevant actions to start the sensor data acquisition loop. An acquisition loop contains one or more rough data. They are compressed (elaborated) in a unique item, time stamped and sent to the TM manager. Note that the science item can contain one or more (elaborated) data plus additional information (e.g. gain). The time stamp resolution is a BCP count (125 msec). The HASI software was designed to maintain the science item time tag precision within two BCP tick (i.e. up to 250 msec) with respect to the expected start of the real time acquisition. A full performance test, during the Software Validation, was demonstrated that design. The different items are collected and formatted into a unique packet and when it will become full, it is queued in the TM queues.
Each science packet contains several science items acquired in successive order. Each packet is time stamp with the HASI Mission Time (HMT) when the first source data (science item) contained in the packet is created. Since the data items are sampled at constant rates, the times of the other data contained in the packet can be easily computed according to their positions.

3.6.2.1 SCIENCE Items data profile reconstruction

Each sensor data type (science item) is collected and formatted into a unique time tag packet. Except for the PWA science, the same packet is transmitted in channel A and B. Each science item is sampled at constant rate; the Interface Data Sheet (IDS) Document (refer to AD(3)) and the Annex 1 of the AD(5)) provide the required inputs to reconstruct the science item data profile with respect to the Mission Time.

> In case of software patches or updated tables (loaded in RAM memory or in EEPROM memory via TCs), the HASI-S/W configuration may change and therefore the IDS shall be updated.
>
> **NOTE J: HASI-S/W Configuration change**

The general rule is to sort the TM packets for the CDMU channel and obtain two distinguished TM queues. Then remove from each queue the 'REDUNDANT' packets. The achieved TM packets shall be sort by each data type (science item) and then they shall be ordered using the packet Time Tag (or the packet sequence count after the DESCENT 2nd state). Each science item profile with respect to Mission time begins from the time when the acquisition of that item was started

(**TINI**) and it continues using the constant rate extracted from IDS (**ITEM RATE** = **FILL RATE** / n, where n is equal to the maximum number of science item contained in a TM packet). The acquisition starting time (**TINI**) can be extracted both by the Experiment Timeline table (see sect 3.2) or by the first packet Time Tag. In last case, the Time Tag may be corrected using the item rate in seconds.

E.g.: the **TEM1 FINE** science item is identified by Format code #96 (**F1**). The **F1** packet FILL RATE is 90 sec and it contains 18 science items acquired at constant rate. The calculated ITEM RATE is 5 sec. The TEM1 FINE acquisition starts at TINI = T0+1min.

Taking into account the following TM packets stream:

1st packet, 2nd packet, 3rd packet ... 5th packet

the Time tag of the 3rd science item (n) in the 5th packet (N) is calculated using the formula:

TIMETAG = TINI + FILL RATE * (N - 1) + ITEM RATE * (n -1)

where: N is the n-th packets in the science item TM stream (**F1** data type);

n is the n-th science item in the N-th packet.

Formula A: Science Item timetag

in the example the Timetag is 430 sec after T0.

According to the Experiment Timeline it is possible that a science item acquisition is finished. In this case the last packet is incomplete (refer to sect 5) and this it would be taken into account to reconstruct the next science item Mission time.

A single sensor channel (e.g. Xservo ACCelerometer channel) can provide more then one science item (e.g. Xservo provides three distinguished science items in different Mission states plus an additional one always present during the Titan Descent). A single sensor channel data profile with respect to the Mission Time will be the chain of each single science item profile.

When the TM is not continuos stream (i.e. they are lost packets), the science item profile with respect to Mission Time starts with the Timetag (it may be corrected with the ITEM RATE in second) of the first packet in the stream and it continues using the above philosophy.

3.6.2.1.1 ACC science items time reconstruction

Each ACCelerometer channel is sampled at fixed rate (400 Hz) and recorded in a memory circular buffer via DMA transfer. The sampling frequency is derived from the µP clock generator. After **TaccSample** time, every BCP the ACC acquisition task starts processing the memory buffer at lower rate according to a pre-defined 'time-tables'. Each channel has a dedicated time table, except for the Xservo channel which has three different tables (one for ENTRY, DESCENT 1st-2nd and DESCENT 3rd mission states). The science item data rate is established by the relevant time-table. For example in the ENTRY state, the Xservo channel data (400 Hz) are first picked-up one every four and then these data are averaged (32 items). The final ITEM rate becomes 0.32 sec (i.e. 3.125 Hz). In this way, the acquisition task produces a science item, it performs its time stamp using HMT and it sends it to the TM manager task. The data processing is performed in background respect to the real time acquisition. An DMA initial synchronisation, performed at **TaccSample**, and the software performances (tested during HASI Software Validation) assure that the processing is faster then the real time acquisition: i.e. no data overlay is envisaged in the memory buffer. The time tag is related to the end of the science item data processing. Therefore the time between two TM packets could be not a multiple of the ITEM rate. Only the three Xservo time-tables are uploadable tables.

The general rule to perform an ACC science item data profile with respect to the Mission time, is that reported in the sect. 3.6.2.1. The following examples will provide detailed procedures in two different cases:

case A) ENTRY / DESCENT 1st / DESCENT 2nd states.
case B) IMPACT detection.

In both cases, only the channel A queue is considered (the channel B queue contains the same packets). In the case A, the queue has been pre-elaborated in order to remove the ‘REDUNDANT’ packets.

case A) ***ACC SCIENCE ITEMS - ENTRY / DESCENT 1ST / DESCENT 2ND STATES***

EGSE Time	Time Tag	Packet Seq. Count	Science Item
%M 12:17:23	-0:21:30.500	A#00917o	ACC SCDP.Z
%M 12:17:24	+0:00:38.875	A#00918o	ACC SCDS.E
%M 12:17:25	-0:21:46.875	A#00920o	ACC SCDS.E
%M 12:17:25	-0:23:26.750	A#00921o	ACC SCDS.E
%M 12:17:27	+0:00:23.125	A#00923o	ACC SCDP.X
%M 12:17:28	+0:00:23.125	A#00924o	ACC SCDP.Y
%M 12:17:29	+0:00:23.125	A#00925o	ACC SCDP.Z
%M 12:17:29	-0:26:29.750	A#00926o	ACC SCDS.E
%M 12:17:29	-0:21:40.000	A#00927o	ACC STD2.XS
%M 12:17:30	-0:21:40.000	A#00928o	ACC STD2.XP
%M 12:17:31	+0:00:55.500	A#00929oi	ACC SCDS.E
%M 12:17:32	+0:00:57.875	A#00930oi	ACC SCDP.X
%M 12:17:34	+0:00:57.875	A#00932oi	ACC SCDP.Y
%M 12:17:34	+0:00:57.875	A#00933oi	ACC SCDP.Z
%M 12:17:35	-0:21:40.000	A#00935o	ACC STD2.YP
%M 12:17:36	-0:21:40.125	A#00936o	ACC STD2.ZP
%M 12:17:36	+0:01:37.625	A#00937	ACC SCDS.D
%M 12:17:36	-0:26:43.000	A#00938o	ACC SCDP.X
%M 12:17:36	-0:26:43.000	A#00939o	ACC SCDP.Y
%M 12:17:38	+0:00:05.625	A#00940o	ACC SCDS.E
%M 12:17:38	-0:26:43.000	A#00941o	ACC SCDP.Z
%M 12:17:39	-0:27:52.375	A#00942o	ACC SCDP.X
%M 12:17:39	-0:27:52.375	A#00943o	ACC SCDP.Y
%M 12:17:40	-0:27:52.375	A#00945o	ACC SCDP.Z
%M 12:17:41	-0:24:58.875	A#00947o	ACC SCDP.X
%M 12:17:42	-0:25:39.875	A#00948o	ACC SCDS.E
%M 12:17:43	-0:24:58.875	A#00949o	ACC SCDP.Y
%M 12:17:44	-0:27:17.750	A#00950o	ACC SCDP.X
%M 12:17:45	-0:27:17.750	A#00951o	ACC SCDP.Y
%M 12:17:45	-0:27:17.750	A#00952o	ACC SCDP.Z
%M 12:17:45	-0:24:58.875	A#00953o	ACC SCDP.Z
%M 12:17:46	-0:27:36.250	A#00954o	ACC SCDS.E
%M 12:17:47	-0:27:03.000	A#00955o	ACC SCDS.E
%M 12:17:48	-0:22:05.250	A#00956o	ACC SCDP.X
%M 12:17:49	-0:22:05.250	A#00957o	ACC SCDP.Y
%M 12:17:50	-0:22:40.000	A#00958o	ACC SCDP.X
%M 12:17:50	+0:01:50.000	A#00959	ACC SCDS.D
%M 12:17:50	+0:01:00.125	A#00960o	ACC SCDS.D
%M 12:17:51	-0:23:49.375	A#00961o	ACC SCDP.X
%M 12:17:52	-0:23:49.375	A#00962o	ACC SCDP.Y
%M 12:17:52	-0:23:49.375	A#00963o	ACC SCDP.Z
%M 12:17:52	-0:22:40.000	A#00964o	ACC SCDP.Y
%M 12:17:52	-0:24:24.125	A#00965o	ACC SCDP.X

case A) *ACC SCIENCE ITEMS - ENTRY / DESCENT 1ST / DESCENT 2ND STATES* (CONT'D)

EGSE Time	Time Tag	Packet Seq. Count	Science Item
%M 12:17:54	-0:25:23.250	A#00966o	ACC SCDS.E
%M 12:17:55	-0:24:24.125	A#00968o	ACC SCDP.Y
%M 12:17:55	-0:24:24.125	A#00969o	ACC SCDP.Z
%M 12:17:56	-0:26:13.125	A#00970o	ACC SCDS.E
%M 12:17:56	-0:22:40.000	A#00971o	ACC SCDP.Z
%M 12:17:57	-0:22:05.250	A#00972o	ACC SCDP.Z
%M 12:17:57	-0:21:30.250	A#00973o	ACC SCDS.E
%M 12:17:58	-0:21:30.500	A#00974o	ACC SCDP.X
%M 12:17:59	+0:00:22.250	A#00975o	ACC SCDS.E
%M 12:18:00	-0:23:43.375	A#00976o	ACC SCDS.E
%M 12:18:01	-0:23:14.750	A#00977o	ACC SCDP.X
%M 12:18:01	-0:25:33.500	A#00978o	ACC SCDP.X
%M 12:18:01	-0:25:33.500	A#00979o	ACC SCDP.Y
%M 12:18:02	+0:02:02.625	A#00980	ACC SCDS.D
%M 12:18:03	+0:01:12.625	A#00981o	ACC SCDS.D
%M 12:18:04	-0:25:33.500	A#00982o	ACC SCDP.Z
%M 12:18:05	-0:25:06.500	A#00983o	ACC SCDS.E
%M 12:18:06	-0:26:46.375	A#00984o	ACC SCDS.E
%M 12:18:06	-0:23:14.750	A#00985o	ACC SCDP.Y
%M 12:18:06	-0:23:14.750	A#00986o	ACC SCDP.Z
%M 12:18:07	-0:22:36.750	A#00987o	ACC SCDS.E
%M 12:18:07	-0:27:53.000	A#00988o	ACC SCDS.E
%M 12:18:08	-0:23:10.000	A#00989o	ACC SCDS.E
%M 12:18:08	-0:27:19.625	A#00990o	ACC SCDS.E
%M 12:18:08	-0:24:00.000	A#00991o	ACC SCDS.E
%M 12:18:10	-0:21:30.500	A#00992o	ACC SCDP.Y
%M 12:18:10	-0:25:56.500	A#00993o	ACC SCDS.E
%M 12:18:11	-0:24:49.875	A#00994o	ACC SCDS.E
%M 12:18:11	-0:22:03.500	A#00995o	ACC SCDS.E
%M 12:18:13	-0:24:33.250	A#00998o	ACC SCDS.E
%M 12:18:13	-0:24:16.625	A#00999o	ACC SCDS.E
%M 12:18:16	-0:22:53.500	A#01002o	ACC SCDS.E
%M 12:18:17	+0:02:15.000	A#01003	ACC SCDS.D
%M 12:18:17	-0:26:08.250	A#01004o	ACC SCDP.X
%M 12:18:17	+0:01:25.125	A#01005o	ACC SCDS.D
%M 12:18:20	-0:26:08.250	A#01008o	ACC SCDP.Y
%M 12:18:22	-0:26:08.250	A#01010o	ACC SCDP.Z
%M 12:18:22	-0:22:20.125	A#01011o	ACC SCDS.E
%M 12:18:23	+0:02:27.500	A#01014	ACC SCDS.D
%M 12:18:27	+0:02:40.000	A#01020	ACC SCDS.D
%M 12:18:28	-0:21:39.500	A#01023	ACC HKD1
%M 12:18:29	-0:21:39.500	A#01024	ACC HKD2

case A) *ACC SCIENCE ITEMS - ENTRY / DESCENT 1ST / DESCENT 2ND STATES* (CONT'D)

	EGSE Time	Time Tag	Packet Seq. Count	Science Item
%M	12:18:32	+0:02:52.500	A#01028	ACC SCDS.D
%M	12:18:37	+0:03:05.000	A#01035	ACC SCDS.D
%M	12:18:40	+0:03:17.500	A#01041	ACC SCDS.D
%M	12:18:43	+0:03:29.875	A#01046	ACC SCDS.D
%M	12:18:48	+0:03:42.375	A#01052	ACC SCDS.D
%M	12:19:00	+0:03:54.875	A#01063	ACC SCDS.D
%M	12:19:12	+0:04:07.375	A#01069	ACC SCDS.D
%M	12:19:26	+0:04:19.875	A#01075	ACC SCDS.D
%M	12:19:37	+0:04:32.375	A#01083	ACC SCDS.D
%M	12:19:50	+0:04:44.750	A#01089	ACC SCDS.D
%M	12:20:02	+0:04:57.250	A#01094	ACC SCDS.D
%M	12:20:15	+0:05:09.750	A#01100	ACC SCDS.D
%M	12:20:28	+0:05:22.250	A#01111	ACC SCDS.D
%M	12:20:40	+0:05:34.750	A#01116	ACC SCDS.D
%M	12:20:53	+0:05:47.125	A#01123	ACC SCDS.D
%M	12:20:57	-0:27:59.000	A#01125	ACC STD2.XS
%M	12:20:57	-0:27:59.000	A#01126	ACC STD2.XP
%M	12:20:57	-0:27:59.000	A#01127	ACC STD2.YP
%M	12:20:58	-0:27:59.000	A#01128	ACC STD2.ZP
%M	12:21:05	+0:05:59.625	A#01134	ACC SCDS.D
%M	12:21:18	+0:06:12.125	A#01141	ACC SCDS.D
%M	12:21:30	+0:06:24.625	A#01146	ACC SCDS.D
%M	12:21:43	+0:06:37.125	A#01153	ACC SCDS.D
%M	12:21:55	+0:06:49.625	A#01163	ACC SCDS.D
%M	12:22:08	+0:07:02.000	A#01169	ACC SCDS.D
%M	12:22:21	+0:07:14.500	A#01175	ACC SCDS.D
%M	12:22:32	+0:07:27.000	A#01181	ACC SCDS.D
%M	12:22:45	+0:07:39.500	A#01187	ACC SCDS.D
%M	12:22:58	+0:07:52.000	A#01194	ACC SCDS.D
%M	12:23:10	+0:08:04.500	A#01201	ACC SCDS.D
%M	12:23:23	+0:08:16.875	A#01211	ACC SCDS.D
%M	12:23:35	+0:08:29.375	A#01217	ACC SCDS.D
%M	12:23:47	+0:08:41.875	A#01222	ACC SCDS.D
%M	12:24:00	+0:08:54.375	A#01229	ACC SCDS.D
%M	12:24:13	+0:09:06.875	A#01235	ACC SCDS.D
%M	12:24:25	+0:09:19.375	A#01240	ACC SCDS.D
%M	12:24:37	+0:09:31.750	A#01247	ACC SCDS.D
%M	12:24:51	+0:09:44.250	A#01256	ACC SCDS.D
%M	12:25:02	+0:09:56.750	A#01264	ACC SCDS.D
%M	12:25:15	+0:10:09.250	A#01269	ACC SCDS.D
%M	12:25:27	+0:10:21.750	A#01277	ACC SCDS.D
%M	12:25:39	+0:10:34.000	A#01283	ACC SCDS.D
%M	12:25:52	+0:10:46.500	A#01288	ACC SCDS.D
%M	12:26:04	+0:10:59.000	A#01295	ACC SCDS.D
		:		
		:		

The **case A)** represents the ACC data stream from the early phase of the mission till DESCENT 3rd state. These data are acquired during a mission simulation performed in OG using the PIFS to simulate the CDMS system. Since all the ACC science items have the same behaviour, it will be considered the Xservo science item only. The Xservo TM packets sequence is shown below. The first packet Time tag is -0:21:30.250 (the '-' sign means T<T0), while the expected HMT is -0:21:30.000 (i.e. **TaccSample**). The difference is that the data is time tag (with a BCP resolution) at the end of the data processing. Therefore, for a better data profile, it is recommended to use a reconstructed time starting from the **TaccSample** (instead to use directly the Time Tag). There are two different science items: SCDS.E (till DESCENT 1st state) and SCDS.D (till DESCENT 3rd state). From the IDS (refer to AD(3)), the relevant TM FILL RATE are 16.64 sec and 12.48 sec. Both the packets contain 52 science items. Therefore the relevant ITEM Rates are 0.32 sec and 0.24 sec. A typical science item profile reconstruction is outlined in the following procedure:

PROCEDURE C: ACC science items profile reconstruction

1. Determine the DDBL time profile (in BCP tick) of the important events: the T0 detection (i.e. when the DDBL time is reset) and the ENTRY to DESCENT 1st state transition, etc.;
1. Select in the CDMU-A TM queue the packets relevant to each science item;
1. Order these packets according to the packet time tag;
1. Associate to each TM data (science item) the time which starts from (**TaccSample** + ITEM rate) and it ends with the time of the last acquired data in the ENTRY state (the time difference between two consecutive data is the ENTRY state ITEM rate);
1. Compare the DDBL time profile (see pt. 1.) with the one reconstructed at pt. 5;
1. Individuate the T0 transition;
1. Calculate the time difference between the T0 and the time of the last science item before this transition;
1. Assign to the next science item the time using the simple formula: TINI = ITEM rate - (difference calculated in the step 7); from now on, TINI is the initial time for the next science item stream;
1. Calculate, till the DESCENT 3rd state, the Mission time of each science items with the following formula: TINI + n * ITEM rate. At every state transition changes the ITEM rate with the relevant one.

Note: the procedure can be used till the IMPACT state also. During the DESCENT 3rd state, the ITEM rate changes to 0.570 sec (FILL RATE = 29.647 sec).

Xservo TM packets sequence:

```
1.    -0:21:30.250 A#00973o ACC SCDS.EACC sampling start
2.    -0:21:46.875 A#00920o ACC SCDS.E

                :    :

23. -0:27:36.250 A#00954o ACC SCDS.E
24. -0:27:53.000 A#00988o ACC SCDS.E  T0 transition
25. +0:00:05.625 A#00940o ACC SCDS.E

                :    :

28. +0:00:55.500 A#00929oi ACC SCDS.E Before DESCENT 1st state
29. +0:01:00.125 A#00960o ACC SCDS.D  After DESCENT 1st state
30. +0:01:12.625 A#00981o ACC SCDS.D

                :    :

35. +0:02:15.000 A#01003 ACC SCDS.D
36. +0:02:27.500 A#01014 ACC SCDS.D   DESCENT 2nd state transition
37. +0:02:40.000 A#01020 ACC SCDS.D

           :    :

77. +0:10:59.000 A#01295 ACC SCDS.D

           :    :                    till DESCENT 3rd state
```

XSERVO SCIENCE DATA PROFILE WITH RESPECT TO MISSION TIME

Packet Sequence Count	# data in the Packet	Mission time	
#00973	01	-0:21:30.320	
#00973	02	-0:21:30.640	
	:		
	52	-0:21:46.640	
#00920	01	-0:21:46.960	
#00920	02	-0:21:47.280	
	:		
#00920	52	-0:22:33.280	
	:		
	:		
#00954	52	-0:27:52.720	
#00988	01	-0:27:53.040	
#00988	02	-0:27:53.360	
	:		
#00988	22	-0:27:59.760	
#00988	23	-0:28:00.080	Expected T0 transition
	:		
#00988	34	-0:28:03.600	0.32sec ITEM rate
#00988	35	-0:28:03.920	
	-------------------------->		T0 transition
#00988	36	+0:00:00.240	
	:		
#00988	52	+0:00:05.360	
#00940	01	+0:00:05.680	(+0:00:05.625 Time Tag)
	:		
#00940	52	+0:00:22.000	
#00975	01	+0:00:22.320	(+0:00:22.250 Time Tag)
	:		
	:		
#00918	52	+0:00:55.280	
#00929	01	+0:00:55.600	(+0:00:55.500 Time Tag)
	:		
#00929	14	+0:00:59.760	
#00929	01	+0:00:55.600	(+0:00:55.500 Time Tag)
	:		
#00929	14	+0:00:59.760	ITEM rate 0.32sec
	-------------------------->		DESCENT 1st state transition
#00960	01	+0:01:00.080	(+0:01:00.125 Time Tag)
#00960	02	+0:01:00.320	ITEM rate 0.24 sec
	:		
#00960	52	+0:01:12.400	

XSERVO SCIENCE DATA PROFILE WITH RESPECT TO MISSION TIME (CONT'D)

```
Packet Sequence   # data        Mission time
     Count       in the Packet

     #00981         01          +0:01:12.640    (+0:01:12.625 Time Tag)
                    :
                    :
     #01003         01          +0:02:15.040    (+0:02:15.000 Time Tag)
                    :
     #01003         52          +0:02:27.280
     #01014         01          +0:02:27.520    (+0:02:27.500 Time Tag)
                    :
     #01014         52          +0:02:39.760
     #01020         01          +0:02:40.000    (+0:02:40.000 Time Tag)
                    :
     #01020         52          +0:02:52.240
                    :
                    :
     #01295         01          +0:10:59.200    (+0:10:59.000 Time Tag)
                    :
                    :
```

The #00929 TM packet is incomplete and it contains 14 science items.

Since the TM stream was done using the PIFS modified time table in order to change the T0 transition at about 28 min after Probe ON, the PIFS Mission time (at T0 transition) is not well known. It seems necessary about 4 sec before the DDBL changes status (T0 transition). Therefore the data profile is reconstructed according. **In order to perform a better data profile, during the NOMINAL (or REAL) mission from T0 to DESCENT 1st state transition, it must be necessary to know the DDBL time at the T0 transition.**

Remark: The reconstructed science item profile, shown in the above Xservo profile, is precise within the ± BCP tick. In fact, after 77 TM packets, the reconstructed mission time is +0:10:59.200 while the packet time tag is +0:10:59.000. That negative difference is not true, since the time tag should be always greater then the time of the last raw data in the average. The above calculation is affected by the initial error: the indeterminate value of the T0 transition.

case B) ***ACC SCIENCE ITEMS - IMPACT DETECTION TRACE***

EGSE Time	Time Tag	Packet Seq. Count	Science Item
%M 14:43:43	+2:13:37.625	A#00043	ACC ID3
%M 14:43:50	+2:13:42.375	A#00047	ACC ID2
%M 14:43:52	+2:13:42.250	A#00048	ACC ID1
%M 14:43:56	+2:13:42.125	A#00050	ACC ID2
%M 14:43:58	+2:13:42.000	A#00051	ACC ID1
%M 14:43:45	+2:13:39.250	A#00044	ACC ID3
%M 14:43:47	+2:13:41.250	A#00045	ACC ID3
%M 14:43:49	+2:13:42.375	A#00046	ACC ID3
%M 14:43:54	+2:13:42.125	A#00049	ACC ID3
%M 14:43:59	+2:13:41.875	A#00052	ACC ID3
%M 14:44:01	+2:13:41.750	A#00053	ACC ID2
%M 14:44:03	+2:13:41.750	A#00054	ACC ID1
%M 14:44:05	+2:13:41.500	A#00055	ACC ID3
%M 14:44:06	+2:13:41.500	A#00056	ACC ID2
%M 14:44:08	+2:13:41.500	A#00057	ACC ID1
%M 14:44:10	+2:13:41.250	A#00058	ACC ID2
%M 14:44:12	+2:13:41.250	A#00059	ACC ID1
%M 14:44:13	+2:13:41.000	A#00060	ACC ID3
%M 14:44:15	+2:13:41.000	A#00061	ACC ID2
%M 14:44:17	+2:13:41.000	A#00062	ACC ID1
%M 14:44:19	+2:13:40.625	A#00063	ACC ID3
%M 14:44:21	+2:13:40.625	A#00064	ACC ID2
%M 14:44:22	+2:13:40.625	A#00065	ACC ID1
%M 14:44:24	+2:13:40.375	A#00066	ACC ID3
%M 14:44:26	+2:13:40.375	A#00067	ACC ID2
%M 14:44:28	+2:13:40.375	A#00068	ACC ID1
%M 14:44:30	+2:13:40.125	A#00069	ACC ID3
%M 14:44:31	+2:13:40.125	A#00070	ACC ID2
%M 14:44:33	+2:13:40.125	A#00071	ACC ID1
%M 14:44:35	+2:13:39.875	A#00072	ACC ID3
%M 14:44:37	+2:13:39.875	A#00073	ACC ID2
%M 14:44:38	+2:13:39.875	A#00074	ACC ID1

:
:
:
:

The shown IMPACT trace is not complete: normally the trace is composed by 66 TM packets. The HASI-S/W recognises the Probe Impact instant (**Timpact**) basing upon Xservo data (sampled at 400 Hz) filtered threshold crossing. Then it stores 6 sec trace of the Probe Impact (Timpact-0.5, Timpact+5.5) containing the three Piezos sensors data sampled at 200 Hz. Afterwards it performs the data time tag and it sends them to the TM task. The TM task collects the data into a unique packet and when the packet becomes full it is queued in the TM queues. The IMPACT trace TM packets have high priority in the TM queues; they jump to the queue beginning and therefore they are transmitted first than the real time data acquired after Impact detection. The **Timpact** (expressed in HMT) is recorded in the EVENT LOG and then is transmitted. It may happen that the packets acquired before **Timpact** (typically PWA TM) are transmitted after the IMPACT trace. The FILL RATE of each impact trace packet has 0.28 sec, while each packet contains 56 science items (see AD(5)). The time tag, performed with a resolution of one BCP, does not allow the identification of two different packets. It can happen that two packets have the same time tag, it depends how faster is the software to create each science item. The way to distinguish the

IMPACT TM packets is to perform the graphic of the data after the first ordering. Each science item profile reconstruction is outlined in the following procedure:

PROCEDURE D: ACC science items during IMPACT

1. Extract the Timpact from the received EVENT LOG packet;
1. Select in the CDMU A queue the science item packets and order these packets according to the packet time tag;
1. Perform a science item figure and correct the packet position according; the ITEM rate is 5 msec.

<u>IMPACT TRACE TM PACKETS SEQUENCE</u>

ID1 science item sequence	ID2 science item sequence	ID3 science item sequence
:	:	:
:	:	:
:	:	+2:13:37.625 A#00043 ACC ID3
:	:	:
:	:	+2:13:39.250 A#00044 ACC ID3
+2:13:39.875 A#00074 ACC ID1	+2:13:39.875 A#00073 ACC ID2	+2:13:39.875 A#00072 ACC ID3
+2:13:40.125 A#00071 ACC ID1	+2:13:40.125 A#00070 ACC ID2	+2:13:40.125 A#00069 ACC ID3
+2:13:40.375 A#00068 ACC ID1	+2:13:40.375 A#00067 ACC ID2	+2:13:40.375 A#00066 ACC ID3
+2:13:40.625 A#00065 ACC ID1	+2:13:40.625 A#00064 ACC ID2	+2:13:40.625 A#00063 ACC ID3
+2:13:41.000 A#00062 ACC ID1	+2:13:41.000 A#00061 ACC ID2	+2:13:41.000 A#00060 ACC ID3
+2:13:41.250 A#00059 ACC ID1	+2:13:41.250 A#00058 ACC ID2	+2:13:41.250 A#00045 ACC ID3
+2:13:41.500 A#00057 ACC ID1	+2:13:41.500 A#00056 ACC ID2	+2:13:41.500 A#00055 ACC ID3
+2:13:41.750 A#00054 ACC ID1	+2:13:41.750 A#00053 ACC ID2	:
:	:	+2:13:41.875 A#00052 ACC ID3
+2:13:42.000 A#00051 ACC ID1	+2:13:42.125 A#00050 ACC ID2	+2:13:42.125 A#00049 ACC ID3
+2:13:42.250 A#00048 ACC ID1	:	:
:	+2:13:42.375 A#00047 ACC ID2	+2:13:42.375 A#00046 ACC ID3
:	:	:
:	:	:

3.6.2.1.2 TEM science items time reconstruction

After DESCENT 1st state, the TEM acquisition task every 1.25 sec (i.e. every 10 BCP) selects a new sensor head according to the TEM scanning Table, and reads it. The TEM reading, according to the specification in the AD(5), takes less then a BCP time. Then it performs the time stamp of the acquired science item and it sends it to the TM manager task. The TEM scanning table is a uploadable table that contains 24 entries (4 TEM sensors x 6 HASI states). The table default allows to read the sensor in the fixed order (F1, C1, F2 and C2) except for the IMPACT state where the sequence changes to 'F1, F2, F1, F2'. During the IMPACT state, the sampling frequency of TEM Fine 1 is double (i.e. every 2.5 sec) and the TM packet FILL RATE becomes half (it passes from 90 sec to 45 sec). The TEM sensor produces four science items and they are formatted in four relevant TM packets: TEM Fine1, TEM Coarse1, TEM Fine2 and TEM Coarse2.
The time tag precision is within (1.5*BCP) tick (i.e. better then 188 msec) with respect to the real time acquisition. The TINI of the TEM science items are summarised in the following:

- TEM Fine1 starts at +0:01:00.000
- TEM Coarse1 starts at +0:01:01.250
- TEM Fine 2 starts at +0:01:02.500
- TEM Coarse 2 starts at +0:01:03.750

where the time is the HASI Mission time expressed in Hours:minutes:seconds.milliseconds. It is positive (negative) when it is after (before) T0.

In the following, there are two example of the TEM science items TM streams (only channel A) received in two different HASI states:

case A) TEM science items TM packets from DESCENT 1st state up to IMPACT state
case B) TEM science items TM packets - IMPACT state

case A) ***<u>TEM SCIENCE ITEMS TM PACKETS - DESCENT 1ST TILL IMPACT STATE</u>***

EGSE Time	Time Tag	Packet Seq. Count	Science Item
%M 11:05:09	+0:01:00.125	A#00511	TEM F1
%M 11:05:12	+0:01:01.375	A#00514	TEM C1
%M 11:05:15	+0:01:02.625	A#00517	TEM F2
%M 11:05:18	+0:01:03.875	A#00520	TEM C2
%M 11:06:10	+0:02:30.125	A#00564	TEM F1
%M 11:06:13	+0:02:31.375	A#00567	TEM C1
%M 11:06:14	+0:02:32.625	A#00568	TEM F2
%M 11:06:16	+0:02:33.875	A#00570	TEM C2
	:		
	:		
%M 11:12:37	+0:10:00.125	A#00813	TEM F1
%M 11:12:39	+0:10:01.250	A#00815	TEM C1
%M 11:12:40	+0:10:02.500	A#00816	TEM F2
%M 11:12:43	+0:10:03.750	A#00818	TEM C2

The **case A**) shows the TEM acquisition cycle form DESCENT 1st state till the IMPACT state. The Time tag of the first TEM F1 packet is +0:01:00.125, while the expected HASI Mission time is +0:01:00.000 (i.e. **Tdata**). The difference is within a BCP count as expected. This time difference (i.e. between the instant when the raw data acquisition starts and when the science item is time stamp) is in the worst case for the TEM acquisition better then 250 msec. A similar conclusion can be done for the other science item. The algorithm to reconstruct the TEM Fine1 (or Coarse1 or Fine2 or Coarse2) science item profile with respect to the Mission time is described in the introduction of the section 3.6.2.1. In the following, the TEM Fine1 science item TM sequence is performed and then the its data profile.

TEM FINE1 TM PACKETS SEQUENCE

Time Tag	Packet Sequence Count	Science Item
+0:01:00.125	A#00511	TEM F1
+0:02:30.125	A#00564	TEM F1
	:	
	:	
+0:10:00.125	A#00813	TEM F1

TEM FINE1 SCIENCE DATA PROFILE WITH RESPECT TO MISSION TIME

Packet Sequence Count	#data item in the Packet	Mission time
#00511	01	+0:01:00.000
	:	
	18	+0:02:25.000
#00564	01	+0:02:30.000
	:	
#00564	18	+0:03:55.000
	:	
	:	
#00813	01	+0:10:00.000
	:	
	:	

case B) *TEM SCIENCE ITEMS TM PACKETS - IMPACT STATE*

EGSE Time	Time Tag	Packet Seq. Count	Science Item
%M 17:07:23	+2:09:57.500	A#04305	TEM F1
%M 17:07:25	+2:09:58.750	A#04306	TEM C1
%M 17:07:29	+2:10:00.125	A#04308	TEM F2
%M 17:07:33	+2:10:01.250	A#04310	TEM C2
%M 17:08:13	+2:11:27.500	A#04333	TEM F1
%M 17:08:17	+2:11:30.125	A#04335	TEM F2
		TEM after HASI enters in IMPACT state	
%M 17:08:59	+2:12:20.125	A#04356	TEM F1
%M 17:09:01	+2:12:21.375	A#04357	TEM F2
%M 17:09:42	+2:13:05.125	A#04378	TEM F1
%M 17:09:46	+2:13:06.375	A#04380	TEM F2
%M 17:10:27	+2:13:50.125	A#04401	TEM F1
%M 17:10:28	+2:13:51.250	A#04402	TEM F2
		Till the SURFACE state.	

The **case B**) shows the TEM acquisition cycle from the IMPACT state to the SURFACE state (i.e. HASI Impact detection). According to the TEM scanning table, the ITEM RATE changes at IMPACT state (i.e. when HASI recognises, in the DDBL, an altitude less then 1 Km). The HASI Mission time of this event shall be determined from the Probe data by the DDBL time retrieval. From now on, the HASI software acquires the two TEM FINE sensors at new rate (each at 2.5 sec). This rate is maintained constant till the IMPACT detection (i.e. SURFACE state), where it restarts with the old acquisition rate (4 sensors, each sensor at 5 sec). The **Timpact** Mission time is logged in the EVENT LOG by the '**Timpact**' event and its relevant HMT. The algorithm to reconstruct the TEM Fine1 (or Fine2) science item profile with respect to the Mission time is that described in the introduction of the section 3.6.2.1 but with a modification introduced to take into account the difference of two ITEM Rates.

TEM FINE1 TM PACKETS SEQUENCE

```
+2:09:57.500 A#04305 TEM F1
+2:11:27.500 A#04333 TEM F1
                                  TEM after HASI goes in IMPACT state
+2:12:20.125 A#04356 TEM F1
+2:13:05.125 A#04378 TEM F1
+2:13:50.125 A#04401 TEM F1               Till the SURFACE
```

The **FILL RATE** is 90 sec between the #04333 and #04305 packets, while it is 52.625 sec between the #04333 and #04356 packets. After the #04356 packet, the **FILL RATE** is always 45 sec. The IMPACT state transition is in the #04333 packet. The duration of the #04333 packet is about 52.5. In order to reconstruct the science item profile with respect to mission time use the following formulas:

52.5 = A * 5 + (B + 1) * 2.5

18 = A + B

Formula B: TEM science item TIMETAG

Where the A is the number of 5 sec rate science items, while B is the number of the 2.5 rate science items. In the above example, the results of the equations are: A = 3 and B = 15. Therefore the TEM Fine1 science data profile with respect to the Mission Time, it evolves as follows:

TEM FINE1 SCIENCE DATA PROFILE WITH RESPECT TO MISSION TIME

```
Packet Sequence     # data          Mission time
    Count       in the Packet

    #04305              01          +2:09:57.500
                      :
                     18          +2:11:22.500
    #04333           01          +2:11:27.500
                      :
                     04          +2:11:42.500
                     05          +2:11:45.000
                      :
                     18          +2:12:17.500
    #04356           01          +2:12:20.000
                      :
                      :
```

Remark: The above science item reconstruction provides in the worst case an precision of 1.25 sec.

TEM FINE2 TM PACKETS SEQUENCE

```
+2:10:00.125 A#04308 TEM F2
+2:11:30.125 A#04335 TEM F2
```

TEM after the IMPACT state

```
+2:12:21.375 A#04357 TEM F2
+2:13:06.375 A#04380 TEM F2
+2:13:51.250 A#04402 TEM F2
```
Till the SURFACE.

In the DDBL information, the IMPACT transition was at about 2:11:44 after T0. Therefore, the reconstruction of the TEM F2 science item will be following:

TEM FINE2 SCIENCE DATA PROFILE WITH RESPECT TO MISSION TIME

```
Packet Sequence     # data          Mission time
     Count      in the Packet

     #04308          01         +2:10:00.125
                      :
                     18         +2:11:25.125

     #04333          01         +2:11:30.125    ITEM rate 5 sec
     #04333          02         +2:11:35.125    ITEM rate 5 sec
     #04333          03         +2:11:40.125    ITEM rate 5 sec
     #04333          04         +2:11:43.875    ITEM rate ≅3.75 sec
     #04333          05         +2:11:46.375    ITEM rate 2.5 sec
     #04333          06         +2:11:49.875    ITEM rate 2.5 sec
     #04333          07         +2:11:51.375    ITEM rate 2.5 sec
                      :
                      :
                     18         +2:12:18.875    ITEM rate 2.5 sec

     #04356          01         +2:12:21.375    ITEM rate 2.5 sec
                      :
                      :
```

The Initial Mission Time of the first TEM F2 science item (for the case B) is the Mission time of the first packet in the sequence. For a better reconstruction, it is necessary to reconstruct the whole TEM F2 science item profile (i.e. from the start of the TEM F2 science data acquisition).

NOTE K: TEM Initial Mission Time

3.6.2.1.3 PRE science items time reconstruction

The PREssure acquisition task, in the frame of the HASI software, starts to acquire the PREssure data from the DESCENT 1st state (i.e. Tdata = 0:01:00 after T0) and it continues till the end of the mission till the loss of the Probe relay link. It performs, every ≈144 msec (average value), a single PREssure measure consisting of a channel selection and a period measurement. The channel selection is loaded from the SESSION tables which are uploadable parameters. A sequence of the seven session tables is cyclically repeated during the whole mission. Three different sequences are foreseen in order to divide the Titan descent in three different phases:

- the upper part from **Tdata** till **Tmid** where the LOW range pressure sensors are sampled;
- the medium part from **Tmid** till **Thigh** where the MEDIUM range pressure sensors are sampled;
- the last part from **Thigh** till the SURFACE where the HIGH range pressure sensors are sampled.

The measured periods (raw data) are grouped and processed by the PREssure task according to the SESSION types: HEALTH CHECK (i.e. **PPI HC #G and #H**, refer to 3.8.1.1) or NORMAL SESSION (i.e. **PPI HC #A, #B and #C**, refer to 3.8.1.1).
In case of HEALTH CHECK, the raw data are time tag and sent to the TM manager task.
The NORMAL SESSION case is more complicated. The sequential reading scheme of raw frequency measurements is modified in order to provide two science items every 2.4 sec (as per AD(5)). A straight-forward readout sequence of 16 readings, composed of two pressure channels and the relevant references, provides the raw measurements to calculate a couple of five Y values (see sect 3.8.1). Each science item is composed by an average (on the 5 Y values) and its relevant variance. The couple of the two science items is time tag and then it is sent to the TM manager task.
This task puts the science items in the relevant packets and, when the packet is full, it is inserted in the TM queues.
The following packets list reports the typical PPI science acquisition on the channel A. The packet list does not include the ‘Copy’ and the it has been already ordered in HMT crescent order.

PRE SCIENCE ITEMS - DESCENT 1ST / DESCENT 2ND / DESCENT 3RD / IMPACT STATES

EGSE Time	Time Tag	Packet Sequence Count	Science Item
%M 03:08:11	+0:01:07.500	A#01422o	PPI N #A
%M 03:08:50	+0:01:00.125	A#01457o	PPI HC #G
%M 03:09:14	+0:01:49.375	A#01477	PPI N #A
%M 03:09:35	+0:02:31.500	A#01496	PPI N #A
%M 03:09:38	+0:03:11.250	A#01499	PPI HC #H
%M 03:10:05	+0:03:18.500	A#01522	PPI N #A
%M 03:10:32	+0:04:00.500	A#01545	PPI N #A
%M 03:10:35	+0:04:40.375	A#01548	PPI HC #G
%M 03:11:00	+0:04:47.625	A#01571	PPI N #A
%M 03:11:30	+0:05:29.625	A#01594	PPI N #A
%M 03:12:12	+0:06:11.625	A#01615	PPI N #A
%M 03:12:20	+0:06:51.500	A#01619	PPI HC #H
%M 03:12:59	+0:06:58.875	A#01642	PPI N #A
%M 03:13:41	+0:07:40.750	A#01666	PPI N #A
	:	:	
%M 03:57:56	+0:52:22.500	A#03140	PPI HC #G
%M 03:58:36	+0:52:29.875	A#03163	PPI N #A
%M 03:59:18	+0:53:11.625	A#03187	PPI N #A
%M 03:59:54	+0:53:53.375	A#03207	PPI N #A
%M 03:59:59	+0:54:32.875	A#03210	PPI HC #H
%M 04:00:27	+0:26:14.000	A#03225	PPI HKV
%M 04:00:49	+0:54:40.375	A#03238	PPI N #A
%M 04:01:23	+0:55:21.875	A#03257	PPI N #A
	:	:	
%M 04:19:32	+1:14:03.500	A#03864	PPI HC #G
%M 04:20:12	+1:14:10.875	A#03887	PPI N #A
%M 04:20:53	+1:14:52.375	A#03909	PPI N #A
%M 04:21:38	+1:15:33.125	A#03932	PPI N #A
%M 04:21:43	+1:16:12.125	A#03935	PPI HC #H
%M 04:22:20	+1:16:19.500	A#03956	PPI N #A
%M 04:23:15	+1:17:00.625	A#03985	PPI N #A
%M 04:23:21	+1:17:39.500	A#03988	PPI HC #G
%M 04:23:52	+1:17:46.875	A#04006	PPI N #B
%M 04:24:36	+1:18:28.375	A#04031	PPI N #B
%M 04:25:12	+1:19:09.125	A#04052	PPI N #B
%M 04:25:18	+1:19:48.125	A#04055	PPI HC #H
%M 04:26:02	+1:19:55.375	A#04079	PPI N #B
%M 04:26:37	+1:20:36.500	A#04099	PPI N #B
	:	:	

PRE SCIENCE ITEMS - DESCENT 1ST / DESCENT 2ND / DESCENT 3RD / IMPACT STATES

```
EGSE Time        Time Tag        Packet Sequence   Science Item
                                      Count

%M 04:48:24 +1:42:51.625 A#04828         PPI HC #G
%M 04:49:05 +1:42:59.000 A#04852         PPI N #B
%M 04:49:41 +1:43:40.375 A#04873         PPI N #B
%M 04:50:21 +1:44:21.250 A#04895         PPI N #B
%M 04:50:26 +1:45:00.250 A#04898         PPI HC #H
%M 04:51:08 +1:45:07.625 A#04920         PPI N #B
%M 04:51:49 +1:45:48.750 A#04944         PPI N #B

%M 04:51:54 +1:46:27.625 A#04947         PPI HC #G
%M 04:52:34 +1:46:35.000 A#04966         PPI N #C
%M 04:53:16 +1:47:16.375 A#04991         PPI N #C
%M 04:53:58 +1:47:57.250 A#05012         PPI N #C
%M 04:54:03 +1:48:36.250 A#05015         PPI HC #H
%M 04:54:52 +1:48:43.625 A#05043         PPI N #C
%M 04:55:29 +1:49:24.750 A#05065         PPI N #C
                      :           :
%M 05:20:45 +2:15:15.625 A#05906         PPI HC #G
%M 05:21:23 +2:15:23.000 A#05925         PPI N #C
%M 05:22:05 +2:16:04.375 A#05947         PPI N #C
%M 05:22:47 +2:16:45.250 A#05968         PPI N #C
%M 05:22:52 +2:17:24.250 A#05971         PPI HC #H
%M 05:23:33 +2:17:31.625 A#05991         PPI N #C
%M 05:24:13 +2:18:12.750 A#06012         PPI N #C
%M 05:24:18 +2:18:51.625 A#06014         PPI HC #G
%M 05:24:58 +2:18:59.000 A#06036         PPI N #C
                      :           :
                      :           : ----->>>  till the SURFACE state
```

The two session types are marked as ‘HC’ for the HEALTH CHECK sessions and ‘N’ for the NORMAL session. The ‘N #A’ string depicts the LOW PREssure NORMAL session table, while the ‘HC #G’ and ‘HC #H’ are the two different HC. The ‘N #B’ and ‘N #C’ strings represent the respectively the MEDIUM and HIGH PREssure NORMAL sessions.

Each HEALTH-CHECK SESSION packet contains 37 science items (raw measurement). A PREssure channel raw acquisition is accomplished every ≈140 msec (average value) by integrating its output along this period. The timetag of each science item refers to the end of the integration time. By calculation, the TM FILL RATE for the PPI HC is about 5.2 seconds. The NORMAL SESSION packet contains 36 science items which are grouped two by two. The acquisition of each couple is performed every ≈2.3 sec. Although each value is a average of 5 values in the 2.3 sec period, for convenience the timetag assignment of each couple refers to end of this time interval. The TM FILL RATE for the PPI NORMAL is about 41.2 seconds

Each packet timetag is marked always with the first data in the packet with a resolution of ± 1 BCP (i.e. ±0.125 sec).

A typical science item profile reconstruction is outlined in the following procedure:

PROCEDURE E: PRE science items profile reconstruction

1. Select in the CDMU-A TM queue the packets relevant to PRE science items (PPI #A, #B and #C, PPI HC #G and #H);
1. Order these packets according to the packet time tag;
1. Estimate each science item timetag by means of the following formulas which depend on the following cases

> 1. case 1: the packet is an HC session.
>   **Timetag of the n-th science item = T_{packet} + (n-1) * 0.14 sec**
>   **where n = 1 .. 37**
>   **T_{packet}** is the Timetag of the HC session packet
>
> 1. case 2: the packet is a NORMAL session.
>   **Timetag of the n-tn couple science item = T_{packet} + (n-1) * 2.3 sec**
>   **where n = 1 .. 18**
>   **T_{packet}** is the Timetag of the NORMAL session packet

1. Repeat the step 3 for all whole mission.

PRE SCIENCE DATA PROFILE WITH RESPECT TO MISSION TIME

```
Packet Sequence    # data       Mission time
    Count       in the Packet

    #01457o              01         +0:01:00.125 (*)
                     :
                    37         +0:01:05.165
    #01422o              01         +0:01:07.500 (1)
                     :
                    18         +0:01:46.600
    #01477          01         +0:01:49.375 (1)
                     :
                    18         +0:02:28.475
    #01496          01         +0:02:31.500 (1)
      :              :              :
      :              :              :
      :              :              :
      :              :              :
```

Note **(*)** because of the HASI timetag resolution (i.e. ±125 msec, refer to 3.6.2), the packet timetag shall not be time tag with '**+0:01:00.140**' as per acquisition.
(1) because of the HASI timetag resolution, the packet timetag may be affected by an error of ±125 msec.

3.6.2.1.4 PWA science item time reconstruction

According to the PWA interface definition (see sect. 3.8.4), the PWA task, in the frame of HASI software, sends every 2 sec (every 8 BCP or each DDBL reception) a SB information and it receives two Science DB. After each reception, it checks the data content and it performs the time stamp. Then it sends the formatted science item to the TM manager task.

The PWA science acquisition internal loop starts at the state transition between DESCENT 1st and 2nd state. This time is about T0+2.5 min (**TdataH =** 150 sec after T0) and it is the Time Tag of the first PWA packet.

Since PWA data packets consist of information which are distributed on two channel A and B, it is necessary to buffer the data flow and to sort the packets according to their internal sequence number on each CDMU channel. Before to process the data, the packets are sorted in a way that packet in channel A and B are positioned at the same location in the queue according to their sequence number. This makes sure that related packets are processed together and in the same sequence as they are acquired.

In the following is reported a list of the PWA packets scheme after **TdataH**. Both CDMU channels Telemetry are shown as they are acquired by the PIFS during a mission simulation performed at OG. The whole PWA acquisition scheme belonging the Mission states is reported into the annex 2: pwa flight software and annex 3: pwa fm users document.

PWA SCIENCE ITEMS - DESCENT 1ST / DESCENT 2ND / DESCENT 3RD / IMPACT STATES

EGSE Time	Time Tag	Packet Sequence Count	Science Item
%M 11:05:20	+0:02:36.125	A#00522	PWA ACDC 1 A
%M 11:05:21	+0:02:36.375	B#00522	PWA ACDC 1 A
%M 11:05:22	+0:02:38.125	A#00523	PWA ACDC 2 A
%M 11:05:22	+0:02:38.375	B#00523	PWA ACDC 2 A
%M 11:05:25	+0:02:40.250	A#00525	PWA ACDC 3 A
%M 11:05:25	+0:02:40.500	B#00525	PWA ACDC 3 A
%M 11:05:26	+0:02:44.375	B#00526	PWA ACDC 5 A
%M 11:05:26	+0:02:44.250	A#00526	PWA ACDC 5 A
%M 11:05:27	+0:02:46.375	B#00527	PWA ACDC 6 A
%M 11:05:28	+0:02:46.125	A#00527	PWA ACDC 6 A
%M 11:05:28	+0:02:48.375	B#00528	PWA ACDC 7 A
%M 11:05:29	+0:02:48.125	A#00528	PWA ACDC 7 A
%M 11:05:30	+0:02:52.125	A#00529	PWA ACDC 9 A
%M 11:05:31	+0:02:52.375	B#00530	PWA ACDC 9 A
%M 11:05:32	+0:02:54.125	A#00531	PWA ACDC 10 A
%M 11:05:32	+0:02:54.375	B#00531	PWA ACDC 10 A
%M 11:05:33	+0:02:56.375	B#00532	PWA ACDC 11 A
%M 11:05:33	+0:02:56.250	A#00532	PWA ACDC 11 A
%M 11:05:34	+0:03:00.250	A#00533	PWA ACDC 13 A
%M 11:05:35	+0:03:00.375	B#00533	PWA ACDC 13 A
%M 11:05:35	+0:03:02.375	B#00534	PWA ACDC 14 A
%M 11:05:36	+0:03:02.125	A#00534	PWA ACDC 14 A
%M 11:05:37	+0:03:04.125	A#00535	PWA ACDC 15 A
%M 11:05:37	+0:03:04.375	B#00535	PWA ACDC 15 A
%M 11:05:39	+0:03:08.125	A#00537	PWA ACDC 17 A
%M 11:05:39	+0:03:08.250	B#00537	PWA ACDC 17 A
%M 11:05:41	+0:03:10.250	A#00539	PWA ACDC 18 A
%M 11:05:41	+0:03:10.375	B#00539	PWA ACDC 18 A
%M 11:05:42	+0:03:12.375	B#00540	PWA ACDC 19 A
%M 11:05:43	+0:03:12.250	A#00540	PWA ACDC 19 A
%M 11:05:44	+0:03:16.375	B#00542	PWA ACDC 21 A
%M 11:05:45	+0:03:16.125	A#00542	PWA ACDC 21 A
%M 11:05:48	+0:03:18.125	A#00545	PWA ACDC 22 A
%M 11:05:48	+0:03:18.375	B#00545	PWA ACDC 22 A
%M 11:05:49	+0:03:20.250	A#00546	PWA ACDC 23 A
%M 11:05:49	+0:03:20.375	B#00546	PWA ACDC 23 A
%M 11:05:50	+0:03:24.250	B#00547	PWA ACDC 25 A
%M 11:05:50	+0:03:24.125	A#00547	PWA ACDC 25 A
%M 11:05:51	+0:03:26.375	B#00548	PWA ACDC 26 A
%M 11:05:52	+0:03:26.125	A#00548	PWA ACDC 26 A
%M 11:05:52	+0:03:28.375	B#00549	PWA ACDC 27 A
%M 11:05:53	+0:03:28.250	A#00549	PWA ACDC 27 A
%M 11:05:57	+0:03:32.375	B#00553	PWA RP 29 A
%M 11:05:57	+0:03:32.375	PWA Scnt= 574, Alt(m)= 149280, Fcnt= 0 @ T=00:03:32(4)	
%M 11:05:57	+0:03:32.250	A#00553	PWA RP 29 A
%M 11:05:57	+0:03:32.250	PWA Scnt= 574, Alt(m)= 149280, Fcnt= 0 @ T=00:03:32(4)	
%M 11:05:58	+0:03:34.125	A#00554	PWA MI 30 A
%M 11:05:58	+0:03:34.375	B#00554	PWA MI 30 A
%M 11:05:59	+0:03:36.125	A#00555	PWA MI 31 A
%M 11:05:59	+0:03:36.375	B#00555	PWA MI 31 A

The first acquired packet has 6 seconds of delay from **TdataH** (i.e. the start of Descent 2nd state): four seconds are necessary to start in the PWA the science acquisition while two seconds are because the first two PWA packets does not contain science data (refer to annex 2: pwa flight software).

The message (4) shows the contents of some sub-fields of the RELaxation experiment packets (PWA RP packet); it reports the following information:

- The values of the SB altitude and time. They are read from the DDBL by the HASI-S/W and they are sent to PWA.. The altitude value provides a feedback to compared with the Probe data during the mission.
- The internal PWA sequence count (**PWA Scnt**). The Sequence Count starts when the HASI-S/W provides the first SB and it is incremented each SB reception. It is an alternative way to perform a PWA Timetag.
- The events counter (**PWA Fcnt**) of the corrupted SB. The PWA after received by PWA is also

3.7 HASI SPECIAL FEATURES

3.7.1 BOOM RELEASE

In the normal operations three actions are required to deploy a boom: Firstly the HASI experiment must be switched ON; Secondly the Protected Power lines must be activated; and Finally the HASI-S/W must command boom deployment at the correct time window based on the DDBL time information. To inhibit boom deployment during ground operations, the HASI-S/W will not perform the commanding operations if the HASI is in CHECKOUT mode. The HASI operative mode is entered only at START-UP (refer to sect. 3.1). At START-UP, if the DDBL mission flag indicates Entry/Descent, the HASI enters into TITAN DESCENT mode. Then when the time in the DDBL shows the predetermined time **Td1**, the HASI-S/W performs two operations (which detailed description is in the sect. 2.2.1.2.2) to execute the boom deployment. Both the operations involve writing data to separate registers, the MCA control register, which selects the MCA (Boom) to be activated (deployed), and the MCA activation register which actually activates the boom deploy circuits (MCA power driver). The Boom#1 is first deployed and then the Boom#2. A second attempt is performed when the DDBL time shows the predetermined time **Td2**. The **Td1** and **Td2** time are uploadable parameters. The PROM default are reported in the sect 3.5 and 3.2.1.
Each boom release attempt is a repetition of 3 times (with 1 sec of time interval) of the following sequence:

a) activate MCA1
b) wait at least 50 msec after (a) and then deactivate MCA1
c) wait at least 10 msec
d) activate MCA2
e) wait at least 50 msec after (d) and then deactivate MCA2
f) wait at least 10 msec

The pulses duration has been measured during the DPU and HASI AIV and its maximum values was about 60 msec.

During the each MCA activation, the HASI-S/W records the status of the Protected Power and both the commands to the MCA power drivers (refer to sect 2.2.1.2.2). Then it reports them into the EVENT LOG packet (**'MCA readout'** event). The Nominal **BOOM RELEASE TRACE** is hereafter reported. The sign '+' means 'presence of' (e.g. '+ENERGY' means the presence of the Energise power), while the sign '-' intends 'not commanded' (e.g. '-MCA1' indicates MCA1 is commanded OFF) or 'not present' (e.g. '-ENERGY' means the Energise power in not present).
figure h shows the BOOM RELEASE TRACE together with the log of the typical events after an HASI switch-ON. Each Boom Release attempt is composed by 18 events and therefore it is contained into two different EVENT LOG packets. Only the first four events of the 2nd Boom Release attempt are sent into the same packets. The other twelve, are stored into the HASI RAM and will be transmitted after HASI enters in IMPACT state (refer also to 3.1.1). Usually, the first packet arrives to the IWS few seconds after the booms have been deployed.

Figure H: BOOM release trace

```
%M 08:57:53 -0:17:46.000 A#00340o DPU HK EVENT LOG

-0:17:46.000  DDBL time wrong
-0:17:46.000  EEPROM SWITCHED      ON
-0:17:46.000  EEPROM SWITCHED      OFF
-0:17:46.000  EEPROM LATCH-UP
-0:17:46.500  DDBL time wrong
-0:27:06.500  ACC range set COARSE
-0:28:01.875  DDBL time wrong
-4:26:30.659  T0
-4:26:30.659  DDBL time wrong
+0:01:00.000  MCA READOUT:        +ENERGY +MCA1 -MCA2  ----------------------
+0:01:00.125  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:00.125  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
+0:01:00.250  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:00.250  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
+0:01:00.375  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:01.125  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
                                                                            |
%M 08:57:47 +0:01:01.250 A#00328o DPU HK EVENT LOG                          |
+0:01:01.250  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:01.250  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |

          >>>>>    BOOM RELEASE 1st  ATTEMPT

+0:01:01.375  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:01.500  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
+0:01:01.500  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:02.250  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
+0:01:02.375  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:02.500  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
+0:01:02.500  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:01:02.625  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
+0:01:02.750  MCA READOUT:        +ENERGY -MCA1 +MCA2  _____________          |

+0:02:20.000  MCA READOUT:        +ENERGY +MCA1 -MCA2 ----------------------
+0:02:20.000  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:02:20.125  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
+0:02:20.250  MCA READOUT:        +ENERGY -MCA1 +MCA2                       |
+0:02:20.250  MCA READOUT:        +ENERGY +MCA1 -MCA2                       |
                                                                            |
          >>>>>    BOOM RELEASE 2nd  ATTEMPT:
```

Note:

1. the '**ACC range set COARSE**' event is logged at the ACC sampling start time (**TaccSample**) due to the Xservo saturation because the Probe System position.
1. The following trace

   -0:28:01.875 DDBL time wrong
   -4:26:30.659 T0
   -4:26:30.659 DDBL time wrong

   represents the T0 transition. The first 'DDBL time wrong' event is related to the DDBL time at T0 transition. The second is because the DDBL time is not monotone at T0 transition. The time '-4:26:30.659' is because the Titan Descent was performed by PIFS. The PIFS provides at T0 transition a wrong time value respect to the expected one (i.e. 0:00:00).

3.7.2 HASI BACKUP SUB-MODE

There are two different ways to drive the TITAN (or CHECKOUT) DESCENT leading to two sub-modes:

- **NOMINAL** sub-mode in which all the activities are fully driven by the DDBL information and BCP;

- **BACKUP** sub-mode in which (because of DDBL or BCP absence or DDBL corrupted) all activities are driven by HASI internal mission time.

To establish if to run in NOMINAL or BACKUP sub-mode, HASI performs the following periodical verifications (at BCP rate) :

- Processor Valid status;
- health check of BCP pulse rate (BCP rate nominally 125 msec);
- DDBL time-out (4 sec);
- DDBL reception errors (as described in the DDBL start-up test and figure g).

if the last DDBL is not okay or DDBL time-out or BCP is not okay, HASI enters in BACK-UP sub-mode. Then HASI swaps the selected CDMU and starts continuing the checks on the other line until next DDBL or BCP is not rejected. At that point the mission time, altitude and functions are synchronised with the DDBL information and the NOMINAL sub-mode is resumed.

HASI NOMINAL in which the HMT is initialised with the DDBL time; the HMT is then incremented every BCP reception (i.e. each 125 msec) and reloaded after DDBL reception with the DDBL time.

HASI BACKUP in which the HMT is initialised with the internal clock and then incremented every BCP reception (each 125 msec). In case of BCP absence, the HMT is incremented by the HASI provided BCP in which the reception is simulated every about 180 msec.

NOTE:

In the TITAN BACKUP sub-mode, the altitude and spin rate information (internally to HASI) are not updated. The mission evolution is performed only using the internal Mission time:

T0 event is internally simulated when the internal mission time is 28:00 (**Predicted-T0),** while the IMPACT state is entered when the internal mission time is 1:59:00 (**Tproximity**).

3.7.3 VALID LINE HANDLING & CDMU SELECTION

The HASI is able to receive and recognise the PROCESSOR VALID line. The CDMU selection is driven by the HASI software. At START-UP mode according to the content of this signal, the HASI selects the CDMU (refer to DDBL Start-up test in the section 3.1). However, the CDMU could be selected against the Processor Valid state; in-fact if the received DDBL (from the Valid CDMU) is corrupted (according to the criteria shown in figure g), the HASI-S/W swaps the CDMU and selects the NOT Valid CDMU in case successfully complete test of the received DDBL.

Every BCP (refer to figure i), HASI-S/W verifies that:

- the Processor valid line has changed state;
- the 4 seconds time-out on DDBL is elapsed;
- the 125msec time-out on BCP is elapsed; and
- the DDBL was correctly received according to the DDBL test reported in figure g.

When the Processor Valid has been swapped by CDMS or one of the other failure condition is true, the HASI-S/W swaps the selected CDMU and starts running in BACKUP sub-mode. Then it checks the other line until next DDBL is not rejected. At this point, the mission time and all HASI functions are synchronised with the new DDBL information and the NOMINAL sub-mode is resumed.

Figure I: CDMU SELECTION CRITERIA

3.7.4 DDBL TIME AND BCP HANDLING

HASI is not able to self recognise a wrong or inconsistent information contained in 'well composed' DDBL packets (e.g. Time suspended, Time not monotonic, Altitude jump). Therefore the last received DDBL information drives the HASI functions.
In case of the DDBL time is not increasing by one DDBL time unit (2 sec), the HASI will report that via an event in the EVENT LOG packet.
In case of DDBL time-out the HASI-S/W keeps on the mission running triggered by the BCP (refer to 3.7.2).

The impacts on wrong time information are wide and they may be not predictable. For example:

- wrong sensor sampling;
- CPU time overhead.

When the DDBL time restarts correctly also HASI will become NOMINAL.

Conclusion: HASI is affected only temporary by the wrong DDBL time.

3.7.5 DDBL ALTITUDE

Upon the reception of correct DDBL, when HASI is in DESCENT 3rd state (i.e. DDBL time greater then Tradar=T0+32min) if the Altitude information jumps, HASI may change state in accordance. A report of the DDBL altitude information is sent via PWA science packets (RP experiment data format). The cases are three:

- **The altitude is wrong, but it is greater than 7 Km**: HASI does not change state or mode.
- **The altitude is wrong, but it is greater than 1 Km**; the PWA changes mode; in fact in DESCENT 3rd state with the altitude is less then 7 Km, it changes from mode C to mode D. This change is too early respect to the expected time and it may be a loss of some PWA science. The mode D is designed when the altitude is less then 7 Km. As soon the altitude comes back before 7 Km, the PWA restarts with mode C. Some PWA functionality it may be affected if the altitude jumps continuously forward and backwards.
- **The altitude is wrong and is less or equal to 1 Km**; the HASI state changes to IMPACT till the detection of the Probe Impact detected by the ACC. No possibility to return or to go forward from this state. The PWA changes immediately to mode D and it remains till the HASI is in SURFACE. No ACC data will be sent in this state, while the TEM sensors are differently acquired.

3.7.6 ENTRY STATE WORST CASE DURATION

One of the HASI major science objectives is to provide the Probe deceleration during the Entry into the Titan atmosphere. To be able to derive the density/temperature profiles during the Probe entry (when the TEM and PRE sensors are not sampled), it is necessary to measure the deceleration of the Probe during the early part of the Probe Entry (a window starting from Tentry and ending at T0).

The HASI ENTRY is the most critical mission state for HASI (refer to the sections 3.1.1 and 3.6.1). In-fact HASI must store all the acquired data (till DESCENT 2nd state) for later re-transmission (i.e. after **TdataH**) because the Probe relay link to the Cassini Orbiter is not assured. Since the sensor data production rate is fixed, in case of an ENTRY state duration longer than expected it may be possible that the TM queues are full (the HASI queues are capable to store about 13 minutes of science data from **TaccSample** till T0 transition). In this case HASI will loose some important science data. In TITAN mode, the duration of the ENTRY state is mainly driven by the T0 detection from the CDMS. After T0 detection, the DDBL mission time increases and so the HASI mission state evolves consequently up to the DESCENT 2nd state. From that point HASI transmits the science data without any further storing.

The three possible scenarios are examined in the following:

in the **ENTRY NOMINAL** CASE scenario (based on the Aerospatiale simulations):

- the range of time from the HASI power ON to the T0 event is 10 minutes;
- the Tentry to T0 window beginning occurs 5 minutes after HASI power ON and therefore well inside the HASI queuing capacity.

in the **ENTRY WORST CASE** scenario:

- **Minimum case**:
  - the minimum range of time from the HASI power ON to the T0 event is 5 minutes and 42 seconds;
  - the Tentry to T0 window beginning occurs 1.5 minutes after HASI power ON and therefore the ACC data are stored starting from 0.5 minutes before the beginning of the entry peak (expected at Tentry+2.5 minutes).
- **Maximum case**:
  - the maximum range of time from the HASI power ON to the T0 event is 13 minutes and 16 seconds;
  - the Tentry to T0 window beginning occurs 8 minutes and 16 seconds after HASI power ON and therefore well inside the HASI queuing capacity without loosing any data between T0 and TdataH.

NOTE: in case of Entry scenario future modification, it is possible to modify the HASI Nominal Timeline table (refer to 3.2) together with the Xservo Entry production rate (refer to 3.8.2.1) in order to optimise the HASI Entry TM production.

3.8 HASI DATA HANDLING

3.8.1 PRE MEASUREMENT

The PREssure measurement comprehends:

- 24 frequency channel in the range 1-30 KHz
- 2 housekeeping voltages in the range 0-10 volt

In case of PPI failure (e.g. the PPI does not provide any frequency), a bit is reset in the HASI-SW showing PPI = NOK and in the EVENT LOG TM packet. A PPI Time-out is also reported in the HC2SEC TM packet.

The frequency channels are grouped in 6 reference channels and 18 sensor channels. They are also hardware organised in 3 blocks of 8 sensors each (6 sensors + 2 references).

The list of PREssure channels is reported in section 2.2.1.6.

The PREssure measurement consists of a period measurement. The optimal measure is to maintain the integration time approximately equal to 100 msec, even if the frequency to be measured is variable. Since this frequency is not known in advance, the measurement is performed in two steps:

- **A fast preliminary rough measure** to select the hardware parameters which will be used in the successive precise measure in order to meet the required measurement accuracy ($2*10^{-6}$ sec) and to keep the measurement time as equal as possible for each measured frequency (refer to UR-3.2.1.6-2 of AD(5)) even under channels faults;
- **A precise measurement using 100 msec of integration time**.

The precise period measurements are transmitted as they are (i.e. raw data) or post-processed using the following formula, averaged and then transmitted:

$$Y = (S - R1(S)) / (R2(S) - R1(S))$$

where :

Si is the period measurement of the sensor output frequency.

R1(S) is the period measurement of 1st Reference channel of the block containing the sensor S. R1 is the reference channel of low frequency (high capacitance).

R2(S) is the measurement of 2nd reference channel of the block containing the sensor S. R2 is the reference channel of highest frequency (lowest capacitance).

Y is the compressed pressure data in the range [-1,+1].

Formula C: Yvalue formula

The following actions are taken in case of Y being outside the above range:

Table N: Y value range

CONDITION	CLASSIFICATION	ACTION
-1 <= Y <= +1	nominal	normal processing
-2 <= Y <= -1	nominal	Y = Y + 1
Yi > 1	failure	Y = 1
Yi < -2	failure	Y = 0
R1 and R2 near value	failure	Y = 1

A dedicated event is written in the EVENT LOG TM packet (**PPI Range fail** message), when a failure condition is detected in the Y value calculation.

3.8.1.1 PRE Sessions sequence

The PRE measurement and its data production begins in the DESCENT 1st state (i.e. at **Tdata**) and it ends till the Probe link will be lost (i.e. **Tloss**). The PRE measurement is defined by a fixed sequence {**SSn**} of NORMAL and HEALTH-CHECK Sessions.
The sequence {**SSn**} is specified repeating NORMAL and HEALTH-CHECK session as in the following 7-session basic cycle [HC+N+N+N+HC+N+N].

3.8.1.1.1 NORMAL Session

The NORMAL sessions include three different types (ranging from A to C). Each of them defines a sequence **{YSh}** of 36 YSi statistical pressure data to be produced at regular rate of 2 each ≈2.4 sec as per AD(5) (i.e. two items every 0.41666 Hz). The **measured** session duration time is 41.2 sec (average value). The three types define each the LOW (session **A**), MEDIUM (session **B**) and HIGH (session **C**) NORMAL session.
The physical channel **S(i,j)** used for each step i of each NORMAL session j is mapped by means of an EEPROM uploadable table of the form

S = f (i,j)	**j**:	0...2	(where 0 corresponds to **A** normal session, 1 to **B** and 2 to **C**)
	i:	1...36	
	S:	0...23	

A special sequence of raw frequency measurement (period) is performed to allow the YSi production rate of 2 every ≈2.4 sec. The two YSi data are obtained from 16 raw frequency measurements, each taking between 120÷145 msec. A straight-forward readout sequence takes between 1.8÷2.1 seconds for each YSi. The sensor measurements of session steps i and i+1 are performed in couples sharing the reference channels measurements thus needing only 16 raw frequency measurements for a pair of YSi and YSi+1 performed in ≈2.4 seconds. **This fact restricts the freedom of channel selection: both channels in one pair has to belong to the same group.**

Each Normal session data is composed of the arithmetical AVERAGE of five YSi value (16 bits) and their VARIANCE (8 bits). The following formula is used to calculate the YSi-VARIANCE:

YSi-variance = (Sum Yi^2)/5 - Y^2

Formula D: YSi-value variance

Each complete Normal session measurement is organised in a unique time-stamped TM packet together with the raw data value (8 bits scaled) of last two reference channels R1, R2 readings. Different TM packet formats are foreseen to distinguish the different Normal Session.

3.8.1.1.2 HEALTH-CHECK Session

The HEALTH CHECK Sessions include up to two different types (from **G** to **H**). Each of them defines a sequence **{Fh}** of 37 frequency channels raw data (either sensor or reference) acquired at regular distance in 5.17 seconds (that corresponds to a regular sampling rate of 7.16 Hz).
The physical channel S(i,j) used for each step i of each HEALTH-CHECK session j shall be mapped by means of an EEPROM uploadable table of the form:

S = f(i,j) **j**: 1 .. 2 (where 1 corresponds to **H** health check session and 2 to **G**);
i: 1 .. 37;
S: 0 .. 23.

Each **Fi** frequency raw data is a 24 bit unsigned integer value of the time corresponding to the frequency period measured.
Each complete HEALTH-CHECK SESSION measurement set of 37 Fi is inserted in a time-stamped TM packet. Two different TM packet format are foreseen to distinguish the two HEALTH-CHECK sessions.

3.8.1.2 PRE sessions along TITAN descent

During the whole Titan descent, the PRE measurement is divided in three fixed different phases in accordance with the following:

LOW pressure phase: **G A A A H A A** if the DDBL time is between the **Tdata** and **Tmid** (PROM default value = 1:15:00 after T0);

MEDIUM pressure phase: **G B B B H B B** if the DDBL time is between the **Tmid** and **Thigh** (PROM default value = 1:45:00 after T0);

HIGH pressure phase: **G C C C H C C** if the DDBL time is between the **Thigh** and Tloss**.**

As soon as the DDBL time is greater of **Tmid** (**Thigh**) and the {SSn} sequence is finished, the HASI passes to the MEDIUM (HIGH) pressure phase. The time transition (i.e. **Tmid** and **Thigh**) are uploadable parameters.

3.8.1.3 PREssure housekeeping

The PPI HK-V0 and V1 housekeeping voltages are measured every 2 sec. The measured values are checked respect to the following ranges:

- HKV0 range is 4.5V to 5.5V
- HKV1 range is 2.5V to 7.5V.

The results of these checks are reported in the HC2SEC TM packet (refer to section 3.8.5).

From the HASI power-on, the two housekeeping signals are arithmetical averaged (one sample each 64 sec) and are inserted in a time stamped TM packet (**PPI HKV TM**). The formula to calculate the voltage from the TM value is hereafter reported.

V = VAL * (10 / ((4096 * 16) - 1)) Volt

where: **VAL** is the 16 bits decimal value extracted from the TM packets

Formula E: PPI HK Voltage reconstruction formula

3.8.1.4 PRE data reconstruction

While the frequencies telemetred in the PPI Health Check data packets are just useful to understand the health conditions of each sensor channel and as a sort of less accurate redundancy, the data contained in the PPI Normal session packets are used to reconstruct from the Y values received the measured physical data. This can be done as follows:

- the pressure sensors data can be converted into pressure units using the following formula which is valid for:

  - HIGH pressure sensor in the range 0 .. 1600 mbar;
  - MEDIUM pressure sensor in the range 0 .. 1160 mbar;
  - LOW pressure sensor in the range 0 .. 400 mbar.

  Temperature dependence compensation was calculated between -35 and +45 °C:

$$P = ((1/(A-Y)) + (K4*Y^4) + (K3*Y^3) + (K2*Y^2) - (O + T_{OFFSET} * t)) / (G + T_{GAIN} * t)$$

Formula F: PRE reconstruction formula - wide range

- to reconstruct the pressure data when in atmospheric pressure (800 .. 1060 mbar), the following reduced formula can be used (in the temperature range between +5 and 45 °C):

$$P = ((1/(A1-Y)) - (O1+T1_{OFFSET}*t)) / (G1 + T1_{GAIN} * t)$$

Formula G: PRE Reconstruction formula - narrow range

the formula can be used for functional check purpose.

- the thermocap data can be converted into temperature using the following formula (temperature range -45 .. +75 °C):

$$t = ((1/(a-Y)) - b) / c$$

Formula H: PPI Temperature reconstruction

Where:

- **'P'** is the measured pressure expressed in mbar;
- **'t'** is the measured temperature expressed in Centigrade degrees:

  for sensor channel 1.1, 1.6 and 1.8 use Thermocap channel 1.3;
  for sensor channel 2.1, 2.6 and 2.8 use Thermocap channel 2.3;
  for sensor channel 3.7 and 3.8 use Thermocap channel 3.3;

- **Y** is the Y value received in the PRE Normal sessions telemetry packets for the relevant to the Thermocap block and channel which is to convert;
- The coefficients for the formulas are reported in the sect 3.8.1.5.

3.8.1.5 PRE calibration tables

Table O: FM coefficients for PREssure reconstruction (formula f)

Block. Ch#	A	K4	K3	K2	G	O	TGAIN	TOFFSET
1.1	0.70933	0.576038	0.420474	0.222446	-0.0016989	3.11431	0.000000191	-0.00027
1.6	0.70944	0.913535	0.322299	0.243633	-0.0015446	3.20610	0.000000176	-0.00029
1.8	0.70900	0.509454	0.421665	0.227899	-0.0017922	3.11988	0.000000210	-0.00027
2.1	0.69483	0.260947	0.346241	0.207277	-0.0012719	2.91446	0.000000146	-0.000167
2.7	0.69070	0.369996	0.377318	0.211959	-0.0011483	2.88523	0.000000131	-0.000201
2.8	0.67356	0.352843	0.390846	0.222883	-0.0011488	2.87117	0.000000121	-0.000173
3.7	0.88774	-0.487971	0.080418	0.028051	0.0084094	1.16132	-0.000001127	-0.000274
3.8	0.88500	-0.130457	-0.286945	0.172239	0.0097982	1.23710	-0.000000834	-0.000392

Table P: FS coefficients for PREssure reconstruction (formula f)

Block. Ch#	A	K4	K3	K2	G	O	TGAIN	TOFFSET
1.1	0.71331	1.044792	0.404739	0.227675	-0.0016447	3.12197	0.000000210	-0.000298
1.6	0.69482	0.343805	0.441491	0.247537	-0.0018527	3.08330	0.000000255	-0.000311
1.8	0.71187	0.548605	0.462056	0.231763	-0.0017767	3.11035	0.000000229	-0.000304
2.1	0.70321	0.482177	0.403505	0.157948	-0.0012205	3.00099	0.000000142	-0.000292
2.7	0.71330	0.415433	0.396660	0.208141	-0.0013283	3.08728	0.000000168	-0.000218
2.8	0.68341	0.691935	0.535742	0.220176	-0.0009638	3.13125	0.000000096	-0.000182
3.7	0.88440	-0.032023	-0.290318	0.107762	0.0103307	1.16256	-0.000000581	-0.000309
3.8	0.89039	-0.423317	0.034923	0.038185	0.0095503	1.09450	-0.000000055	-0.000713

Note The FS coefficients must be checked with respect to the FS ADP (refer to AD(10)).

Table Q: FM coefficients for PREssure reconstruction (formula g)

Block. Ch#.	A1	O1	T1OFFSET	G1	T1GAIN
1.1	0.66564	3.43558	-0.0002492	-0.0019271	0.000000152
1.6	0.67903	3.41678	-0.0002530	-0.0016707	0.000000138
1.8	0.65843	3.50068	-0.0002464	-0.0020780	0.000000171
2.1	0.67007	3.06852	-0.0001099	-0.0013585	0.000000100
2.7	0.66816	3.01934	-0.0001566	-0.0012158	0.000000090
2.8	0.65058	3.01282	-0.0001183	-0.0012223	0.000000078
3.7	0.91039	1.63925	-0.0004214	0.0064046	-0.000000167
3.8	0.91512	1.88268	-0.0005567	0.0067805	0.00000164

Table R: FS coefficients for PREssure reconstruction (formula g)

Block. Ch#	A1	O1	T1OFFSET	G1	T1GAIN
1.1	0.66420	3.48664	-0.0002575	-0.0018939	0.000000154
1.6	0.62375	3.63223	-0.0002921	-0.0022870	0.000000199
1.8	0.65127	3.56985	-0.0002663	-0.0021190	0.000000172
2.1	0.68238	3.12848	-0.0002283	-0.0012849	0.000000086
2.7	0.69148	3.21738	-0.0001620	-0.0013942	0.000000120
2.8	0.67623	3.13426	-0.0001306	-0.0009509	0.000000053
3.7	0.91461	1.90883	-0.0005951	0.0070237	0.000000585
3.8	0.91830	1.79427	-0.0008229	0.0067602	0.000000782

Note The FS coefficients must be checked with respect to the FS ADP (refer to AD(10))

Table S: FM & FS coefficients for PPI Temperature reconstruction (formula h)

Block. Ch#	Flight Model			Flight Spare		
	a	**b**	**c**	**a**	**b**	**c**
1.3	0.95520	4.34272	0.0239358	0.94498	3.55843	0.0198621
2.3	0.94665	3.35377	0.0182452	0.94969	4.01079	0.0222757
3.3	0.92365	2.52352	0.0137031	0.91917	2.47625	0.0136819

Note The FS coefficients must be checked with respect to the FS ADP (refer to AD(10))

3.8.2 ACC MEASUREMENT

During the HASI states evolution the seven ACCelerometer physical channels are sampled and data processed and telemetred in different modes. The channels are read throughout the entire Titan mission (i.e. after Start-up mode) at 400 Hz with a 12 bit (bipolar) resolution (one ADC unit is equal to 10Volt/2048). The reading is performed via DMA and data are stored in to RAM in a circular buffer. From **TaccSample** (uploadable parameter), HASI starts processing the data from this buffer. The data are processed with a rate lower than the acquisition rate by extracting one every 'n' samples in accordance with the ACC specification (refer to RD(10)). For example when n=4, the data are processed at 100 Hz. These samples are called **raw data**. The seven channels and their sampling rate are reported hereafter:

- Xservo LOW gain at 100 Hz
- X servo HIGH gain at 100 Hz
- Xpiezo at 50 Hz
- Ypiezo at 50 Hz
- Zpiezo at 50 Hz
- Temp 1 (Tservo) at 1.5625Hz
- Temp 2 (Tpiezo) at 1.5625Hz

3.8.2.1 Xservo data handling

3.8.2.1.1 Xservo range selection

The Xservo has two physical channels which are set at **FINE** range after every HASI **START-UP** mode completion and will be switched to **COARSE** range prior to saturation or anyhow after **Tdata**. When the range changes, an Event is reported in the EVENT LOG TM packet ('**ACC range set to COARSE**' message). The ACC X-servo range command is monitored every 2 sec and its status is reported in the HC2SEC TM packets. The range change is based on the following algorithm:

> at Xservo production rate (i.e. the PROM default value is 3.125 Hz), the Xservo LOW Gain raw data are checked against a threshold parameter (PROM default = 95% of 10 Volt Full Scale) and if the value is trespassed, HASI switches the range to COARSE.

The Xservo values must be scaled taking into account the range which is selected; the Range switching time can be extracted reading the Mission time related to the switching event reported into EVENT LOG TM packet.
Note that:

- When a range change occurs during the integration for Xservo statistics, the calculated STD2.Xs value is meaningless.
- After the range change, the Xservo outputs (LOW and HIGH gain) need about 1 sec to stabilise.

3.8.2.1.2 Xservo channels selection

The best Xservo channel selection (between the LOW and HIGH gain) is performed examining periodically at Xservo data production rate (i.e. 3.125 Hz in ENTRY or 4.167 Hz till DESCENT 3rd or 1.754 Hz till the end of the mission taking into account the PROM default value), the two channels raw data and selecting the best channel to be telemetred using the following method:

case Xservo = LOW gain: if the value is lower than a threshold parameter (PROM default = 7% of 10 Volt Full Scale), then select and transmit the HIGH gain channel.

case Xservo = HIGH gain: if the value is higher than a threshold parameter (PROM default = 90% of 10 Volt Full Scale), then select and transmit the LOW gain channel.

Since the Xservo samples can be selected from one of the two channels (HIGH and LOW gain) all the data are tagged with a bit indicating the selected channel.

3.8.2.2 ACC data production during ENTRY state

The Xservo raw data are arithmetically averaged every 3.125 Hz (this production rate may be changed via uploading parameter), while the piezo raw data are arithmetically averaged every 1.6129 Hz. Each data type is organised in a unique time-stamped TM packet:

- SCDS.E contains Xservo samples scaled within signed 16 bit
- SCDP.X contains Xpiezo samples scaled within signed 16 bit
- SCDP.Y contains Ypiezo samples scaled within signed 16 bit
- SCDP.Z contains Zpiezo samples scaled within signed 16 bit.

Using a method similar to the one foreseen for the above channels, statistics are produced and transmitted at lower rate: data from each of the four channels (Xservo selected channel, Xpiezo, Ypiezo and Zpiezo) are integrated over the statistics time period (0.1 Hz) taking one sample every 32 from the 400 Hz samples. Over this period, 128 values are accumulated for the integration and transmitted via TM packets, one for each channel:

- STD2.XS contains Xservo samples within signed 24 bits
- STD2.XP contains Xpiezo samples within signed 24 bits
- STD2.YP contains Ypiezo samples within signed 24 bits
- STD2.ZP contains Zpiezo samples within signed 24 bits.

The piezo and servo temperatures raw data are integrated over a time period (0.097 Hz) taking one sample every 16. Over this period, 16 values are accumulated for the integration and transmitted via TM packets, one for each channel:

- HKD1 contains servo temperature samples within signed 16 bits
- HKD2 contains piezo temperature samples within signed 16 bits.

3.8.2.3 ACC data production during DESCENT 1st & 2nd states

Till **Tradar**, the Xservo raw data are arithmetically averaged every 4.167 Hz (this production rate may be changed via uploading parameter) and organised in a time-stamped TM packet:

- SCDS.D contains Xservo samples scaled within signed 16 bit

Moreover the statistics and the housekeeping temperatures continue to be produced at same rate:

- STD2.XS contains Xservo samples within signed 24 bits

- STD2.XP contains Xpiezo samples within signed 24 bits
- STD2.YP contains Ypiezo samples within signed 24 bits
- STD2.ZP contains Zpiezo samples within signed 24 bits.
- HKD1 contains servo temperature samples within signed 16 bits
- HKD2 contains piezo temperature samples within signed 16 bits.

3.8.2.4 ACC data production during DESCENT 3rd to SURFACE states

Till the last kilometers, the Xservo raw data are arithmetically averaged every 1.754 Hz (this production rate may be changed via uploading parameter) and organised in a time-stamped TM packet:

- SCDS.R contains Xservo samples scaled within signed 16 bit

Moreover the statistics and the housekeeping temperatures continue to be produced at same rate:

- STD2.XS contains Xservo samples within signed 24 bits
- STD2.XP contains Xpiezo samples within signed 24 bits
- STD2.YP contains Ypiezo samples within signed 24 bits
- STD2.ZP contains Zpiezo samples within signed 24 bits.
- HKD1 contains servo temperature samples within signed 16 bits
- HKD2 contains piezo temperature samples within signed 16 bits.

The IMPACT state is dedicated to the detection of the Probe impact and no ACC data are transmitted until the SURFACE state. The original seven channels, 400 Hz sampling is still maintained and the resulting data are used for the Impact detection and Impact trace generation. The Impact trace is constructed for a period 0.5 sec before Impact to 5.5 sec after detection. This buffer holds one sample every 2 from the 400 Hz X, Y and Z piezo data sampling (e.g. the data is stored at 200 Hz). The Impact detection uses quadratically filtered 400 Hz Xservo LOW gain values (Xs) to compare against a threshold value (**QfT**):

$$Y(n) = QfA * Y(n-2) + QfB * Y(n-1) + QfC * Xs(n)$$

where

Xs(n)	is the Xservo LOW gain channel output at the n-th instant;
Ys(n)	is Filter output at the n-th instant;
Ys(n-2)	is Filter output at the (n-2)-th instant;
Ys(n-1)	is Filter output at the (n-1)-th instant;
QfA, **QfB**, **QfC**	are the filter coefficients (PROM default are **QfA** = 0.1, **QfB** = 0.2, **QfC** = 0.7);
QfT	is the threshold value (PROM default is **QfT** = +5Volt).

Formula I: Impact detection filter

The Impact detection function (i.e. **ImpactFun**) is changeable uploading a memory patch as well as the filter coefficients (**QfA**, **QfB**, **QfC** and the threshold **QfT** values)

After Impact detection, HASI enters in the SURFACE state and reports it in the EVENT LOG TM packet. Then the HASI-S/W sends (immediately) the Impact trace (66 packets):

- ID1 contains Xpiezo samples at 200 Hz within signed 16 bits
- ID2 contains Ypiezo samples at 200 Hz within signed 16 bits
- ID3 contains Zpiezo samples at 200 Hz within signed 16 bits.

The Impact detection time is extracted reading the Mission time related to the impact event reported into EVENT LOG TM packet ('**TIMPACT**' message).

After IMPACT state, HASI restarts to transmit the ACC data as in DESCENT 3rd state.

3.8.2.5 Acceleration reconstruction

The FM ACC sensors have been calibrated at S/S level and the results are reported in the RD(1). Each calibration is the combination of each sensor head Scale factor (initially measured and calibrated by the sensor head manufactured) and the S/S electronics behaviour in the qualification tests (i.e. Initial Performance test, Thermal Vacuum test and Final Performance Test). same results are for the FS ACC sensors (refer to AD(6)).

The ACC output Voltages are separately amplified/filtered and then converted in **raw data** by the DPU S/S using a ±10V bipolar 12 bits A/D (refer to sect 3.8.2 and sect 2.2.1.3). Each ACC channel analogue chain has same amplification and bandwidth. The NOMINAL 'scale factor' value used to convert the FM DPU reading into voltage values is **SF= (RF * 1.02405)**, where the **1.02405** number is amplifier gain and **RF** is the voltage resolution of the TM data (refer to 5.3). The ACC calibration errors have been calculated and reported in the DPU PFM Summary report for FM (refer to sect 3.3.1 of the RD(12)). The calibration errors are independently calculated for each ACC sensors: Xservo (best channel), Xpiezo, Ypiezo, Zpiezo, Temp1 and Temp2. The measurements were performed in accordance to the DPU PFM AIV plan (refer to AD(13)) using the ACC simulator. The calibration takes into account the completed analogue to digital chain errors (i.e. the amplifier, the filter and the A/D converter).

3.8.3 TEM MEASUREMENT

The resistance of each TEM sensor is measured using a four wire configuration. A current generator drives the measuring current in the TEM sensor and into a series Reference high stability resistance (refer to sect. 2.2.1.3). From this measurement method we obtain the following formula:

$$R_{TEM} = R_{REF} * (V_{TEM}/V_{REF})$$

Formula J: TEM resistance raw value

In order to gain in accuracy and resolution, HASI measures a linear combination of the V_{TEM} and V_{REF} (refer to RD(5) sect 3.2.3.8). The same linear combination is used to measure the **TEM** and **REFERENCE** offsets (i.e. without current flowing). Each **raw data** measure is performed under the HASI-S/W control and is composed by a sequence of **eight** A/D converter (12 bits) readings. These readings are taken in less than 1msec. The **TEM** and **REFERENCE** voltage offsets raw data are then averaged in a period of 108 sec. These averages and the seven most significant bits of the raw data offsets are inserted in the TEM TM packets. Two temperature measurement ranges are foreseen and consequently the acquired data are tagged with a bit indicating the selected range. These data are telemetred to ground via a time-stamped TM packet. Each TEM sensors head has a distinguished TM packet (i.e. **F1**, **F2**, **C1** and **C2**).

3.8.3.1 TEM range selection

At the end of each measurement and for each TEM sensors, HASI selects which channel (between **LOW** and **HIGH** gain) will be used in the next measure. The **LOW** (**HIGH**) gain channel means to measure the temperature in the **LOW** (**HIGH**) resolution range; i.e. HASI is using the wide (narrow) temperature range. The temperature ranges in HASI are:

- 60K to 110K (i.e. **HIGH** resolution range)
- 100K to 330K (i.e. **LOW** resolution range)

At HASI power ON or reset the TEM range is always set to **LOW**.

The range change is performed by the HASI-S/W calculating the rough resistor **RRx** using the following formula:

$$RRX = ((VF - OVF) / (VR - OVR)) + 1$$

where:

- **VF** is the actual TEM voltage
- **OVF** is the actual TEM mean offset voltage
- **VR** is the actual REFERENCE voltage
- **OVR** is the actual REFERENCE mean offset voltage

Formula K: TEM range selection

and selecting the new gain channel in the following two cases depending on the current gain selection:

case **HIGH** gain: if the RRx value * Gradient HIGH (PROM default = **7.32K**) is greater than the HIGH threshold (PROM default = **105K**), than select **LOW** gain.

case **LOW** gain: if the RRx value * Gradient LOW (PROM default = **27.3K**) is greater than the LOW threshold (PROM default = **105K**), than select **HIGH** gain.

3.8.3.2 TEM measurement during Titan descent

The TEM sensors measurement starts from **Tdata**. Every 5 seconds a measurement cycle of all the four TEM sensors (in the order: TEM1 Fine, TEM1 Coarse, TEM2 Fine, TEM2 Coarse) is performed. Each set of measurement on one TEM sensor (Fine and Coarse) starts with 2.5 seconds period. A TEM measure is performed every 1.25 sec.

From **Tdata** to the beginning of the IMPACT state, HASI produces the following TEM data (each data type is organised in a unique time-stamped TM packet):

- F1 contains the TEM1 Fine sensor VF, OVF, OVFMEAN, VR, OVR and OVRMEAN
- C1 contains the TEM1 Coarse sensor VF, OVF, OVFMEAN, VR, OVR and OVRMEAN
- F2 contains the TEM2 Fine sensor VF, OVF, OVFMEAN, VR, OVR and OVRMEAN
- C2 contains the TEM2 Coarse sensor VF, OVF, OVFMEAN, VR, OVR and OVRMEAN

During the IMPACT state HASI performs a measurement cycle of only the FINE sensors (in the order: TEM F1, TEM F2) every 2.5 seconds. Each set of measurement on one TEM sensor starts with 1.25 seconds period and therefore it produces the following TEM data (each data type is organised in a unique time-stamped TM packet):

- F1 contains the TEM1 Fine sensor VF, OVF, OVFMEAN, VR, OVR and OVRMEAN
- F2 contains the TEM2 Fine sensor VF, OVF, OVFMEAN, VR, OVR and OVRMEAN

When in SURFACE state HASI resumes the TEM acquisition used from **Tdata** to IMPACT.

As above described, when passing to IMPACT state (at DDBL altitude = 1 Km) the TEM acquisition switches mode and therefore the F1 and F2 packets may contain data acquired at different rate (i.e. 5 sec and 2.5 sec rate). To distinguish them, it shall be used the DDBL Time when altitude information shows 1 Km (example is reported in the sect. 3.6.2.1.2). The C1 and C2 packets stops in IMPACT state and re-starts in SURFACE state. These packets will be sent not before their completion and therefore they may contain data acquired before IMPACT state and data acquired after Probe Impact. The DDBL Time when altitude information shows 1 Km and the Impact Time (sent by HASI in the EVENT LOG) shall be used to reconstruct the C1 and C2 science items profiles.

The TEM measurement sequence is an up-loadable parameter re-definable singularly for each HASI state.

NOTE L: TEM sequence table

3.8.3.3 Temperature reconstruction

3.8.3.3.1 TEM resistance Nominal value formula

The formula to reconstruct (unless the calibration factors) the **RTEM nominal** value (in Ohm) is given in the following:

RTEM = K * (((VF - OFFVF) / (VR - OFFVR)) + 1)

the voltage values are extracted and then processed from the TEM TM packets according to the rules indicated in the sect 5.4. The name of the values are the same in the TEMs TM packet formats (refer to the table in the sect 5.4) except for the OFFVF and OFFVR that indicate post-processed voltage values:

- **VF** is the TEM actual measured voltage (raw value);
- **OFFVF** is the TEM actual post-processed offset voltage (raw value);
- **VR** is the REFERENCE actual measured voltage (raw value);
- **OFFVR** is the REFERENCE actual post-processed offset voltage (raw value);
- **K** are the values reported in the following table:

Table T: TEM Reference resistance

	FM	FS
G = HIGH resolution range	K= 1.5077 Ω	K= 1.5075 Ω
G = LOW resolution range	K= 4.0276 Ω	K= 4.0312 Ω

G indicates the name of the GAIN selection field in the TEM TM packet format (refer to the table in the sect 5.4).

The actual post-processed offset voltages are obtained from the telemetred offset data using the formula:

OFFVF = ((OVF << 1)½(OVFMEAM & 0xFF00H)) * (ADU / 8)

OFFVR = ((OVR << 1)½(OVRMEAM & 0xFF00H)) * (ADU / 8)

where:

- **OVF** (**OVR**) is the hexadecimal value (extracted from the TM packet) of the TEM (REFERENCE) offset actual raw value;
- **OVFMEAN** (**OVRMEAN**) is the hexadecimal value (extracted from the TM packet) of the TEM (REFERENCE) offset average value;
- '**<<**', **'&'** and **'**½ are the C language bit operators **'left shift',** '**And**' and '**Or**' respectively;
- (**ADU / 8)** is the scale factor (10V/(4096*8)) to convert the value in volts.

Formula L: TEM resistance nominal value

3.8.3.3.2 TEM science reconstruction

Each TEM sensors have been calibrated at unit level and the results are reported in the RD(3). The TEM sensors complete calibration is the combination of each sensor head calibration (initially measured and calibrated by the sensor head manufactured) and the DPU S/S electronics behaviour in the qualification tests (i.e. Initial Performance test, Thermal Vacuum test and Final Performance Test).
The FM DPU calibration errors (accuracy) have been calculated and reported in the DPU PFM Summary report (refer to sect 3.3.2 of the RD(12). The DPU reading electronics is common to all the TEM sensors. The DPU s/s calibration has been performed in accordance to the DPU PFM AIV plan (refer to AD(13)) using the simulated resistors (measured with high accuracy instrument) applied to the TEM inputs. The accuracy error (calibration) are obtained comparing the values of the simulated resistors with the actual resistance given extracted by the TEM packets. The formula used to calculate the resistance was the following:

RTEM = K * (((VF - OVFMEAN) / (VR - OVRMEAN)) + 1)

where the voltage values and the K are those examined in the sect 3.8.3.3.1. Note that the offset voltage are the average since during the calibration tests the actual voltage offset raw values provide negligible contribution.

The calibration takes into account the completed analogue to digital chain errors (i.e. the filter and the ADC).
For the DPU FS refers to s/s tests which results are shown in the AD(13).

3.8.3.3.3 Range change

A special case is when the TEM Range change in the middle one packets. In-fact the TEM and REFERENCE offset mean values in that packet are not meaningful. However the **raw data** offsets in the packets are available and they are correct.
Because the hysteresis value in the selection criteria (refer to 3.8.3.1), during Titan descent the range change it is expected just ones time during the descent. Same conditions have been experienced during the Probe system AIV Thermal Vacuum tests.

The following procedures will be used in the two analysed cases.

case A: TEM range passes from LOW to HIGH resolution

1. Locate the packet where happens the range change (packet(1));
1. Extract from the previous packet the OVFMEAN and OVRMEAN mean offsets related to the LOW resolution range;
1. Extract from the next packet the OVFMEAN and OVRMEAN mean offsets related to the HIGH resolution range;
1. Locate in the packet(1) the last science item which uses the LOW resolution range (Tem_last);
1. Calculate the RTEM from the beginning of the packet(1) till the Tem_last using the formula I with the mean value of the Offsets found at the step 2;
1. Calculate the RTEM from the Tem_last (excluded) till the end of the packet using the formula I with the mean value of the Offsets found at the step 3.

case B: TEM range passes from HIGH to LOW resolution

1. Locate the packet where happens the range change (packet(2));
1. Extract from the previous packet the OVFMEAN and OVRMEAN mean offsets related to the HIGH resolution range.
1. Extract from the next packet the OVFMEAN and OVRMEAN mean offsets related to the LOW resolution range.
1. Locate in the packet(2) the last science item which uses the HIGH resolution range (Tem1_last).
1. Calculate the Rtem from the beginning of the packet(2) till the Temp1_last using the formula I with the mean value of the Offsets found at the step 2.
1. Calculate the Rtem from the Tem_last (excluded) till the end of the packet using the formula I with the mean value of the Offsets found at the step 3.

Because the most significant bytes of the two mean values Offsets do not change so much, the formula I can be used without modification in case of the more than ones range change during the mission.

3.8.4 PWA MEASUREMENT

3.8.4.1 Introduction

The DPU main processor manages the PWA activities by means of information exchanging through the DPU-PWA data link. The interface is a 8-bits parallel read/write register with two handshaking lines and interrupts. The DPU main processor is master, while the DSP is slave. The parallel port is half-duplex; it allows data exchange in one direction at a time.

The PWA embedded firmware performs the scientific measurements and periodically sends the results to DPU main processor by means of data packet. The PWA measures are syncronised with the 2 second mission time and depend by the HASI states. The altitude information is also used to switch from the PWA mode C to PWA mode D (refer to 3.2).

The main tasks of the data link between PWA and DPU main processor are:

- PWA to receive currently updated (every 2 sec) mission information (SB);
- PWA to periodically send scientific data according to the mission phases (DB).

The PWA operational modes are fully driven by the STATUS BLOCK (SB) information provided by the DPU main processor even when **Entry** state. The content of each SB includes the DDBL information as they are received from the CDMU (i.e. Mission phase and time, Altitude and Spin rate) plus the HASI internal states and a socket for PWA test command. When HASI is in **back-up** sub-mode, only the HMT is inserted into SB while the other DDBL information are not meaningfull.

For health-check purposes, the HASI-S/W checks the PWA data flow to verify its compliance with mission time and mode.

3.8.4.2 PWA data link PROTOCOL

The physical level of the PWA interface consists in a 8 bit parallel port that allows exchanging of information only in one direction at a time. The HW provides signals for completion of read (RX) or write (TX) single byte operations.

As the HW does not provide any information about the current busyness of the line, the two communicating processes (DPU and PWA) synchronise the messages exchange on a time basis and a defined order of TALK/LISTEN states transition as depicted here after.

- At Power on/reset DPU main processor configures as TALKER and PWA as LISTENER by software initialisation.

- The DPU main processor transmits 1 SB every 2 seconds ± 100 msec.

- PWA does not transmit Data Blocks until it receives a complete SB.

- PWA transmits ALWAYS two Data blocks between two SB, soon after the reception of the SB and 0.5 sec before the next (rough value).

- The DPU main processor in case of I/F conflicts, discovered by means of a 100 msec time-out on the device either when TALKING or LISTENING, reconfigures itself as a 2 second period TALKER

- PWA in case of I/F conflicts, discovered by means of a 150 msec time-out on the device when TALKING, reconfigures itself as a LISTENER.

3.8.4.3 PWA to DPU Data Block

The Data Block sent by PWA is conform to Standard ESA TM packets of 120 bytes composed as follows:

- HEADER (6 bytes)
- DATA FIELD HEADER (1 byte)
- DATA FIELD (112 bytes)
- XOR (1 byte)

Table U: PWA DB layout

BYTE #	VALUE	MEANING
1	0000 1XXX	**PACKET IDENTIFIER (version + flags + app proc id)**
2	XXXX XXXX	
3	11 + high	**PACKET SEQUENCE COUNT**
4	low	
5	high	**PACKET LENGTH (fixed to 115)**
6	low	
7	DATA TYPE	**DATA TYPE HEADER**
8	112 Bytes	**SCIENCE DATA VECTOR**
.....		
119		
120	XOR 1-119	**PACKET ERROR CONTROL**

Three different application PID are used to distinguish between:

- SCIENCE data packets (PID = 0x083FH)
- TEST data packets (PID = 0x0FE0H)
- HC data packets (PID = 0x0800H)

while the DATA TYPE HEADER is used to discriminate between different data. The DATA TYPE HEADER range is between 128 to 159 (decimal value).

3.8.4.4 DPU to PWA Status Block

The STATUS BLOCK sent by DPU main processor to PWA is a packet of 15 bytes composed as follows:

- HEADER (6 bytes)
- DATA FIELD (8 bytes)
- XOR (1 byte)

Table V: PWA SB layout

BYTE	VALUE	MEANING
1	0001 0000	**PACKET IDENTIFIER (version + flags + app proc id)**
2	1111 1111	
3	11 + high	**PACKET SEQUENCE COUNT**
4	low	
5	high	**PACKET LENGTH (fixed to 9)**
6	low	
7	from DDBL	**MISSION PHASE**
8	0-255	**TEST COMMAND PARAMETER (*)**
9		**MISSION TIME (from DDBL)**
10		
11		**PROBE ALTITUDE (from DDBL)**
12		
13		**PROBE SPIN RATE (from DDBL)**
14	HASI status	**HASI Status: ENTRY (0), DESCENT 1st (1), DESCENT 2nd (2), DESCENT 3rd (3), IMPACT (4) and SURFACE(5)**
15	XOR 1-14	**PACKET ERROR CONTROL**

Note (*) 0 means no test command present
N means test command #N is present

3.8.4.5 DPU/PWA checking

Every 2 sec (i.e. at DDBL rate), the DPU main processor starts to send the SB (15 bytes) to the PWA processor and if a time-out is detected (PWA acknowledge for each byte is not within 100 msec) the HASI reports that in the EVENT LOG packet and in the HC2S packet. Then the DPU main processor re-synchronises to 2 sec talker.

As soon as the PWA acknowledges the SB transmission, the DPU main processor prepares to receive the first Data Block.

In case of transmission time-out (a PWA byte transmission is not within 100 msec or PWA transmits less then the expected data) the DPU main processor reports that in the EVENT LOG packet and in the HC2S packet. Then it re-synchronises to 2 sec talker. **Note** when a time-out occurs during the first DB reception, the second Data Block reception is skipped.

The received DB is checked according to the following tests:

- **number of bytes**: if the number of received bytes is less than the expected then a '**Time-out**' message is reported in the EVENT-LOG packet;
- **PID value**: it is checked against the following types: 'SCIENCE' or 'TEST' or 'HC' (refers to 3.8.4.3); when it is NOT correct, a dedicated event ('**Invalid Packet Id**' message) is reported in the EVENT LOG packet;
- **XOR value**: when is NOT correct a dedicated event ('**Invalid Packet error control**' message) is written in the EVENT LOG packet;
- **DATA TYPE value**: the value is checked against its allowed range 128 to 159 (decimal value): in case it is out of range a dedicated event ('**Invalid Data Field Header**' message) is written in the EVENT LOG packet.

When these checks are complited, depending on PID type the following actions type are taken:

- when HMT is less than **TdataH** (Descent 2nd state) or the PID indicates HC then no PWA TM is created;

otherwise:

- if the PID indicates SCIENCE a PWA SCIENCE TM packet is created: its FORMAT TYPE will be equal to the DATA TYPE HEADER;
- if the PID indicates TEST a PWA TEST TM packet is created;
- if the PID was incorrect a PWA CORRUPTED TM packet is created;

Furthermore:

- if the DATA TYPE HEADER is outside the allowed range the packet created is marked as PWA TEST;
- if a Time-out was notified during the DATA BLOCK reception, a PWA TM packet is created according to the DATA BLOCK PID and DATA TYPE HEADER. When the DATA BLOCK PID and DATA TYPE HEADER are incorrectly received, a PWA CORRUPTED TM packet is created. In both these cases the data field of the created packet will contain sequences of 0x20H (helpful to recognise it on ground).

After these activities, the HASI-S/W waits for the reception of the second DATA BLOCK from PWA processor and repeats all the activities performed on the first.

The first received DATA BLOCK is always sent via CDMU-A telemetry channel, the DATA BLOCK received as second is always sent via CDMU-B telemetry channel.

3.8.4.5.1 Data Block Identifier check

After receiving the two DB, the HASI-S/W performs the check of the two Packet Identifiers. It reports the type of DB identification header in a internal status: 'Science' and 'Test' are meaningful while Health Check are discarded. This internal status bit is copied into HC2SEC packets (i.e. **PWA STATUS** bit, refer to 3.8.5.1.1).
In TITAN DESCENT mode, before the **TdataH**, the PWA sends only HC DBs and therefore they are discarded: the status remains set to 'Science'. After **TdataH**, the PWA sends both HC and 'Science' according to the internal polling table: the status remains set to 'Science' till the end of the Titan mission.
In CHECKOUT mode, HASI can receive TCs. Upon the reception of a 'PWA TEST mode' command, the PWA terminates the 'Science' or HC mode and it enters after 8 sec maximum in 'test' mode: the internal status is set to 'Test'. The status remains unchanged till the reception of on of the following commands '**PWA test mode 0**' or '**PWA test mode 23 .. 27**'. The '**PWA Test mode 0**' terminates definitively the PWA test mode, while the other activate temporarily the 'Science' mode.
Note that some test commands have mixed 'Science' and 'Test' DB, then the status correspondingly changes.

3.8.4.5.2 PWA Time-out check

In case of time-out during a SB transmission or a single DB reception, the HASI-S/W sets an internal software status. Every two seconds, the status is copied into HC2SCE report (i.e. **PWA link status** bit, refer to 3.8.5.1.1).

3.8.4.6 PWA software capability

Refer to the ANNEX 2 & 3.

3.8.4.7 Test Command list

The PWA test commands are listed together with all the other HASI Telecommands in the dedicated chapter. For details on their functions refer to the 6.2.2.

3.8.5 HOUSEKEEPING

3.8.5.1 Housekeeping activity

At DDBL rate (nominally every 2 sec) HASI performs the following periodical functions:

- Update of the following bits of the HASI-SW according to the realt time information mantained into the HASI-S/W

  PWA data link status
  HASI modes/sub-modes/Internal states
  CDMU currently used
  Test mode
  Last TC status
  Protected power presence

- Health check of BCP pulse rate. The nominal BCP rate is 125 msec.

- Health check of DDBL information.

- Readout of Protected power presence.

- Health check of PWA data link.

- Health check report on HC2SEC packet.

- Read the DPU temperature.

3.8.5.1.1 HC2SEC information

As soon as the START-UP mode is complete, the HASI-S/W records every two seconds, into a 16 bits report, the results of periodical hardware and software checks. Each report is collected into a HC2SEC TM packet. When the packet is full (every 112 sec), it is queued for CDMU transmission. Each HC2SEC packet is marked with the HMT of the first recorded data. The acquisition time of each other data shall be recontructed according to the formula a.

Each 2 sec report contains information which are not real time acquired. For example, when a PWA time-out occurs, to find which PWA packet was lost, it is necessary to analyse the PWA TM queue in the range of [-4sec, +2sec] from the time extracted by the HC2SEC.

The table w shows the bit content of each item data field (refer to 5.6). The bits are normally TRUE (different from the value 0) when the relevant check is successfully completed.

Table W: HC2SEC bits content

BIT	NAME	DESCRIPTION
DPU Health Checks		
15	**DPUHCV1/V2/V3**	The bit is 0 when the +5V, +15V and -15V are contemporary out of the range (5% of nominal voltage value), otherwise is 1.
PPI Health Checks		
14	**PPI HKV1**	The bit is 0 when the HKV1 housekeeping (PPI) voltage is out of the range [4.5 ÷ 5 Volt], otherwise is 1.
13	**PPI HKV2**	The bit is 0 when the HKV2 housekeeping (PPI) voltage is out of the range [2.5 ÷ 7.5 Volt], otherwise is 1.
12	**PPI TO**	The bit is 0 when a frequency measure (at the time of HC2SEC sampling) of a PPI channel is lower than 1KHz (refers to 3.8.1), otherwise is 1.
ACC RANGE Status		
11	**ACC RANGE**	The bit is 1 when the Xservo range is FINE (HIGH gain), otherwise is 0 (i.e. range is set to COARSE (LOW gain)). For major details, it refers to 3.1.1 and 3.8.2.1.1.
TEM ADC Heath Check		
10	**ADC2**	The bit is 1 when the TEM and HK Analog to Digital Converter provides the EOC, otherwise is 0.
CDMS Health Checks		
9	**VALID**	It is the status of VALID line: 1 means Channel B while 0 means Channel A.
8	**CDMU A/B**	It indicates the currently selected CDMU ML channel at the instant of the HC2SEC sampling: 1 means CDMU-B while 0 means CDMU-A.
7	**DDBL**	It reports the DDBL periodical test: 1 the test is successfully completed, 0 otherwise.
6	**BCP**	It reports the BCP presence test at the instant of the HC2SEC sampling: 1 when the BCP is occurred, 0 when time-out (time between two consecutive BCP greater than 125 msec).
MCA & PROTECTED POWER Presence status		
5	**MCA S2**	MC2 command Status: 0 means that the MC2 command has been issued (refer to 2.2.1.2.2 and 2.2.1.4.4), 1 otherwise. It is always 1 during the CHECKOUT.
4	**MCA S1**	MC1 command Status: 0 means that the MC1 command has been issued (refer to 2.2.1.2.2 and 2.2.1.4.4), 0 otherwise. It is always 1 during the CHECKOUT.
3	**MCA E**	Energise power presence: 0 means that the ENERGISE power is present, 1 otherwise. It is nominally 1 during the CHECKOUT.
PWA Health Checks		
2	**PWA LINK**	The bit is 0 when a time-out is found, otherwise is 1. It is not real time indication, but indicates that within DB had a number of bytes less than the expected. The TM packet is filled with a pattern of 0x20H (refer to the sections 3.8.4.5 and 3.4.1).
1	**PWA STATUS**	It indicates the ID status of the PWA DB: 1 means PWA is in Science mode while 0 means PWA in Test mode (i.e. it has received a PWA Test Command).
0		NOT USED

3.8.5.2 DPU START-UP packet

The packet contains the report of the activities performed during START-UP mode (refers to section 3.1.1).

The first field of the first DPU START-UP packet contains the possible reset cause: power-on or watch-dog or NMI (refer to table x). The other fields contain the ‘PAR_LOAD_REPORT’ of each EEPROM parameter loaded into the RAM memory (refers also to section 3.1.1).

Table X: RESET FLAG CONTENT

RESET TYPE	RESET FLAG Content	Description
Power-on	**A string of 10 random ASCII characters**	After each bootstrap, the HASI-S/W checks if a watch-dog time-out is occurred. If not, the HASI-S/W copies the RAM content of a fixed location into the RESET FLAG field of the first DPU START-UP packet. The content is composed by ten random ASCII characters. (1)
Watch-dog	“**WATCH-DOG**”	When the Watch-dog timer is expired (refers to section 2.2.1.1.3), HASI is reset. After a new bootstrap, the HASI-S/W checks if a watch-dog time-out is occurred and it reports it into RAM at a fixed location (‘WATCH-DOG’ message). Then it copies the message into RESET FLAG field of the first DPU START-UP packet. (1) The causes of a watch-dog reset are numerous and they normally depend by a software crash. They are not predictable and only a later analysis provides information to avoid the situation again. (2)
NMI	“**NMI INTR**”	When a NMI is triggered, the HASI-S/W jumps to the NMI routine that reports it into RAM at a fixed location (‘NMI INTR’ message). Then HASI-S/W performs a new bootstrap (hot reset) and checks if a watch-dog time-out is occurred. If not, it copies the RAM content into RESET FLAG field of the first DPU START-UP packet. (1) The NMI reset is generated when an hardware failure (either permanent or occasional) of the address bus or the address decoding logic is detected (refers to section 2.2.1.1.4).

Notes: (1) The Reset message is stored a fixed location into RAM memory. The RAM content is normally destroyed after some time of a Power-OFF. When a Power-ON/OFF cycle happens shortly, the RAM keeps a message relevant to the previous power-On/reset which will be erroneous reported into the DPU START-UP packet. For example, if a Power-ON/OFF cycle occurs after a SOFT RESET TC, the new reset will be decoded as ‘Watch-dog’ reset that is certainly an error. Thus it is necessary wait for some minutes before to Power-ON again HASI in order to avoid the erroneous decoding.

(2) A predictable watch-dog reset is caused by SOFT RESET TC also (refers to section 6.3.1).

3.8.5.2.1 PAR_LOAD_REPORT content

The content of each report is summarised in the following:

- **LOAD RESULT** indicates that the parameter loading procedure is successfully completed (i.e. the calculated CRC is equal to the EEPROM stored CRC): when 1, the parameter is loaded into the RAM;
- **NUMBER** is the parameter number read in the EEPROM UPDATE LIST;
- **SIZE** is the parameter size read in the EEPROM UPDATE LIST;
- **ADDRESS** is the parameter RAM address read in the EEPROM UPDATE LIST;
- **CRC** is the parameter CRC calculated by the loading procedure.

3.8.5.3 DPU Temperature

The DPU temperature is monitored by a thermistor located on the DPU base-plate close to the Reference hole. The thermistor type is a GB32JM4 2K H49 acquired according to the SCC 4006/001 specification.
The resistance is measured using a two wire configuration. A stable current is obtained by the +10V ADC reference and 10KΩ resistance in series. From the START-UP mode completion and during the HASI states evolution the voltage across the thermistor is read every 2 seconds by means of 12 bits ADC. The voltage is averaged every 16sec and packed into the DPUBOX TM packet. When the packet is full (i.e. every 112 seconds), it is queued and telemetred.

Because the measurement circuit, the DPU temperature shall be used for housekeeping only. The following formula extracts from the measured voltage '**V**', the resistance value **RDPU**.

$$R_{DPU} = 10000 * V / (10 - V)$$

Formula M: DPU Temperature resistance value

The table y provides the information to reconstruct the temperature from the calculated resistance.

Table Y: DPU TEMPERATURE: resistance / temperature characteristics

TYPE	Tolerance	RESISTANCE/TEMPERATURE (OHMS)								
		-40°C	-20°C	0°C	+25°C	+40°C	+60°C	+80°C	+100°C	+120°C
GB32JM4	± 1 %	44135	14055	5700	2001	1146	583.1	318.7	184.7	113.1

3.8.5.4 EVENT-LOG packet

When an Event happens, HASI reports the HMT and the event number in the EVENT LOG packet. The EVENT LOG packet is stored in RAM till the packet is completed (i.e. it must be generated more than 16 events) then is transmitted. If is not complete, the EVENT LOG is transmitted if the deactivation flag in the DDBL is set (only in CHECKOUT mode) or when HASI reaches the IMPACT state.

In order to avoid an over-production of EVENT-LOG packets during the Titan Descent, the number of events of the same type is limited to 64.

The TM packet layout is shown in AD3) (refer to section 5.6).

The table z summarises the Events and their meaning

Table Z: EVENT LOG LIST

EVENT	EVENT NAME	DESCRIPTION
DDBL EVENTS		
0	**T0**	It refers to the T0 transition according to the DDBL flag (refer to section 3.1.1).
1	**DDBL Time wrong**	It indicates that the DDBL time is not monotone (two consecutive DDBLs have Mission time difference greeter than 2sec). Refer for details to section 3.1.1.
4	**TIMPACT**	When HASI recognises the Probe Impact by Xservo data elaboration (filter). for major detail, it refers to section 3.6.2.1.1 and 3.8.2.4.
5	**DDBL nok line A**	When the DDBL layout test results unsuccessfully completed on CDMU line A.
6	**DDBL nok line B**	When the DDBL layout test results unsuccessfully completed on CDMU line B.
TC EVENTS		
7	**UNKNOWN TC**	When a TC is correctly received (refer to sections 3.4.3 and 3.4.2), but has an unknown Command Header (see section 6.1.1), the TC is discarded and the event is reported.
8	**TC RX incorrect**	Refer to 3.4.2.
SENSORS EVENTS		
9	**PWA LINK ERROR**	The PWA DB is checked against its protocol and the following Event data are hereafter reported: - 0 means **Invalid Packet Id** - 1 means **Invalid Sequence count** - 2 means **Invalid Packet length** - 3 means **Invalid Packet error control** - 4 means **Invalid Data Field Header** Refer to 3.8.4.5. - 5 means **Time-out** The SB is sent while the DB has a umber of bytes less than the expected. The TM packet is filled with a pattern of 0x20H (refer to the sections 3.8.4.5 and 3.4.1).
10	**MCA READOUT**	The message reports the Energise status, MAC1 and MC2 activation status during a Boom release (refer to 3.7.1).
12	**PPI RANGE FAIL**	The message is issued when the **Y-value** calculation is out of the expected range (refers to 3.8.1).
16	**PPI Time-out**	The message is issued when a frequency measure of a PPI channel is lower than 1khz (refers to 3.8.1).
13	**ADC1 FAILURE**	When the ACCelerometer Analog to Digital Converter does not provide the EOC.
14	**ADC2 FAILURE**	When the TEM and HK Analog to Digital Converter does not provide the EOC.
18	**ACC range set COARSE**	The Xservo range changes from FINE (HIGH gain) to COARSE (LOW gain). For major details, it refers to 3.1.1 and 3.8.2.1.1.
EEPROM EVENTS		These three events report when the EEPROM device is used for memory load operation. It happens during START-UP mode or after a MEMORY LOAD TC or MEMORY DUMP TC (refer to section 3.1.1).
11	**EEPROM LATCH-UP**	It is part of the nominal switch-ON/OFF sequence of the EEPROM procedure. Nominally, it happens after the EEPROM SWITCHED OFF message. In the case it happens before, a hardware latch-up is happened when using EEPROM and its content and the next operations may result corrupted or incomplete. A severe latch-up may destroy the device itself.
19	**EEPROM SWITCHED**	The message has two event data: 0 (OFF) and 1 (ON). Before any read/write operation the EEPROM must be switched on (EEPROM SWITCHED-ON) and then shall be switched OFF EEPROM SWITCHED-OFF).
20	**EEPROM LOCKED**	It refers to the EEPROM overwrite capability. Refer to procedure a: eeprom override and to the section 8.1.1.

4 HASI STATUS WORD

The HASI status word interface is a serial digital data channel (from a 16 bits register) which provides monitor data to the Probe CDMS system. In the HASI DPU, two independent Status Word interfaces are realised to ensure full redundancy, but the same data are available on both of them.
At DPU power ON or Reset the data in the HASI Status Word register are cleared by hardware, then the software sets the SW bit 15 at software start (refer to HASI START-UP Mode activities).

The assignment of each Status Word bit is reported in the following:

Bit 15..15 "**CPU Health Check**"

0 => HASI main CPU is not started;
1 => HASI Start-up OK (i.e. the main CPU is correctly started).

After power-on/reset the Status Word register is reset (all bits are in LOW status). The CPU will latch the SW bit 15 HIGH as first operation. Reading the SW bit 15 = 0 one CDMS cycle after HASI power ON or Reset is symptom of a major failure in the CPU logic circuits.

Bit 14..14 "**RAM Health Check**"

NOT USED: always set to 1

Bit 13..13 "**EEPROM Health Check**"

0 => EEPROM Start-up verification FAILED.
1 => EEPROM Start-up verification PASSED.

In the frame of the EEPROM test executed at HASI START-UP, each EEPROM UPDATE BLOCK CRC is verified to be correct. If the verifications on all the UPDATE BLOCKS give positive results, the STATUS word bit 13 is set to 1, otherwise even if one EEPROM Parameter checksum results wrong, the STATUS word bit 13 is set to 0.

Bit 12..12 "**PWA data link status**"

0 => PWA/CPU Main processor data exchange is FAILED.
1 => PWA/CPU Main processor data exchange is NOMINAL.

This bit is set by HASI software when the PWA/Main processor data exchange is nominal.

Bit 11..11 "**PPI health status**"

0 => PPI (PREssure measurement) failed;
1 => PPI (PREssure measurement) is in nominal condition

HASI S/W sets this bit HIGH when the PPI (PREssure measurement) frequency output is in the expected range (1 to 30 KHz). HASI S/W resets this bit when a time-out occurs on the frequency measurement (i.e. frequency < 1 KHz).

Bit 10..10 "**DPU Temperature**"

0 => DPU temperature out of range;
1 => DPU temperature inside the operative range;

The HASI software sets this bit when the internal temperature of the DPU box is in the operating range. The range limits are set to:

T_{min}= -20°C. and T_{max} = 50°C.

Bit 9..9 "**ACC Temperature**"

0 => ACC temperature out of range;
1 => ACC temperature inside the operative range;

The HASI software sets this bit LOW when both the internal temperatures of the ACC box (measured on ACC servo and ACC piezo) are out of the expected range. The range limits are set to:

Tmin = -20° C. and Tmax = 50°C.

Bit 8..8 "**Protected Power Presence**"

0 => Protected Power is not present (OFF).
1 => Protected Power is PRESENT (ON).

The HASI software sets this bit when the Protected Power presence is detected on the HASI power input circuit.

Bit 7..7 "**CDMU currently used**"

0 => Memory Load CDMU-A lines is chosen in accordance to the HASI selection criteria.
1 => Memory Load CDMU-B lines is chosen in accordance to the HASI selection criteria.

Bit 6..6 "**Last TC Status**"

0 => Last TC wrongly received.
1 => Last TC correctly received (if any).

The HASI software sets this bit when it receives a correct Telecommand. The bit is reset when a corrupted TC is received. The bit remains 0 until the next successful TC reception. At HASI start-up this bit is set to 1.

Bit 5..5 "**Test mode**"

0 => HASI NOMINAL operation
1 => HASI enters in test mode.

The HASI software sets this bit when a "TEST mode N" Telecommand has been received. This bit will be reset by a "TEST mode 0" or "Soft Reset" Telecommands. This bit is active only in Checkout.

Bit 4..3 "**Modes**"

These two bits contain the code of the HASI operating modes:

Table AA: Status word - HASI mode bits

BIT 4	BIT 3	MODE
0	0	START UP
0	1	TITAN
1	0	CHECKOUT
1	1	TC EXECUTION

Where:

START-UP: After HASI Power-On or "Soft Reset" Telecommand execution, HASI enters in START-UP mode. If DDBL provides valid inf., within 20 sec (minimum) HASI shall enter to TITAN (real mission) or CHECKOUT modes; otherwise after 3 minutes HASI enters in TITAN mode, BACKUP sub-mode.

TITAN: HASI is executing the real Titan mission programs driven or not by DDBL information according to the sub-mode bit.

CHECKOUT: HASI is executing the Checkout Mission programs driven or not by DDBL information according to the sub-mode bit.

TC EXECUTION: HASI is executing EXECUTABLE Telecommands.

Bit 2..2 "**Sub-modes**"

0 => HASI in BACKUP sub-mode;
1 => HASI in NOMINAL sub-mode.

HASI sets this bit when the mission functions are driven by DDBL information and BCP pulse. This bit is reset when HASI mission is driven by the experiment internal mission time.

Bit 1..0 "**Internal States**"

These two bits contain the code of the HASI mission states:

Table BB: Status word - HASI state bits

BIT 1	BIT 0	STATE
0	0	ENTRY till Tdata
0	1	DESCENT after Tdata
1	0	IMPACT
1	1	SURFACE

Where:

ENTRY till Tdata: HASI is executing the mission program pertaining to the ENTRY state.

DESCENT after Tdata: HASI is executing the mission program pertaining to the DESCENT 1st, 2nd or 3rd states. The three states last from *Tdata* till *last kilometer* DDBL altitude information.

IMPACT: HASI is executing the mission program pertaining to the impact event detection by means of accelerometer outputs evaluation.

SURFACE: HASI is executing the mission program pertaining to the activities after the impact event.

4.1 STATUS WORD evolution

The SW at HASI Power-On (or after each Reset caused either by ‘Software Reset’ command or by internal Watch-Dog reset and NMI interrupt) is reset by H/W (i.e. HASI-SW = 0x0H). HASI enters in the START-UP mode and the HASI-SW is set at 0x8000H. This means the HASI main processor and the HASI-S/W are correctly started. During START-UP, the significant bits are 15, 4 and 3; the other bits do not care. Then the HASI-S/W starts to initialise the HASI hardware devices, the Operating System, the tasks and to check the EEPROM contents. Next step is the current CDMU selection. At the end, the HASI Status Word is updated reporting the HASI status after START-UP. The bit status and the relevant failure conditions are reported in the sect 4. The HASI-SW corresponding to the CDMU-A and B channels are nominally the same. Since HASI updates the two HASI-SW every 2sec, they may be different, but within one CDMU cycle they return the same.

4.1.1 START-UP mode

In the nominal case (DDBLs from both CDMUs are correctly received), the START-UP activities last at minimum 20 sec: 14 sec for the EEPROM check plus 6 sec for the CDMU selection). The table h shows the approximate duration relevant to the different cases according to the results of the EEPROM and DDBL tests.

4.1.2 Status word after EEPROM check

In the START-UP mode, the EEPROM is checked to verify if any parameters (tables or software patches) have been loaded. When a parameter is found, the EEPROM updated block (parameter) CRC is verified and if correct the parameter is updated in the RAM memory. When one EEPROM updated block is corrupted, the SW bit 13 is reset and remains 0 till next START-UP verification.

Before any EEPROM check, the EEPROM override capability is ensured by the presence of Checkout mission flag (Cruise or Ground) and Spin rate field equal to 0xFFH in the DDBL inf.

4.1.3 Status word and HASI operating modes and sub-modes

The HASI operating modes are reported in the Bit 4 and 3 of the Status Word. The TITAN and CHECKOUT operating modes are chosen once after the START-UP according to the DDBL information taken from the selected CDMU. There are two different ways of driving the HASI modes leading to two different SUB-MODES:

- **NOMINAL**: in which all the activities are driven by the DDBL information;
- **BACKUP**: in which all activities are driven by HASI internal mission time.

Refer to the sect 3.7.2. The sub-modes are selected according to the results of periodical verifications of the DDBL information and the BCP pulses rate. The SW Bit 2 is 1 when HASI is in NOMINAL Sub-mode and 0 in BACK-UP Sub-mode.

4.1.3.1 STATUS WORD and DDBL Mission Phase

The HASI behaviour during the CHECKOUT mode is the same either in Cruise or in the Ground. In the following table the HASI SW bit values (Bit 4 and 3) relevant to the DDBL Mission phase flags are reported.

Table CC: Status word and DDBL Mission flag

DDBL MISSION PHASE	HASI-SW Bits	
	4	3
Entry/Descent	0	1
Ground C/O	1	0
Ground C/O suspended	1	0
Ground C/O de-activate	1	0
Flight C/O	1	0
Flight C/O suspended	1	0
Flight C/O de-activate	1	0

4.1.4 Status word after Telecommand Reception

After TC reception, the Telecommand is checked against the protocol (see sect 3.4). The SW bit 6 is reset if a corrupted TC is received. This bit remains 0 until the next successful TC reception. Two types of TC are allowed for HASI: Executable TC and Set-up commands. Only the Executable commands require an HASI operative mode change to TC Execution mode (bits 4 and 3 equal to 1). The SW is updated every 2 sec and is read by CDMS every 16 sec. If the TC execution time is less than the SW sampling interval, the TC Execution mode may not be seen. The 'Test Mode N' TCs, named '*HASI_TEST_MODE0_A/B.BIN*' and '*HASI_TEST_MODE1_A/B.BIN*' (refer to the HASI test command list in AD(3) page 6I) in the Probe System Data Base, change the SW bit 5 respectively to 0 and 1.

4.1.5 Status Word during Mission

The HASI internal status varies in function of the DDBL information of mission time and/or altitude. It also changes as consequence of a TC reception or after Impact detection by the ACC Xservo. Refer to the figure nn for the flow chart of the HASI states. The different HASI states are reported in the Bit 0 and 1 of the SW. Their values are summarised in the following table:

Table DD: HASI-SW - Mission Evolution

HASI State	SW bit 1	SW bit 0
ENTRY	0	0
DESCENT 1st	0	1
DESCENT 2nd	0	1
DESCENT 3rd	0	1
IMPACT	1	0
SURFACE	1	1

4.1.6 Not nominal cases recorded by Status Word

The SW bits 12 to 8 contain the HASI housekeeping information and they may change during the mission independently from the HASI mode and state.

4.1.7 Current CDMU in the Status Word

The SW bit 7 indicates the current CDMU selected by HASI according the HASI selection criteria (refer to the sect 3.1 and 3.7.3). The current CDMU may not correspond to the Processor Valid status.

5 HASI TM PACKETS PRODUCTION & FORMATS

The TM packets are sent by HASI to CDMS according to Mission Time Evolution (Refer to the 3.6.1). Each channel is independent and transmits at CDMU polling rate.

The HASI TM packets are composed by a "**Packet Header**" and by a "**Packet Data Field**" (which is different for each HASI source and it will be described in the following sub-sections). Refer to AD(3) pages 7A, 7B and 7C for the bits layout.

The "**Packet Header**" contains:

- Packet Identification: it is as defined by AD(1) EID-A for HASI.
- Packet sequence count: it counts the number of packets. It resets after 16384 packets of after START-UP mode (refer to 3.1).
- Packet length: it specifies the (number of octets-1) contained within the Packets Data Field.

The **Packet Data Field** contains:

- the HASI Mission Time when the first source data contained in the Data Field was created. Since the data are sampled at constant rate, the time of creation of the other data contained in the Data Field can be easily computed according to their position (refer to sect. 3.6.2). The Bit resolution is 1msec. **Note that the Time Stamp resolution is one BCP (i.e. 125 msec)**.
- the Data Format which encodes the *Source* and the *Type* of data contained in the Data Field. Refer to AD(3) (pages 7D, 7E and 7F) for the 256 possible data format codes.
- the Ancillary field which contains:
    - the *Index* of the last valid data byte contained in the Data Field when Ancillary's *Data Status* field shows that packet is *Incomplete*;
    - the *Data Status* which contains information on the data contained in the Data Field:
        - *Original*: means that this packet has been redounded by one or more packets (Refer to the 3.6.1).
        - *Incomplete*: the Data Field is not full of valid data, the *Index* shall indicate last valid data byte.
        - *T0 flag*: states if the HASI Mission Time shall be intended as Before or After T0.
        - *Redounded*: means that this packet is a redundance of another packet (i.e. it is stored in the memory, refer to 3.6.1).
- the Data Field which contains the science data (112 bytes).

At the end of each packet a Packet Error Control included in order to verify at ground the integrity of the received Packets. The Packet Error Control is the XOR function computed on all the words starting from the Packet Identification (included) till the last data in the Data Field. The general approach is to extract the data contained in the received packets when the calculated XOR is equal to the Packet Error Control. However, if corrupted packets are received (i.e. with there is a difference between the calculated and the Packet Error Control), a dedicated algorithm may be used to reconstruct the data inside these packets. This method depends on which problem is occurred.

5.1 TM packet Interface Data sheet

Each Data Format has different Data Field bits layout. The document will not detail the contents of each science data type. Refer to the ANNEX 1 of the AD(5) for the for each Data Field bits layout. The PWA science packets bits layout is reported in annex 2: pwa flight software**.**

5.2 PRE TM output

The PRE reading and production rate during the Mission is reported in the sect. 3.8.1. This section summarises the PRE TM products and it gives the references to extract the data from the TM packets (i.e. the size, the layout and the description of each fields and sub-fields, the bits resolution, the fill rate and the raw data source).

Table EE: PRE TM packet Types

FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCENT 2nd	DESCENT 3rd	IMPACT	SURFACE	
SESSION #0 (A)	NO	YES	YES	YES	NO	NO	48
SESSION #1 (B)	NO	NO	NO	YES	NO	NO	51
SESSION #2 (C)	NO	NO	NO	YES	YES	YES	52
HC SESSION #0 (G)	NO	YES	YES	YES	YES	YES	53
HC SESSION #1 (H)	NO	YES	YES	YES	YES	YES	55
HKV	NO	YES	YES	YES	YES	YES	56

(1) Of the Annex 1 in the AD(5).

5.3 ACC TM output

The ACC data types and relevant production rate depend on the HASI state. The ACC reading during the Mission is summarised in the sect. 3.8.2. This section outlines all the ACC TM products and it provides the references to extract the data from the TM packets (i.e. the size, the layout and the description of each fields and sub-fields; the bits resolution; the fill rate and the raw data source).

The ACC packets telemetred to ground by HASI contain:

- **Xservo reading** average values and statistics:

Table FF: Xservo Average & Statistics TM Packets Types

AVERAGE Types							
FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCEN T 2nd	DESCENT 3rd	IMPACT	SURFACE	
SCDS.E	YES	YES	NO	NO	NO	NO	18
SCDS.D	NO	NO	YES	NO	NO	NO	20
SCDS.R	NO	NO	NO	YES	NO	YES	22
STATISTICS Type							
STD2.XS	YES	YES	YES	YES	NO	YES	34

(1) Of the Annex 1 in the AD(5).

- **Xpiezo reading** average values and statistics:

Table GG: Xpiezo Average & Statistics TM packet types

AVERAGE Types							
FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCEN T 2nd	DESCENT 3rd	IMPACT	SURFACE	
SCDP.X	YES	NO	NO	NO	NO	NO	24
ID1	NO	NO	NO	NO	YES(2)	NO	42
STATISTIC Type							
STD2.XP	YES	YES	YES	YES	NO	YES	36

(1) Of the Annex 1 in the AD(5).
(2) The packet contains the Impact trace.

- **Ypiezo reading** average values and statistics:

Table HH: Ypiezo Average & Statistics TM Packet Types

AVERAGE Types							
FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCEN T 2nd	DESCENT 3rd	IMPACT	SURFACE	
SCDP.Y	YES	NO	NO	NO	NO	NO	26
ID2	NO	NO	NO	NO	YES(2)	NO	44
STATISTICS Types							
STD2.YP	YES	YES	YES	YES	NO	YES	38

(1) Of the Annex 1 in the AD(5).
(2) The packet contains the Impact trace.

- **Zpiezo reading** average values and statistics:

Table II: Zpiezo Average & Statistics TM Packet Types

AVERAGE Types							
FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCEN T 2nd	DESCENT 3rd	IMPACT	SURFACE	
SCDP.Z	YES	NO	NO	NO	NO	NO	28
ID3	NO	NO	NO	NO	YES(2)	NO	46
STATISTICS Types							
STD2.ZP	YES	YES	YES	YES	NO	YES	40

(1) Of the Annex 1 in the AD(5).
(2) The packet contains the Impact trace.

- **ACC Temp 1 and Temp 2 reading**

Table JJ: ACC Temperatures TM Packet Types

FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCEN T 2nd	DESCENT 3rd	IMPACT	SURFACE	
HKD1	YES	YES	YES	YES	NO	YES	30
HKD1	YES	YES	YES	YES	NO	YES	32

(1) Of the Annex 1 in the AD(5).

5.4 TEM TM output

The TEM data production rate and types depend on the HASI state. The TEM reading during the Mission is reported in the sect. 3.8.3. This section summarises the all TEM TM products and the references to extract data from the TM packets (fields and sub-fields size and layout, description, bits resolution, fill rate and raw data source).

Table KK: TEM TM packet Types

FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCEN T 2nd	DESCENT 3rd	IMPACT	SURFACE	
F1	NO	YES	YES	YES	YES(2)	YES	58
C1	NO	YES	YES	YES	NO	YES	61
F2	NO	YES	YES	YES	YES(2)	YES	62
C2	NO	YES	YES	YES	NO	YES	63

(1) Of the Annex 1 in the AD(5).
(2) The production rate is double respect to the other (refer to sect. 3.8.3.2).

5.5 PWA TM output

The HASI-S/W checks the received Data Blocks (refer to 3.8.4.3) and the 'Science and Test Data Block' are inserted in the PWA TM packet. The type of PWA TM packets corresponds to the 'Data type header'. A special PWA TM packet type is foreseen when it is founded a communication failure (refer to the 3.8.4.5). This section summarises all the PWA TM products and the references to extract data from the TM packets (i.e. fields and sub-fields size and layout; fill rate). For bits description and meaning refers to the relevant PWA document (annex 2: pwa flight software).

Table LL: PWA TM packet Types

FORMAT NAME	HASI STATE						Pag. # (1)	Pag. # (2)
	ENTRY	DESCENT 1st	DESCENT 2nd	DESCENT 3rd	IMPACT	SURFACE		
EM SCIENCE	NO	NO	NO	NO	NO	NO	64	-
CORRUPTED(3)	YES	YES	YES	YES	YES	YES	65	-
TEST(4)	YES	YES	YES	YES	YES	YES	66	26
AC/DC	NO	NO	YES	NO	NO	NO	67	7
AC/DC/AU	NO	NO	NO	YES	YES	YES	68	11
RADAR	NO	NO	NO	YES	YES	NO	69	16
MI	NO	NO	YES	YES	YES	YES	70	22
RP	NO	NO	YES	YES	YES(5)	NO	71	24

(1) Of the Annex 1 in the AD(5).
(2) Of the annex 2: pwa flight software.
(3) Sporadic only in case of communication failure.
(4) If a PWA test command is received by HASI.
(5) Till 200m and then RP is OFF.

5.6 Housekeeping TM output

The H/K packets telemetred to ground by HASI contain:

- Memory start-up test reports: the reset cause test and the EEPROM Parameters loading to RAM.
- Occurred event report: main s/w events (link errors; ADC failures; Time-outs; DDBL not OK; etc. recognition; LATCH-UP; SEU; range changes) are reported together with measured Mission time when event is happened.
- Health check reports: main health check parameters status sampled every 2 sec.
- DPU box internal temperature value: read every 16 sec.
- TC ECHO after receiving a Telecommand.
- TC report containing the information of the Telecommand execution.

Table MM: HOUSEKEEPING TM Packet Types

FORMAT NAME	HASI STATE						Pag. # (1)
	ENTRY	DESCENT 1st	DESCENT 2nd	DESCENT 3rd	IMPACT	SURFACE	
DPU START-UP	NO	YES	YES	NO	NO	NO	9
EVENT-LOG(2)	YES	YES	YES	YES	YES	YES	11
HC2SEC	YES	YES	YES	YES	YES	YES	14
BOXTEM	YES	YES	YES	YES	YES	YES	16
TC ECHO(3)	YES	YES	YES	YES	YES	YES	72
MEMORY DUMP(4)	YES	YES	YES	YES	YES	YES	73
ML ECHO(5)	YES	YES	YES	YES	YES	YES	75

(1) Of the Annex 1 in the AD(5).
(2) Sporadic.
(3) After the receiving of a TC (CHECKOUT mode only).
(4) After the execution of a Memory Dump TC (CHECKOUT mode only).
(5) After the execution of a Memory Load TC (CHECKOUT mode only).

6 HASI TELECOMMAND

HASI accepts commands in CHECKOUT mode. HASI does not distinguish between GROUND and FLIGHT CHECKOUT.

The HASI Telecommands are divided in two main classes according to their impact on the CHECKOUT mode (refer to sect 6.2):

- **SET-UP** TCs that do not require an HASI operative mode change;
- **EXECUTABLE** TCs that require an HASI operative mode change.

The TCs received in TITAN mode are always discarded.

When HASI receives an **EXECUTABLE** TC, the CHECKOUT mode is suspended and the **TC EXECUTION** mode is entered. The TC is executed with higher priority respect to the science acquisition loop. At the end of the TC EXECUTION mode, the HASI returns to CHECKOUT mode and it is ready to receive a new TC (refer to section 3.4).

6.1.1 Telecommand layout

The HASI TC packets are composed by a "**Packet Header**" and by a "**Packet Data Field**" (which is different for each HASI TC). Refer to AD(3) pages 6A, 6B/1 and 6B/2 for the bits layout.

The "**Packet Header**" contains:

- Packet Identification: it is a word as defined by AD(1) EID-A for HASI (Telecommand type).
- Packet sequence count: it counts the number of sent TC. It resets after 16384 packets. The Packet sequence count is not internally generated in the CDMU.
- Packet length: it specifies the (number of octets-1) contained within the Packets Data Field. HASI receives TC with fixed length (119 bytes).

The **Packet Data Field** contains:

- the Command Header identifies the command type (refer to pages 6C, 6D, 6F, 6G and 6H of AD(3)).

- the Command Content is a variable number of command parameters whose layout depends on the Command Header.

- the Dummy Field is a variable number of ZERO value words to fill 126 byte fixed packet length of the Telecommand packet (126 bytes includes all bytes from the **Header** to CRC).

At the end of each packet a Packet Error Control according to AD(1), is included in order to verify at ground the integrity of the received Packets.

6.2 SET-UP TC GROUP

The SET-UP TELECOMMANDS are executed without HASI operative mode change. They are two:

- PWA TEST (refer to AD(3) page 6F);
- SET TEST MODE(refer to AD(3) page 6D).

6.2.1 SET TEST MODE COMMAND

The command is used to the check the TC-TM loop and health status of the TC link when only HASI-SW is available. The command sets or reset the **Test Mode bit** of the HASI-SW. It has two parameters:

TEST MODE 0 it reset **Test mode** bit; The HASI is in the default checkout mode (i.e. the nominal simulated descent).

TEST MODE 1 The **Test Mode bit** is set to 1. It remains set till a **TEST MODE 0** TC is received afterwards.

6.2.2 PWA TEST COMMAND

The received PWA Test Command Number is inserted in the dedicated "socket" (PWA TEST PARAM) of the SB and transmitted to PWA. Refer to sect 4.2 of the annex 3: pwa fm users document for the complete description of each test commands. The list of valid PWA test Telecommands is reported in the table nn and table oo.

Remark: Some command changes the TM production rate of PWA. Consequently it may happen the TM queue becomes full for a long test duration.

Table NN: PWA Command list (part#1)

PWA TEST #	CMD NAME IN THE PROBE FLIGHT DATA BASE	CMD MEANING
0	HASI_TEST_PWA0_(*)	The PWA returns to ‘science’ (if it was in ‘test’) or continues in ‘science’.
1	HASI_TEST_PWA1_(*)	Acoustic sensor output test
2	HASI_TEST_PWA2_(*)	Radar Signal 1 input test
3	HASI_TEST_PWA3_(*)	Radar Signal 2 input test
4	HASI_TEST_PWA4_(*)	MI-Rx input test (gain = 0 dB)
5	HASI_TEST_PWA5_(*)	MI-Rx input test (gain = 40 dB)
6	NOT USED(1)	RP 1 input test
7	HASI_TEST_PWA7_(*)	RP 2 input test
8	HASI_TEST_PWA8_(*)	MI-Tx output test (O/P gain = -40 dB)
9	HASI_TEST_PWA9_(*)	MI-Tx output test (O/P gain = -20 dB)
10	HASI_TEST_PWA10_(*)	MI-Tx output test (O/P gain = 0 dB)
11	HASI_TEST_PWA11_(*)	MI-Tx output test (O/P switched-OFF)
12	NOT USED(1)	RP 1 output test (+5V)
13	NOT USED(1)	RP 1 output test (Ground)
14	NOT USED(1)	RP 1 output test (-5V)
15	NOT USED(1)	RP 2 output test (+5V)
16	NOT USED(1)	RP 2 output test (Ground)
17	NOT USED(1)	RP 2 output test (-5V)
18	HASI_TEST_PWA18_(*)	Radar 1 Blanking input test
19	HASI_TEST_PWA19_(*)	Radar 2 Blanking input test

(1) These commands switch-ON the RP relays permanently. Therefore it may become dangerous for the DC/DC conv.
(*) **A** (or **B**) in case of **CDMU-A** (or **CDMU-B**).

Table OO: PWA Command list (part#2)

TEST #	CMD NAME ON PROBE FLIGHT DATA BASE	CMD MEANING
20	HASI_TEST_PWA20_(*)	DAC MONITOR TEST
21	NOT USED(1)	MI-RX LOW GAIN TEST
22	NOT USED(1)	MI-RX HIGH GAIN TEST
23	HASI_TEST_PWA23_(*)	MI EXPERIMENT TEST
24	HASI_TEST_PWA24_(*)	AC-DC EXPERIMENT TEST
25	HASI_TEST_PWA25_(*)	RAE EXPERIMENT TEST
26	HASI_TEST_PWA26_(*)	AC-DC-AU EXPERIMENT TEST
27	HASI_TEST_PWA27_(*)	RP EXPERIMENT TEST
28	HASI_TEST_PWA28_(*)	MI CYCLE 1 TEST
29	HASI_TEST_PWA29_(*)	MI CYCLE 2 TEST
30	HASI_TEST_PWA30_(*)	MI CYCLE 3 TEST
31	HASI_TEST_PWA31_(*)	MI CYCLE 4 TEST
32	HASI_TEST_PWA32_(*)	MI CYCLE 5 TEST
33	HASI_TEST_PWA33_(*)	MI CYCLE 6 TEST
34	HASI_TEST_PWA34_(*)	MI CYCLE 7 TEST
35	HASI_TEST_PWA35_(*)	MI CYCLE 8 TEST
36	HASI_TEST_PWA36_(*)	MI-DAC MONITOR TX-OFF
37	HASI_TEST_PWA37_(*)	MI-DAC MONITOR TX-LOW
38	HASI_TEST_PWA38_(*)	MI-DAC MONITOR TX-MID
39	HASI_TEST_PWA39_(*)	MI-DAC MONITOR TX-HIGH

(1) These commands switch-ON the RP relays permanently. Therefore it may become dangerous for the DC/DC conv.

(*) **A.BIN** (or **B.BIN**) in case of **CDMU-A** (or **CDMU-B**).

6.3 EXECUTABLE TC GROUP

The EXECUTABLE TELECOMMAND changes the HASI operative mode from CHECKOUT to TC EXECUTION while the Experiment is performing the operations to accomplish the Telecommand. The TC list is hereafter reported:

- SOFT RESET (refer to AD(3) page 6C);
- MEMORY DUMP (refer to AD(3) page 6G);
- MEMORY LOAD (refer to AD(3) page 6H).

6.3.1 SOFT RESET

After eighteen second the TC reception, the HASI is reset by forcing a watch-dog time-out.

6.3.2 MEMORY DUMP

The requested consecutive memory location are dumped into dedicated TM packets (MEMORY DUMP format). Because the command does not distinguish from the parameter content between the EEPROM and RAM memory, it always switches-on the EEPROM memory before to start the dump. At the end it switches-OFF the EEPROM device (refers to the EEPROM switch-ON event trace in the section 3.1.1). Each memory dump block (55 words) lasts about 3 sec to assure the MEMORY DUMP packet is queued and send to CDMU. The PWA activities (SB and DB) are suspended till the completion of the command.

6.3.3 MEMORY LOAD

The requested EEPROM or RAM locations (physical addresses) are loaded. Dump of verified loaded locations is reported by means of dedicated TM packets (ML ECHO format). Because the command does not distinguish between the EEPROM and RAM memory, it always switches-ON the EEPROM and writes the memory according to the EEPROM device timing (about 30 msec for each word). At the end it switches-OFF the EEPROM device (refers to the EEPROM switch-ON event trace in the section 3.1.1). Each memory load block (54 words) lasts about 2 sec including the ML ECHO packet. The Nominal Checkout activities restart after the completion of the command.

6.4 HASI TEST COMMAND LIST

The following table reports the list of TCs which have been validated during the Probe integration and ground tests. They are included in the Flight Data Base at ESOC.

CMD NAME ON PROBE FLIGHT DATA BASE	CMD MEANING	IDS PAGE (AD(3))
HASI_TEST_MODE0_(*)	Resets Test MODE bit in the HASI-SW.	PAGE 6D
HASI_TEST_MODE0_(*)	Sets Test MODE bit in the HASI-SW.	PAGE 6D
HASI_SOFT_RESET_(*)	Reset HASI Experiment triggering the watch-dog.	PAGE 6C
HASI_FM_PA_RTS_(*)	Reset the HASI EEPROM memory data; it writes to the EEPROM start the END type parameter (refer to 8.2.3).	PAGE 6N
HASI_FM_PA_RAM_(*)	Memory patch which will be loaded in RAM at the address 0x0; the result is a reset because a watch-dog triggering.	PAGE 6N
HASI_FM_PA_PPINS0_(*) HASI_FM_PA_PPINS1_(*) HASI_FM_PA_PPINS2_(*)	Memory patch loaded in EEPROM to modify the PPI NORMAL SESSION tables; it is used for special PREssure verification (refer to sect 8.5.1.1)	PAGE 6L
HASI_FM_PA_EV0_(*)	Memory patch loaded in EEPROM to check the HASI software patch capability; the result is to create 64 Event message ('Event #2 every 2sec) and send those via EVENT LOG packets.	PAGE 6M
HASI_FM_PA_EV1_(*)		PAGE 6M
HASI_FM_PA_EV2_(*)		PAGE 6M
HASI_FM_MCA_RST_(*)	Memory patch loaded in EEPROM to initialise a MCA control register. It MUST BE LOADED in HASI EEPROM during nominal working (ground/flight checkout). It has any impact on the HASI working when Titan mode.	PAGE 6N
HASI_FM_MEM_DUMP_(*)	It checks the Memory Dump capability.	PAGE 6G

(*) **A.BIN** (or **B.BIN**) in case of **CDMU-A** (or **CDMU-B**).

7 HASI HANDLING, SERVICING AND INTEGRATION PROCEDURES GUIDELINES

7.1 HANDLING REQUIREMENTS

7.1.1 ACC handling requirements

The ACC input connector J01 is protected by a blue (inner metallised) cap; the cap shall be removed only before integration or test operations.

The ACC shall be handled by authorised personnel with plastic gloves. People **must be** grounded to QUITE GROUND before to start any handling/integration/test operations with the item.

The ACC instrument is shock sensitive.

7.1.2 DBS handling requirements

The DBS shall be handled by authorised personnel with plastic gloves. The operators **must be** grounded to QUIET GROUND before starting any handling/integration/test operations with the item.

The MI-TX MCA connector will be mated in the J02 connector of the HASI-B bracket. The MCA cable backshell connector will be mated in the J01 connector of the HASI-B bracket.

The TX, RX and RELaxation electrodes are not protected by red caps. The operators **must pay attention** not to damage them during the handling and the integration of the DBS.

During the DBS handling, the RX and RELaxation electrodes are provisionally protected by grounding to the HINGE bracket feedthrough via wires terminated with crocodile clips. A special grounding D-type connector is plugged into the HASI-I connector J01 and provides connection between signal ground and housing (pin 11 of the J01 connector) of the HASI-I box.. As a result the RX and RELaxation electrodes and the signal ground are all connected together to the HASI-I box housing since the HASI-I box housing is connected as well to the HINGE bracket body, via cable with overall shield.

These protection provisions must remain in place during all DBS handling operations.

7.1.3 DPU handling requirements

The DPU shall be handled by authorised personnel with plastic gloves. The operators **must be** grounded to QUIET GROUND before to start any handling, integration or test operations with the item.

The DPU (HASI) test connector J07 (37 pin D-type) is protected by a metallic connector cover; it shall always remain in place; only for special test or troubleshooting it can be removed. All the other electrical connectors are protected via red caps; they shall be removed before the integration in the Probe or before any tests that will be performed at level.

The Wall fitting pressure connector is protected via a red cap flagged with 'NOT FOR FLIGHT'. It must be removed only in clean area and before the integration with the STUB.
On the DPU it is foreseen an external removable jumper, located in the rear wall of the DPU, that links the HASI feedthrough to the HASI Bonding Stud. It is strongly required to maintain it in place during the integration/tests with the HASI experiment.

7.1.4 STUB handling requirements

The STUB shall be handled by authorised personnel with plastic gloves. People **must be** grounded to QUIET GROUND before to start any handling/integration/test operations with the item.

The TEM cable backshell connector is labelled with P09 and it will be mated in the J09 connector of the DPU. The ACU cable backshell connector is labelled with P10 and it will be mated in the J10 connector of the DPU.

Both the two TEM sensors and the KP are protected via red caps. The protective caps must be left in place except when it is required (e.g. functional tests).

7.2 SERVICING PROCEDURES GUIDELINES

7.2.1 DPU test connector cover removal instruction

Before starting, the operator must be grounded to the QUIET GROUND. The following sequence can be used to remove the test connector cover:

- Locate the test connector on the top the DPU box.
- Use a flat screwdriver (with appropriate size) to unscrew the two fixing screws of the test connector cover until they are loosing.
- Remove the test connector cover from the DPU and store it. NOTE: the fixing screws remain together to the cover.

7.2.2 HASI External jumper removal instruction

Before starting, the operator must be grounded to the QUIET GROUND. The following sequence can be used to remove the HASI external jumper:

- Locate the jumper on the rear wall of the DPU box.
- Use a normal tool to unscrew the M3 nut on the Bonding stud a small flat head screwdriver to unscrew the M3 screw on the Feedthrough. Unscrew them until they are loosing.
- Turn clock wise the HASI jumper until it will be in vertical position (i.e. parallel to the DPU X axis).
- Screw back the M3 nut and the M3 screw. Now the feedthrough (i.e. the HASI start point) is insulated from ground.

7.2.3 DPU Pressure inlet Wall Fitting protection cap removal instruction

Before starting, the operator must be grounded to the QUIET GROUND.

- Turn counter clock wise by hand the Wall fitting protection cap until it is loosed. Store it in the DPU transportation container.

7.2.4 STUB TEM sensors protective cap removal/assembly instructions

This procedure must be performed taking care NOT TO DAMAGE the TEM sensitive wires under the protective cap.

Before starting, the operator must be grounded to the QUIET GROUND.

The following sequence can be used to remove the TEM protective cap:

- Unscrew the cap by hand, holding the base of the cap (which is a rim about 1 mm wide) to prevent it turning, until the cap can be pulled off. Take care to pull the cap in the TEM axial direction so as not to damage the sensitive wire element. After this operation the base of the protection cap will remain attached to the sensor frame.
- Find the two fixing screws which are sunk in the screw thread on the base of the protection cap.
- Use a normal screwdriver (with a small head) to unscrew the two fixing screws. The base of the cap will divide in two.
- Reassemble the two halves using the two fixing screws, screw the main part of the cap back on and store the protective cover in a safe place.

The following sequence can be used to reassemble the TEM protective cap:

- Unscrew the main part of the cap from the base and separate the two halves of the base.
- Locate the two halves of the base of cap on opposite sides of the base of the stem of the TEM sensor and screw them together with the two screws removed before.
- Pass the cap carefully over the sensor frame in the axial direction of the TEM until it touches the base.
- Hold the cap base to prevent it turning and screw the cap on by hand without over-tightening.

7.2.5 DBS ESD provisional grounding Removal instructions

This procedure must be performed taking care NOT TO DAMAGE the RX and the RELaxation electrodes.

Before starting, the operator must be grounded to the QUIET GROUND. The following sequence can be used to remove the ESD provisional grounding cable to prepare the DBS to the integration into the Probe:

- Connect the RELaxation electrode (there is a Kapton tape fixed on the electrode plate which holds a wire terminating with a loop to facilitate the grounding of the electrode) to the MI-Rx electrode (the one with larger loop) using crocodile clips, then connect both the grounding to the BOOM HINGE bracket feedthrough.
- Un-plug the D-type connector from the HASI-I box connector J01
- Integrate the DBS into the Probe following the proper instructions (see sect. 7.3.5.3).

7.2.6 BOOMS Hand-Deploying instructions

The BOOMS can be deployed manually **but this considered an hazardous operation and therefore the automatic operation is always preferable**. It can be done through the insertion of a special tool: a plastic flat head screwdriver (provided by HASI) inside the hollow of the Boom stem latch (in the Release mechanism) between the stem latch and the actuator pin end, and pushing up the pin, working on the base of the hollow, until the locking pin has reached the locked position.

7.2.7 BOOMS Hand-Stowing instructions

After deploy the BOOMS can only be stowed manually. This operation shall be done holding the BOOM stem with one hand (dressed with polythene gloves) as close as possible to the hinge; pulling out the locking pin (by pliers) moving the stem toward the release mechanism with a circular motion and having care to avoid forcing the stem up and down with respect to its fulcrum (hinge). When the BOOM stem is inside the release mechanism hollow, the stem latch shall be rotated up to close the stem into the hollow. At that point the proper peek tool (provided by HASI) shall be introduced through the opening of the cap which protects the actuator and the shaft of the actuator shall be pushed to lock the stem latch and maintain the BOOM in folded position.

7.3 INTEGRATION PROCEDURES GUIDELINES

7.3.1 INTEGRATION/TESTING CONDITIONS

All the integration and test activities treated in this section are under responsibility of the Probe integration team. An integration manager will attend all the integration phases and will be responsible for their correct execution.
Any unattended event, during the integration/test execution, shall be processed using a non conformance report written in the proper form.
The person conducting each stage of the integration/test procedure shall have been trained in the processes involved in that stage and shall have a through understanding of the procedure as a whole.
Prior to the commencement of the integration/test, a pre-procedure briefing shall be held for all integration personnel. This briefing shall include operational hazards, precautions, emergency actions, critical task items, basic flow and procedure/communication discipline.

7.3.2 Handling rules and Safety precautions

During all integration and testing activities executed in clean room (Class 100000 minimum for FM and FS) people must be dressed with special authorised clothes.

- During all integration activities the HASI items must be handled with polythene gloves.
- Any shock must be avoided to the HASI items.
- Finger rings, wrist watches and other items which could scratch any sensitive hardware surfaces of the HASI items shall not be worn in the vicinity of the HASI items. Items which cannot be removed shall be covered with tape or other medium which will prevent hardware damage in the event of inadvertent contact with the subsystem.
- Work areas shall be kept free of extraneous materials and equipment which could create crowded or other working conditions which could be hazardous to the subsystems. Prior to commencement of the integration, the work area shall be inspected for, and cleared of, any static hazard producing materials.
- Worn or damaged tools shall not be used on HASI hardware.
- Eating, drinking and smoking shall be prohibited in the hardware integration, inspection, test or storage area.
- Particular attention must be paid to the HASI experiment protruding parts as BOOMS, STUB, TEM sensors
- The red protection covers shall be left on the TEM sensors and Kiel probe if the removal is not strictly needed for the integration. In those cases a note on the integration procedure indicates to proceed to their removal.
- For the Experiment items transportation out of clean room the suitable containers, used for the shipment to the integration site, must be used.
- The DBS electrodes are very sensitive to ESD. When the HASI-I J01 connectors are disconnected from the DPU, the proper ESD provisional grounding cable shall be integrated using all ESD precautions. The ESD provisional grounding cable grounds the amplifiers input and the DBS electrodes when it is connected to each:
  - HASI-I J01 connector

  - MI-Rx electrode (the one with the larger loop)
  - RELaxation electrode (the disk shaped one)

- Only when the ESD provisional grounding cable is on, the DBS booms can be handled and put into the transport container

For more detailed handling precautions on each HASI subsystem, additional information are reported in chapter 7.1.1 to 7.1.4.

7.3.3 Items required for HASI Integration

The following HASI items shall be available before integration starting:

- HASI ACC (one box)

- HASI DBS (4 units):
  - Articulated boom B1 from which exit 3 cables: 2 of these cables are permanently connected to the box HASI-I1, the third cable is fitted with a connector P01
  - Release mechanism A1 with cable and P01 connector
  - Articulated boom B2 from which exit 3 cables: 2 of these cables are permanently connected to the box HASI-I2, the third cable is fitted with a connector P01
  - Release mechanism A2 with cable and P01 connector
  - Tool for BOOM manual opening (2 pieces)
  - Tool for MCA locking pin movement (to be used for BOOM stowing)
  - Two sets of DBS grounding cables for protection against ESD.

- HASI DPU (one box)

- HASI STUB (6 units)
  - STUB STEM
  - PRESSURE TUBE SUPPORT (2 items)
  - PRESSURE TUBE PT2
  - PRESSURE JOINT GASKET
  - WALL FITTING GASKET

- one set of HASI SCREWS (provided by AS)
  - 4 M3 screws for ACC
  - 4 M4 screws for DPU
  - 2 M3 screws for HASI-I1
  - 2 M3 screws for HASI-I2
  - 16 M3 screws for HASI STUB
  - 10 M3 screws for HASI DBS A1
  - 12 M3 screws for HASI DBS B1
  - 10 M3 screws for HASI DBS A2
  - 12 M3 screws for HASI DBS B2

- one set of HASI cables (provided by AS)

7.3.4 Tools required for HASI Integration

The following tools shall be available before integration starting:

- 7 mm open end wrench
- 18 mm open end wrench
- 20 mm open end wrench
- special tool (peek) to move (reset) the BOOM actuator pin (provided by HASI)
- special tool (plastic flat head screwdriver) to move up the BOOM actuator pin during manual deploy (provided by HASI)
- special Allen key (modified) suitable to insert the fixing screws of DBS Hinge and Release mechanism brackets where there is not enough room to work for a standard key (provided by HASI)
- Torque wrench capable of applying torque between 0.1 and 0.3 Kg×m with an accuracy of 0.01 Kg×m, with the following bits and heads:
  - bit for AS supplied M3 bolts
  - bit for AS supplied M4 bolts
  - small (about 4 mm blade) flathead screwdriver bit
  - Allen Key bit 2.5 mm
  - long shafted Allen key for HASI ACC M3 bolts
- Standard Lab instrumentation for electronic measurements

7.3.5 HASI Mechanical/Electrical Integration Procedures

In this chapter the procedures to be used as basis for the integration of the HASI Experiment on the HUYGENS Probe are reported. The procedures are ordered in an optimised sequence of subsystems integration, but it is not mandatory to follow the suggested sequence which can be changed when needed, however the DPU shall be integrated as last to leave a working space where to connect break-out boxes on its connection cables.

The philosophy used in designing this procedure is the following:

- we assume that all the subsystems are correctly working at the moment of integration because they have just passed the incoming test prior at subsystem and then at Experiment level

- we assume that the External (toward the other probe subsystems) electrical interfaces to the DPU will be checked according to DASA procedure and not according to HASI inputs, therefore no inputs are given for these tests

- we just want to check that the subsystem whose cabling connection to DPU are Probe part are still working fine with these cabling (seen from the DPU side)

- no electrical checks are foreseen on the STUB prior to connection to DPU since it has its own cabling and therefore nothing has changed between the Experiment level incoming test and the integration on the Probe.

7.3.5.1 Preliminary operations

<u>During all integration phases the operator(s) involved shall always be connected to QUITE GROUND</u>

- Install (or check that it is already done) the HASI harness on the Probe Experiment Plate

7.3.5.2 ACC integration

(refer also to 7.1.1 for handling instructions)

7.3.5.2.1 ACC Mechanical Integration

- Since the ACC Servo sensor is required to have its seismic mass in the X axis positioned as near to the Probe's entry CoG as possible (displacement in any direction shall be not greater than 3 mm sphere radius), shimming shall be done, if necessary, prior ACC sensor mounting on the Probe.

- Install the ACC in the proper position of the Probe Experiment Plate (Refer to figure mm).

- Verify that the reference Hole of the ACC (indicated by "R") corresponds to its position on the Probe Experiment Plate (Refer to figure bb).

- Verify that the box footprint fits properly with the plate and no damage to the box can be caused by the fixation

- If the above verifications have given positive results, then proceed tightening the four M3 screws to the required tightness (defined by AS) using the torque wrench

7.3.5.2.2 ACC Electrical integration

- Remove the connector blue cover and connect ACC-P01 of the Probe harness to J01 (without saver) of the ACC box. Tight the connector backshell screws to 0.3 Nm using the torque wrench with the flathead screwdriver end bit.
- ACC electrical/functional check: Probe shall be horizontal (ACC box shall be such that the connector and the lid are in the horizontal plane).
- Record the environment temperature T=____°C.
- Through the use of a 25 pins BoB connected on ACC cable, in the place of the DPU J04 connector, power up the ACC s/s by providing +15V (0.25A) on pin 2, -15V (0.25A) on pin 15 and GND on pin 3.

Using a voltmeter, measure the output voltage between pin 16 (X PZT Signal Output) and pin 3 (Power Return). Record the o/p voltage and verify it to be in the expected range :

[4 ± 1Volt]

Using a voltmeter, measure the output voltage between pin 17 (Y PZT Signal Output) and pin 3 (Power Return). Record the o/p voltage and verify it to be in the expected range

[-2 ± 1Volt]

Using a voltmeter, measure the output voltage between pin 18 (Z PZT Signal Output) and pin 3 (Power Return). Record the o/p voltage and verify it to be in the expected range

[4.5 ± 1Volt]

- Short circuit pins 12 and 14.

Using a voltmeter, measure the output voltage between pin 8 (SERVO HIGH Signal Output) and pin 3 (Power Return). Record the o/p voltage and verify it to be in the expected range

[4<V<7 Volt]

- Using a voltmeter, measure the output voltage between pin 21 (SERVO LOW Signal Output) and pin 3 (Power Return). Record the o/p voltage and verify it to be in the expected range [0.4<V<0.7 Volt]
- Using a voltmeter, measure the output voltage between pin 10 (TEMP1 Signal Output) and pin 3 (Power Return). Record the o/p voltage and verify it to be in the expected range [2<V<3 Volt]
- Using a voltmeter, measure the output voltage between pin 11 (TEMP2 Signal Output) and pin 3 (Power Return). Record the o/p voltage and verify it to be in the expected range and it tracks the output voltage obtained from pin 10 [2<V<3 Volt]. Note that if ACC has been ON for a short time both TEMP signals should increase with time to a stable value (as ACC warms up).
- Remove the voltmeter probes.
- Power down the ACC s/s by disconnecting the pin 2 and 15 from the external power supply.
- Remove the BoB.

7.3.5.3 DBS integration

(refer also to 7.1.2 for handling instructions)

THE MECHANICAL INTEGRATION REQUIRES TWO OPERATORS!

7.3.5.3.1 BOOM 1 Mechanical integration

- A1 is removed from the DBS container (Refer to figure mm, item A1, MCA1).
- The cable of A1 is engaged through the opening located at the centre of the ring interface removing the connector saver first.
- A1 is temporarily attached to the ring interface with four M3 screws and washers: the actuator is located on top, towards the +Xp direction (refer to

figure ff and figure mm).

- The cable starting from A1 is connected to the bracket HASI-B1 J01 (refer to figure mm, item HASI-B1): method is defined by AS.
- B1 (refer to figure ee, item B1 and figure ff), already in deployed configuration, is removed from the container. Be sure that all precautions for handling ESD sensitive devices are taken, than remove the grounding cabling clips from the MI-Rx and Relaxation electrodes and unplug the D type grounding connector from HASI-I1 J01(see sect. 7.2.5).
- The box HASI-I1 (refer to figure ee, item HASI-I1 and figure gg) and the cable of B1 are engaged through the opening located at the centre of the ring interface.
- B1 is temporarily attached to the ring interface with four M3 screws and washers: the rotation axis XB1 makes an angle less than 90deg. with the XP direction (refer to

figure ff and figure mm).

- The cable starting from B1 is connected to the bracket HASI-B1 J02 (SMA connector) without saver.
- Install the HASI-I1 in the proper position of the Probe Platform.
- Verify that the HASI-I1 reference hole (marked with "R") corresponds to its position on the Probe Experiment Plate.
- Verify that the box footprint fits properly with the plate and no damage to the box can be caused by fixing it.
- If all this is verified then proceed tightening the two M3 screws and washers to 1÷1.2 Nm using the torque wrench. Connect HASI-I1 J01 to Probe HASI-I1 cable P01 (provided by AS) without saver.
- The locking pin of B1 (refer to figure ff) is pulled out by small flat end pliers and the BOOM stem is folded back manually to verify that the positions of A1 and B1 are nominal. The BOOM can be maintained in a folded position by pushing the shaft of the actuator; this operation is executed with the HASI provided special tool introduced through the opening of the cap which protects the actuator (refer to figure hh).
- B1 and A1 are attached to their interfaces with the remaining screws and washers hand tightened. B1 can be deployed again, if needed, to facilitate this operation. Note that some of the nominal length screws provided by AS can be difficult to mount due to the reduced working space, in that case some special screws with reduced length (provided by HASI) can be used.
- B1 screws (12) and A1 screws (10) are tighten definitively to the required tightness (1÷1.2 Nm) by the torque wrench (or the special Allen key where there is not enough room for the standard torque wrench). Integrate the bonding straps between B1 flange Bonding Stud (torque = 0.45 Nm) and probe structure and between A1 flange Bonding Stud (torque = 0.45 Nm) and Probe structure.

7.3.5.3.2 BOOM 2 Mechanical integration

- A2 is removed from the DBS container (refer to figure ee, item A2).
- the cable of A2 is engaged through the opening located at the centre of the ring interface removing the connector saver first.
- A2 is temporarily attached to the ring interface with four M3 screws and washers: the actuator is located on top, towards the +Xp direction (refer to figure hh and figure mm).
- The cable starting from A2 is connected to the bracket HASI-B2 J01 (refer to figure mm, item HASI-B2): method is defined by AS.
- B2 (refer to figure ee, item B2 and figure hh), already in deployed configuration, is removed from the container. Be sure that all precautions for handling ESD sensitive devices are taken, than remove the grounding cabling clips from the MI-Rx and RELaxation electrodes and unplug the D type grounding connector from HASI-I2 J01 (see sect. 7.2.5).
- The box HASI-I2 (refer to figure ee, item HASI-I2 and figure gg) and the cable of B2 are engaged through the opening located at the centre of the ring interface.
- B2 is temporarily attached to the ring interface with four M3 screws and washers: the rotation axis XB2 makes an angle less than 90°. with the Xp direction (Refer to figure ee and figure mm).
- The cable starting from B2 is connected to the bracket HASI-B2 J02 (SMA connector) without saver.
- Install the HASI-I2 in the proper position of the Probe Platform.
- Verify that the HASI-I2 reference hole (marked with "R") corresponds to its position on the Probe Experiment Plate.
- Verify that the box footprint fits properly with the plate and no damage to the box can be caused by fixing it.
- If all this is verified then proceed tightening the two M3 screws and washers to 1÷1.2 Nm using the torque wrench. Connect HASI-I2 J01 to DBS HASI-I2 cable P01 (provided by AS).
- The locking pin of B2 (refer to

figure ff) is pulled out by small flat end pliers and the BOOM stem is folded back manually to verify that the positions of A2 and B2 are nominal. The BOOM can be maintained in a folded position by pushing the shaft of the actuator; this operation is executed with the HASI provided special tool introduced through the opening of the cap which protects the actuator (refer to figure hh).

- B2 and A2 are attached to their interfaces with the remaining screws and washers hand tightened. B2 can be deployed again, if needed, to facilitate this operation. Note that some of the nominal length screws provided by AS can be difficult to mount due to the reduced working space, in that case some special screws with reduced length (provided by HASI) can be used.
- B2 screws (12) and A2 screws (10) are tighten definitively to the required tightness 1÷1.2 Nm by the torque wrench (or the special Allen key where there is not enough room for the standard torque wrench). Integrate the bonding straps between B2 flange Bonding Stud (torque = 0.45 Nm) and probe structure and between A2 flange Bonding Stud (torque = 0.45 Nm) and Probe structure.

7.3.5.3.3 Electrical Integration

- DBS Mechanical integration is finished. Now through the use of a 7WD BoB connected on the DPU J02 connector (of the Probe harness), measure by an ohmmeter the resistance between the pin A1 (inner contact) and the DBS B1 Tx electrode (Tx electrode is the one with the small loop). It shall be > 1MΩ.
- Always with the ohmmeter, measure the resistance between the pin A2 (inner contact) and the DBS B2 Tx electrode (Tx electrode is the one with the small loop). It shall be > 1MΩ.
- Using a sine-wave generator (8 Vpp, 100 KHz) and an oscilloscope, test the AC continuity between DBS B1 Tx electrode and the inner contact of pin A1 in BoB: inject 8 Vpp sine wave, 100 KHz on inner contact of A1 w.r.t. chassis (i.e. Probe ring) and measure the voltage on Tx electrode w.r.t. chassis (i.e. the Probe ring) with oscilloscope (probe impedance 10 MOhms, 14 pF). Measured voltage Vpp shall be: [160<Vpp<280mV]
- Note hereafter the probe impedance ...... MOhms .... pF
- Using a sine-wave generator (8 Vpp, 100 KHz) and an oscilloscope, test the AC continuity between DBS B2 Tx electrode and the inner contact of pin A2 in BoB: inject 8 Vpp sine wave, 100 KHz on inner contact of A2 wrt chassis (i.e. Probe ring) and measure voltage on Tx electrode wrt chassis (i.e. Probe ring) with oscilloscope (probe impedance 10 MOhms, 14 pF). Measured voltage Vpp shall be: [160<Vpp<280mV]
- Note hereafter the probe impedance ...... MOhms .... pF.
- Remove the 7W2 BoB from P02 connector.
- Connect a 25 pins BoB on DPU J06 connector (Of the Probe harness).
- Test of HASI-I1 relay coil: using an ohmmeter measure resistance between pins 5 & 6 of P06 BoB. Result shall be 50 Ohms ±10%.
- Test of HASI-I2 relay coil: using an ohmmeter measure resistance between pins 18 & 19 of P06 BoB. Result shall be 50 Ohms ±10%.
- Test of HASI-I1 relay actuation: Supply HASI-I1 relay coil through P06 BoB: give +5 V on pin 5 and 0 V on pin 6.
- To verify relay actuation: using an ohmmeter measure resistance between P06 BoB pin 4 and HASI-B1 RP electrode (the disk shaped one). Measurement shall be [<2W].
- Test of HASI-I2 relay actuation: Supply HASI-I2 relay coil through P06 BoB: give +5 V on pin 18 and 0 V on pin 19.
- To verify relay actuation: using an ohmmeter measure resistance between P06 BoB pin 17 and HASI-B2 RP electrode (the disk shaped one). Measurement shall be [<2W]
- In order to test the DBS BOOM 1 power consumption, a DC power supply is connected to the P06 BoB, through amperometers, as follows: +15 V on pins 8 & 13; -15 V pins 9 & 12; 0 V on pins 10 & 11 (one amperometer is on the +line and the other is on the -line).
- Measure the DBS BOOM 1 current drawn on +15 Volt power line to be [I=1.15 mA ±20%].
- Measure the DBS BOOM 1 current drawn on -15 Volt power line to be [I=1.15 mA ±20%].
- Supply the HASI-I1 relay coil through P06 BoB: give +5V on pin 5 and 0V on pin 6. The power supplies grounds shall be connected together.
- Supply HASI-I1 contact relay through P06 BoB: +5 V on pin 4.
- Measure voltage on DBS-B1 RP electrode wrt reference ground pin 10 with multimeter (input impedance 10 Mohms): 5V±5%.
- Measure RELAX OUT voltage on P06 BoB, pin 2 wrt reference ground pin 10 with multimeter [5V±5%].
- Switch Off all the power supplies.
- In order to test the DBS BOOM 2 power consumption, a DC power supply is connected to the P06 BoB, through an amperometer, as follows: +15 V on pins 20 & 25; -15 V pins 21 & 24; 0 V on pins 22 & 23.
- Measure the DBS BOOM 2 current drawn on +15 Volt power line to be [I=1.15 mA ±10%].
- Measure the DBS BOOM 2 current drawn on -15 Volt power line to be [I=1.15 mA ±20%].
- Supply the HASI-I2 relay coil through P06 BoB: give +5V on pin 18 and 0V on pin 19. The power supplies grounds shall be connected together.

- Supply HASI-I2 contact relay through P06 BoB: +5 V on pin 17.
- Measure voltage on DBS-B2 RP electrode wrt reference ground pin 22 with multimeter (input impedance 10 Mohms): 5V±10%.
- Measure RELAX OUT voltage on P06 BoB, pin 15 wrt reference ground pin 22 with multimeter [5V±5%].
- Switch off all the test power supplies and remove the BoB.

7.3.5.3.4 MCA check:

- MCA CHECK: Connect a 9 pins BoB on the DPU P01 connector (Probe harness).
- DBS-B1 MCA coil resistance check: using an ohmmeter measure the resistance between pin 1 and 6 of P01 BoB to be [7.8W ± 20%].
- DBS-B1 MCA coil resistance check (redundant connection): using an ohmmeter measure the resistance between pin 2 and 7 of P01 BoB to be [7.8W ± 20%].
- DBS-B2 MCA coil resistance check: using an ohmmeter measure the resistance between pin 4 and 8 of P01 BoB to be [7.8W ± 20%].
- DBS-B2 MCA coil resistance check (redundant connection): using an ohmmeter measure the resistance between pin 5 and 9 of P01 BoB to be [7.8W ± 20%].
- µSwitches function shall be verified on CDMU side with the procedure defined by AS. Expected output values are:

- Resistance>10MW for BOOMS in DEPLOYED configuration
- Resistance<100W for BOOMS in STOWED configuration

- Switch OFF all instrumentation used and dismount the set-up.

7.3.5.4 DPU integration

(refer also to 7.1.3 for handling instructions)

- Install the DPU in the proper position of the Probe Experiment Plate (refer to figure mm, item 1).
- Verify that the reference Hole of the DPU (indicated by "R") corresponds to its position on the Probe Experiment Plate.
- Verify that the box footprint fits properly with the Probe Experiment Plate and no damage to the box can be caused by fixing it on the plate.
- If the above verifications have given positive results, then proceed tightening the four M4 screws to the required tightness (defined by AS) using the torque wrench. Integrate the bonding strap between the DPU Bonding stud (torque = 0.45 Nm) and probe structure.

7.3.5.5 STUB integration

(refer also to 7.1.4 for handling instructions)

7.3.5.5.1 STUB Mechanical integration

- Using the torque wrench, fix each Pressure Tube support (refer to figure mm, item 3), provided as accessories to the STUB, in the proper position of the Probe Experiment Plate with two M3 screws and washers. Leave the screws loose coupled.
- Remove the two M3 x 12 hexagonal screws of both the Pressure tube support covers and remove the cover itself to allow insertion of PT2 in the support seat underneath.
- Remove the DPU Pressure Connector red cover. Integrate the part with the nut on the end of the STUB pressure tube 2 (PT2: refer to figure mm, item 4) with the DPU box pressure connector together with the gasket that was inside BAG Nr 1. Turn the nut by hand until the gasket surface touches firmly.
- Verify that PT2 properly lean on the supports. If this is OK, than tight the screws which fix the pressure supports to the probe platform using the torque wrench with the proper end bit 1÷1.2 Nm (torque defined by AS). Mount back the pressure support covers (note that two lines are engraved on the side of one of them and one line is engraved on the side of the other, when the cover is installed the line(s) on the cover shall correspond to the line(s) on the base of each Pressure Tube support) installing the four M3 x 12 hexagonal screws (HASI provided) plus washers and leaving them loose coupled. Remove the red cover from the end of PT2.
- Remove the red cover from the pressure tube PT1 coming out from the STUB flange. Holding the STUB STEM in one hand (refer to figure mm, item 16), pass the P10 connector & backshell through the squared interface window in the Probe ring bracket (refer to figure mm, item 5). Do the same for the P09 connector.
- Pulling the two cables (ACU and TEM) from the other side of the ring, bring the STUB flange near to the ring itself.
- Verify that the STUB flange reference hole (marked with "R") corresponds to its position on the Probe Experiment Ring.
- When the STUB flange is close to the interface window (about 5 cm), bend up the STUB STEM to allow the PRESSURE JOINT and the PRESSURE TUBE passing through the window.
- When the STUB FLANGE is close to the interface window then insert the gasket, that is in BAG Nr 2, between the STUB stem (end of PT1) and PT2. Put again the STUB horizontal and join the two surfaces.
- After to have verified that the STUB Flange well fits to the Probe Ring interface, provisionally fix the STUB tightening four of the sixteen M3 screws and washers (one on each flange side) by the torque wrench to the tightness defined by AS (1÷1.2 Nm).
- Check that the pressure tube and other parts are in their correct position. If required, loosen the nuts of the fastening (pressure supports) and bend or rotate the PT1 tube carefully by hand until the required pose is achieved without residual strains
- Being determined the required pose of PT1, remove now the STUB flange fixing screws and remove it from the Probe having care not to modify the PT1 position. PT1 shall be now fixed and the thermal sealing shall be applied on the stub flange closure: a line of Stycast glue (≈3 millimeter thick) shall be placed (by means of a syringe) all over the STUB flange metal to metal joints (around the closure supports perimeter and around the PT1 outlet from closure support). Then, to let the glue polymerise, the STUB shall either be left at ambient temperature for about 10 hours.
- When the Stycast glue is polymerised the mount back the STUB on the Probe:
- Holding the STUB STEM in one hand (refer to figure mm, item 16), pass the P10 connector & backshell through the squared interface window in the Probe ring bracket (refer to figure mm, item 5). Do the same for the P09 connector.
- Pulling the two cables (ACU and TEM) from the other side of the ring, bring the STUB flange near to the ring itself.

- Verify that the STUB flange reference hole (marked with "R") corresponds to its position on the Probe Experiment Ring.
- When the STUB flange is close to the interface window (about 5 cm), bend up the STUB STEM to allow the PRESSURE JOINT and the PRESSURE TUBE passing through the window.
- When the STUB FLANGE is close to the interface window then insert the gasket, that is in BAG Nr 2, between the STUB stem (end of PT1) and PT2. Put again the STUB horizontal and join the two surfaces.
- After to have verified that the STUB Flange well fits to the Probe Ring interface, provisionally fix the STUB tightening the sixteen M3 screws by the torque wrench to the tightness defined by AS (1÷1.2 Nm).
- At this point the two Pressure tube parts should be joined: Connect the two parts of the tube by means of the nut on the end of PT1 (coming out from the STUB flange) having care of putting few drops of solythane on the threads. Turn the nut by hand until the gasket surfaces touch firmly.
- When the parts are all together as described above, the mounting and fastenings are tightened to the following specifications:

  - If they have been loosen, tight the four M3 screws fastening the Pressure Tube supports to the platform to the torque defined by AS using a torque wrench.
  - Put few drops of solythane on the threads, then tight the four M3 screws which fasten the covers of the Pressure Tube supports to a torque of 0.5 Nm using a 2.5 mm Allen head torque wrench.
  - Loose the nut which joins PT2 to the DPU wall fitting, put few solithane drops on the threads of the DPU wall fitting and then hand tight the nut. From the hand tightened position, turn 45 to 55 degrees with a 20 mm open head wrench.
  - From the hand tightened position, turn the nut which joins the two pressure tubes, PT1 and PT2, 45 to 55 degrees with a 18 mm open head wrench and using a second tool (7 mm open head wrench) to supply counter torque on PT2.

7.3.5.5.2 STUB Electrical integration

- Connect the TEM cable connector P09 to a 25 pins BoB and perform the following measurements:

  - ❍ Measure by a megaohmeter the insulation (with 50 Volts) between each pin of the BoB and the STUB bonding stud [> 1 MΩ]
  - ❍ Measure by an ohmmeter the resistance between pin 5 and 18 (TEM 1 COARSE) [15÷17 Ω]
  - ❍ Measure by an ohmmeter the resistance between pin 6 and 19 (TEM 1 FINE) [15÷17 Ω]
  - ❍ Measure by an ohmmeter the resistance between pin 9 and 21 (TEM 2 COARSE) [15÷17 Ω]
  - ❍ Measure by an ohmmeter the resistance between pin 8 and 20 (TEM 2 FINE) [15÷17 Ω]

- Remove the 25 pins BoB
- Connect the ACU cable connector P10 to a 9 pins BoB and perform the following measurements:

  - ❍ Measure by a megaohmeter the insulation (with 50 Volts) between each pin of the BoB and the STUB bonding stud [> 1 MΩ]

- ❍ Measure by an ohmmeter the resistance between pin 1 and 6 [2300Ω ± 20%]
- ❍ Measure by an ohmmeter the resistance between pin 1 and 7 [> 30 MΩ]
- ❍ Measure by an ohmmeter the resistance between pin 5 and 9 [1450 Ω ± 20%]

- Remove the 9 pins BoB
- Perform the appropriate routing of STUB TEM cable and mate the connector P09 to J09 of the DPU box. Tight the connector backshell screws to 0.3 Nm using the torque wrench with the flathead screwdriver end bit. Fix the cabling to the plate using strips
- Perform the appropriate routing of STUB ACU cable and mate the connector P10 to J10 of the DPU box. Tight the connector backshell screws to 0.3 Nm using the torque wrench with the flathead screwdriver end bit. Fix the cabling to the plate using strips
- Integrate the bonding strap between the STUB flange Bonding stud (torque = 0.45Nm) and the Probe structure.

7.3.5.6 Cabling connection

- Cabling Integration:

  - Connect PO1 connector of *MCA-OUT* cable to DPU J01
  - Connect PO2 connector of *PWA MI-TX* cable to DPU J02
  - Connect PO4 connector of *ACC INPUT* cable to DPU J04
  - Connect PO6 connector of *PWA-RX* cable to DPU J06

- The DPU is now ready for External interfaces verification (to PCDU, to CDMS, to PROXIMITY Sensors). Procedures are defined by AS.

8 SOFTWARE MAINTENANCE

8.1 Introduction

The HASI parameters are listed in the table pp, table qq, table rr, table tt, and table ss in this section. They are organised in four functional groups: three are relevant to the ACC, TEM and PRE sensors and one to the whole experiment. It may be also changed the content of any RAM location (refer to the annex 1: hasi-s/w linker's map for the address of the each RAM object). An useful example is the actually loaded parameter in the EEPROM (HASI FM and FS) to initialise the MCA control register. All HASI software tasks are installed as part of the START-UP activity. They are activated only after **EEPROM test** (refer to 3.1), thus the software tasks will use the EEPROM parameters (if any). However some software activities (i.e. from the HASI Bootstrap up to **EEPROM test**) will be not able to be modified:

- the sequence of activities till the EEPROM test;
- the detection of the possible causes of the HASI bootstrap;
- the initial NMI interrupt routine (till the EEPROM test);
- the initial HASI-SW content;
- the initial Operating System installation (except for its configuration table);
- the initial devices and registers initialisation (till the EEPROM test);
- the EEPROM test routines: EEPROM loading and EEPROM Override.

Two parameter types are foreseen in the frame of the HASI software maintenance:

- <u>TABLES</u> which contain one or more then one data type (e.g. an array of long integers, an single byte, an array of HASI-S/W defined data type, etc.);
- <u>SOFTWARE PATCH</u> which contains the object code (**8086** INTEL® Microprocessor).

Each <u>table</u> is allocated in RAM. The default values reside in the PROM and they are copied at the relevant RAM location at START-UP (refer to 3.1). After the **EEPROM parameters loading** (refer to the procedure b), the update table overrides the relevant default value. figure j shows a typical <u>tables</u> update:

- In the example, a generic software package (marked with **'*_pkg'**) has three different tables: PARAM #1, PARAM #2 and PARAM #N. Each default is stored in PROM and it is copied at START-UP to RAM memory at the correspondent table address which resides in PROM in the E2PARAMS structure. Let's assume to load the EEPROM with two tables: TABLE 2 (PARAM #2) and TABLE N (PARAM #N). After **EEPROM parameters loading** procedure, the Update parameter #2 and #N are copied from EEPROM to RAM at the address reported in the relevant UPDATE LISTS. The addresses are obviously the ones for PARAM #2 and #N.

To make easy a software patch, in the HASI-S/W is foreseen a jump (i.e. a call) to a fixed RAM location **0x0040H:0x000CH** (where the first value, before the colon, is the hexadecimal value of the RAM base address and the second is the RAM offset; refer also to RAM memory notation for the 8086 Intel microprocessor). At START-UP mode, this location is initialised with the address of the **'Stub'** routine which is in PROM. figure j shows an example of software patch. Before to load the software patch, the HASI-S/W allocates a RAM dynamic memory buffer. Then the patch is copied into this buffer and the 'Stub' address is substituted with the new buffer address. **The software patch must begin from the start of this memory buffer.**

8.1.1 EEPROM override capability

This software capability allows to override the EEPROM content. By this procedure at the START-UP, the EEPROM activities are skipped and afterward via TC the content is modified.
It happens that, because a wrong EEPROM content, the HASI behaviour is not corrected or the HASI experiment could be lost. A typical example is when the EEPROM is loaded with a corrupted software patch (even if the parameter CRC is corrected) which induces a software deadlock (e.g. HASI is contiguously reset after RAM loading from EEPROM).
The procedure runs in flight also without hardware modification. It is part of the EEPROM test (refer to 3.1). Before any EEPROM activities, the HASI checks the DDBL presence. In case three consecutive DDBL information show Ground or Flight CHECKOUT flag with the SPIN rate set to hexadecimal value 0xFF (maximum value), the EEPROM content is NOT loaded into RAM. The '**EEPROM LOCKED**' message is recorded into EVENT LOG packet.

The requirement is that **both Probe CDMU** must perform a special Flight/Ground Checkout with the DDBL Spin rate = 0xFF (hexadecimal value) and the DDBL time/altitude set to any place in the mission profile. A recommended solution is to perform the special Checkout after **TdataH** time (i.e. DDBL time greater than T0+2.5 minutes) when the HASI TM packets are not stored in the RAM (refer to 3.6.1). Note that this special Checkout mission may have impacts on the other Probe experiments which use the Spin Rate information. Anyhow the procedure does not require HASI be switched-ON alone.

8.1.2 EEPROM scanning procedure

During the EEPROM test, the EEPROM is scanned in order to search of a valid parameter (refer to **EEPROM Parameter loading** procedure in 3.1). The scanning procedure matches the Header string (refer to section 8.2.1) starting from the first byte of the EEPROM memory. According to the section 8.2.1, the string is constituted by 12 bytes considering the last '\0' character which identifies the end. When a valid Header is found, the UPDATE BLOCK data are extracted taking in consideration the read ParSize value. Then the CRC is calculated and compared with the CRC in the EEPROM. There two cases:

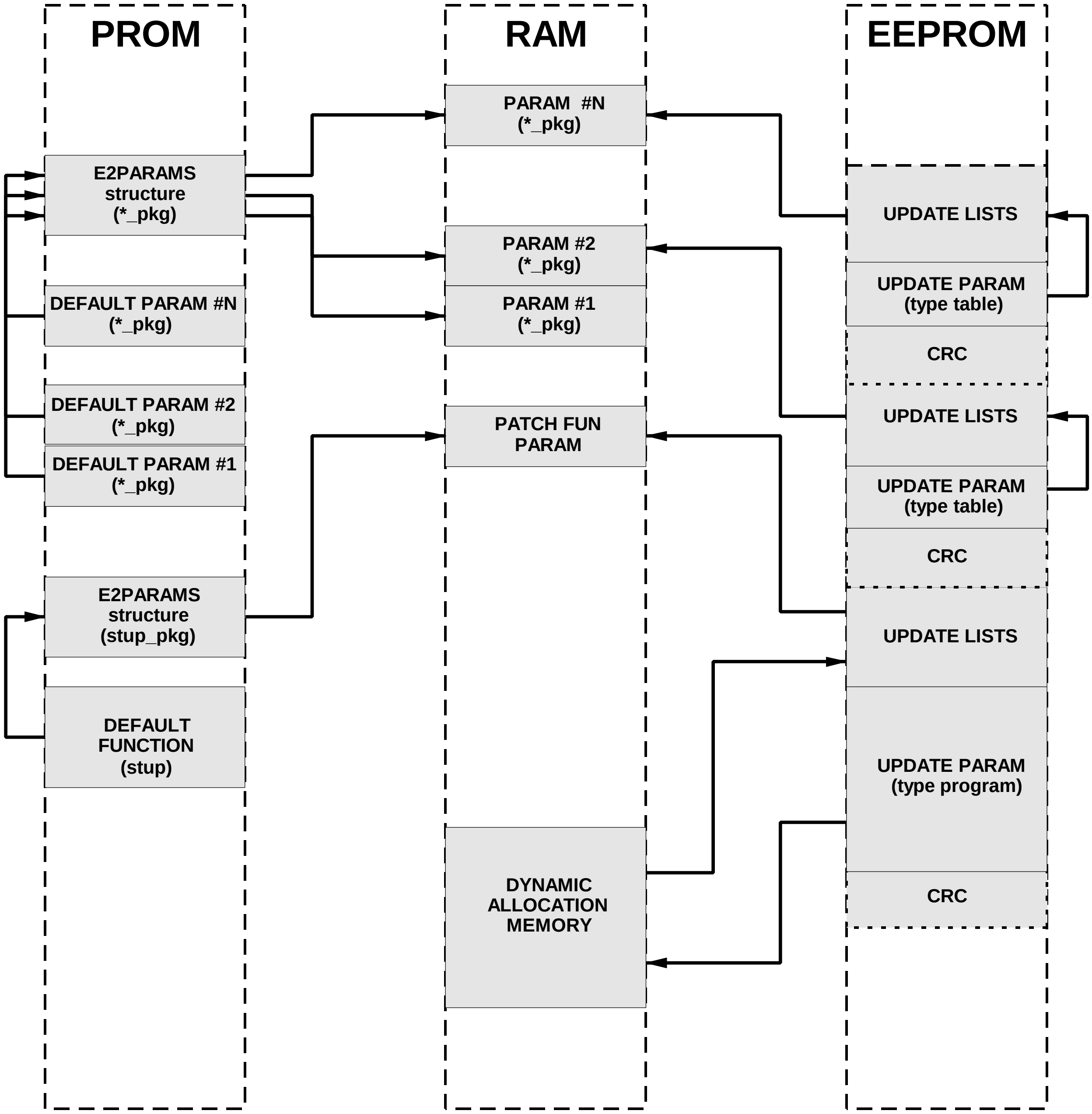
- **CRC is valid**: the parameter (UPDATE BLOCK) is fully extracted and it is loaded in RAM according to the procedure shown in the section 8.1. The scanning restarts from the next byte after the CRC.
- **CRC is not valid**: the data (UPDATE BLOCK) are not meaningful and the new scanning restarts from the following thirteenth byte. In this case the HASI-SW **EEPROM Health Check** bit is set to fail.

The procedure continues till the EEPROM memory end or if an END type parameter (refer to 8.2.1) is found. In both condition a 'PAR-LOAD-REPORT' message is queued on the DPU START-UP packet.

Remark: Operation with long parameter blocks must take care that CRC computation takes about 3 msec par word.

The conclusion is that the Parameters or software patch must be loaded in the EEPROM memory by steps of 12 bytes block. Otherwise it could happen that the parameter is not loaded in RAM even with correct CRC.

Figure J: HASI PARAMETERS UPDATE



8.2 EEPROM parameters loading

8.2.1 UPDATE BLOCK organisation

The parameters in the EEPROM memory (if loaded) are block organised. The **UPDATE BLOCK** is divided three sections:

- UPDATE LIST;
- UPDATE PARAMETER ;
- CRC.

The UPDATE LIST is 22 bytes long and it contains:

- The *Header* which is a fixed string of 12 ascii characters: "**HASI FM 1.0\0"**, where the character '\0' marks the end of the string according to the common C language notation.

- The *ParNumber* (16 bits unsigned integer) which identifies the parameter in the **UPDATE_PAR_REPORT** message in the DPU START-UP packet (refer to); the allowed range is 0 to 32767.

- The ParSize (16 bit unsigned integer) in bytes of the parameter; the allowed range is 1 to 8168.

- The *ParType* (16 bits unsigned integer) that indicates which relevant action will be performed by the HASI-S/W during the EEPROM test:

  - 0 (**NULL**): the parameter is discarded.
  - 1 (**PROG**): the parameter is a 'software patch': a dynamic memory allocation is performed before to load in RAM.
  - 2 (**TABLE**): the parameter is a 'table' and it overrides the RAM when is loaded.
  - 3 (**END**): the **EEPROM parameters loading** (refer to procedure b) stops, even if EEPROM is completely filled.

- the *ParAddress* (4 bytes long: Base:Offset) where the parameter is loaded in RAM.

The UPDATE PARAMETER contains the data of the parameter. **It must contain an even number of bytes**. If the number of bytes is odd, a byte (e.g. 0x0) must be added to the end of the UPDATE PARAMETER. **The added byte shall not be included in the *size***.
The CRC is the cyclic redundancy code and it is word calculated from the header till the end of the UPDATE PARAMETER including the trailer 0x0 value. The algorithm is shown in the AD(1) sect 3.6.3.6.1.1.

8.2.1.1 UPDATE LIST filling rule

The rules to fill each field of the UPDATE LIST and the content of the UPDATE PARAMETER depend on the **data type**. In general, they are the memory dump of the RAM image. The rules are hereafter summarised:

- **byte type** (8 bits): **Most Significant bit** first and then **Less Significant bit** last (for example: the ascii code of the letter 'A' is the hexadecimal 0x31H and therefore the hexadecimal memory dump of the byte is '31').

- **word type** (16 bits): **Less Significant Byte** first and **then Most Significant Byte** (for example if the *size* of the parameter is 10 bytes long ⇒ the unsigned integer is the hexadecimal 0x000AH ⇒ the hexadecimal memory dump of the *size* field is '0A00').

- **address type** (32 bits): **Offset** first and then **Base**; the **Base** and the **Offset** are word type (for example: if the *address* of the parameter is the hexadecimal '0x0040H:0x0A16H', where the '0x0040H' is the RAM Base address and the 0x0A16H is the Offset where is located the parameter ⇒ the hexadecimal memory dump of the *address* field is '160A4000').

- **unsigned long integer** (32 bits): **Less Significant Word** first and **then Most Significant Word** (for example if the value is equal to 18739 ⇒ the unsigned long is the hexadecimal 0x00004933H ⇒ the hexadecimal memory dump of this *long integer* is '33490000').

8.2.2 Parameter loading example

The following example reports a 'TABLE' type parameter. The figure k shows the needed information to fill the input file to the **eep_crc** IWS tool (refer to RD(18)) which calculates the CRC of the UPDATE BLOCK. The input information are contained in an Ascii file (with the extension '**.txt'**) which in the example is shown in the figure l ('***mca.txt***'). The IWS software tool organises the UPDATE BLOCK as expected to be loaded in the EEPROM memory with ML commands and stores it into a new Ascii file (with the extension '**.crc'**). The content of this file is reported in the figure m ('***mca.crc***'). This file is then divided by a new IWS tool in a sequence of Memory Load TCs to perform EEPROM memory loading. The name of this tool is '**tc**' (refer to RD(18)). In the example, only one TC is sufficient to load the ***MCA control register patch*** (refer to figure p). The IWS command file used to create the ML Telecommand from the input file (extension **.txt**) is shown in the figure o. The address where the HASI-S\W will load the TC data into the EEPROM, is an parameter of the **'tc'** command. It **shall be an even address** and it shall be in the range 0xF400H:0x0000H to 0xF400H:0x3FFEH. In the example, the ***MCA control register patch*** is loaded at the beginning of the EEPROM memory (i.e. 0xF400H:0x0000H).

Figure K: MCA control register initialisation input

UPDATE LISTS

Header: 'HASI FM 1.0\0'
ParNumber is 255
ParSize is 4 byte long
ParType is 'TABLE'
ParAddress is 0x0040H:001EH

UPDATE PARAMETER

The parameter contains '00 00 00 00'

When this TABLE parameter is loaded at the RAM address 0x0040H:0x001EH, it initialises to '0' the following location (one byte long):

- **MCA control software register** located to the address 0x0040H:0x001EH;
- **EEPROM software state** located to the next address (i.e. 0x0040H:0x001FH);
- **TEM Current generator HASI-S/W state** located to the next address (i.e. 0x0040H:0x0020H);
- **TEM Mux software state** located to the next address (i.e. 0x0040H:0x0021H).

Figure L: mca.txt file - MCA control register UPDATE BLOCK

```
48 41 53 49 20 46 4D 20 31 2E 30 00   ; Header
FF 00                                 ; ParNumber (0x00FFH)
04 00                                 ; ParSize
02 00                                 ; ParType
1E 00                                 ; ParAddress Offset
40 00                                 ; ParAddress segment
00 00 00 00                           ; Parameter Body (Content)
00 00                                 ; CRC is not calculated yet and
                                      ; therefore it is equal to 0
```

Note that the words after '**;**' are comments and therefore they are discarded by the IWS tool.

Figure M: mca.crc file - MCA patch UPDATE BLOCK

```
0048                    ; Start of UPDATE BLOCK Header
0041
0053
0049
0020
0046
004d
0020
0031
002e
0030
0000                    ; End of UPDATE BLOCK Header
00ff                    ; ParNumber (Low byte)
0000                    ; ParNumber (High byte)
0004                    ; ParSize (Low byte)
0000                    ; ParSize (High byte)
0002                    ; ParType (Low Byte)
0000                    ; ParType (High Byte)
001e                    ; RAM ParAddress Offset (Low Byte)
0000                    ; RAM ParAddress Offset (High Byte)
0040                    ; RAM ParAddress Base (Low Byte)
0000                    ; RAM ParAddress Base (High Byte)
0000                    ; Start of parameter content
0000
0000
0000                    ; End of parameter content
00e2                    ; UPDATE BLOCK CRC (Low byte)
0065                    ; UPDATE BLOCK CRC (High byte)
```

Note that only the **LSByte** (i.e. the right part of each word) is meaningful and it contains the UPDATE BLOCK data. The EEPROM device is connected to the Less Significant Byte of HASI memory. The EEPROM device is byte memory device and its size is 8Kbytes. The µP writes and reads the EEPROM memory at the even address starting from the 0xF4000H (refer to figure n for the HASI memory map). The HASI-S\W reads a word data from the TC content and it writes it in the memory.

Figure N: HASI Memory layout - addresses space

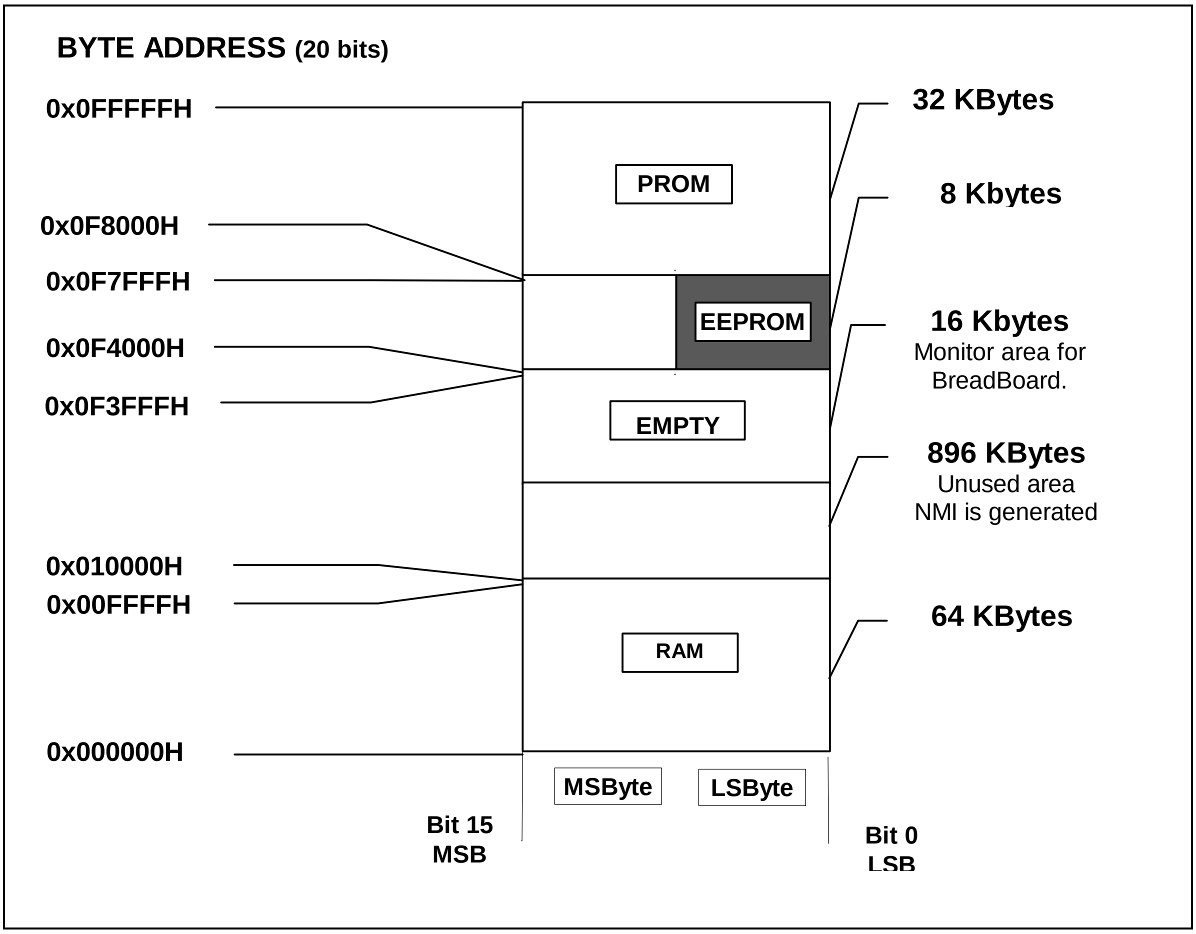


Figure O: mca.com file - VMS command file

```
$ pu
$ del/log *.crc;*
$ del/log *.a;*
$ del/log *.b;*
$ eep_crc mca.txt mca.crc
$ tc 4 f400 0000 mca.crc
$ rename/log TC_0.A mcafm0.a
$ rename/log TC_0.b mcafm0.b
```

1f91	CDMU-A Command header.
0000	Command Sequence Count (it is automatically assigned by the Ground Station).
0077	Command length (it is fixed for HASI).
e204	HASI Command Type: 0xE204H means EEPROM/RAM load memory command.
0000	
f400	Parameter address: Base & Offset; EEPROM Base address is fixed (i.e. 0xf400H) while the Parameter offset changes (in this case is 0x0000H).
001c	Command Word counter (0x1CH means that the command contains 28 words and they will be loaded at the 0xF400H:0x0000H address (i.e. into the EEPROM memory starting from the first location). The other command words will be discarded.
0048	Start of UPDATE BLOCK.
0041	
0053	
0049	
0020	
0046	
004d	
0020	
0031	
002e	
0030	
0000	
00ff	
0000	
0004	
0000	
0002	
0000	
001e	
0000	
0040	
0000	
0000	
0000	
0000	
0000	
00e2	
0065	End of the UPDATE BLOCK.
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	
0000	Command CRC; it is automatically calculated and then updated by the Ground Station.

Figure P mcafm0.a file - Content of the MCA patch Telecommand

8.2.3 END type parameter

Considering the section 8.1.2, at the end of the last meaningful UPDATE BLOCK, it is required to load an **END type** parameter in order to avoid loss of time in START-UP mode. The EEPROM scanning ends up to the END type parameter.
The EEPROM address where the **END type** parameter will be loaded is the first byte address next to CRC of the last meaningful parameter.

The figure q shows the input file to the **eep_crc** IWS tool (refer to RD(18)). The tool output is shown in the file reported in figure r (‘***tc_end.crc***’). This file is then divided by a ‘***tc***’ tool in a sequence of one Memory Load TC to perform EEPROM memory loading. The IWS command file used to create the ML Telecommand from the input file (extension **.crc**) is shown in the figure s. The address where the HASI-S\W will load the data into the EEPROM, is a parameter of the **‘tc’** command. In the example is 0xF400H:0x0000H; it means that the EEPROM will be scanned only to extract the END type parameter.

Note that the **ParAddress** is present but is not meaningful.

```
48          ; H
41          ; A
53          ; S
49          ; I
20          ;
46          ; F
4d          ; M
20          ;
31          ; 1
2e          ; .
30          ; 0
00          ; \0

01 00       ; ParNumber
00 00       ; ParSize
03 00       ; ParType END EEPROM load
0c 00       ; RAM ParAddress it is NOT meaningful since END type
40 00       ; parameter, but it must be present

            ; Parameter body is not present since the ParSize is odd

00 00       ; CRC
```

Figure Q: tc_end.txt - EEPROM END UPDATE BLOCK

```
0048
0041
0053
0049
0020
0046
004d
0020
0031
002e
0030
0000
0001
0000
0000
0000
0003
0000
000c
0000
0040
0000
0078
0038
```

Figure R: tc_end.crc file - EEPROM END UPDATE BLOCK

```
$
$ pu/log
$ del/log tc_end.a;*
$ del/log tc_end.b;*
$ del/log tc_end.crc;*
$
$ eep_crc tc_end.txt tc_end.crc
$
$ tc 4 f400 0000 tc_end.crc
$
$ rename/log  TC_0.A tc_end.a
$ rename/log  TC_0.b tc_end.b
```

Figure S: tc_end.com file - VMS command file

8.2.4 RAM memory map

The HASI has 64Kbytes of RAM memory. The HASI RAM is divided in three main area:

- **Interrupt vector addresses**: from starting address (absolute) of 0 up to 1Kbytes;
- **HASI-S/W static data**: of 4Kbytes;
- **Operating system data**: of 59Kbytes.

The Operating System sub-divides the last area in two data regions:

- **Region 1**: of 15Kbytes. The region is allocated for program stacks and for the Operating System messages (e.g. mail-box). Only 0.6 Kbytes are free in the actual configuration. The Operating System configuration table is also here stored.
- **Region 2**: of 44Kbytes which is used for dynamic data allocation (i.e. TM packet queues, Accelerometers data buffers and Software patch). In the actual HASI-SW configuration the area available for memory patch is 1.79Kbytes long taking into account a maximum number of TM packets (for each TM queue) of 130.

The HASI-S/W memory map corresponding to the actual configuration is reported in **Annex 1**.

8.3 Parameter modifying and loading procedure

The loading of the one parameter (table) in the EEPROM memory is performed through a sequence of at least one ML command (refer to sect. 6.3.3). The procedure is the following:

1. Prepare the following parameter information:
   - **ParSize**: read the data 'SIZE' in the table reported in sect. 8.5;
   - **ParType**: is equal to 2 (i.e. 'TABLE' type, refers also to section 8.2);
   - **ParAddress**: read the data 'ADDRESS' in the table reported in sect. 8.5.
1. Prepare the parameter data changing the default value (i.e. the data 'DEFAULT' as reported in the table of sect. 8.5).
1. Assign to the **ParNumber** the next free number according to the actual software configuration; it is suggested to use an unique number for each parameter.
1. Write into an ascii file, with the extension '**.txt**', all the above information using a common editor; the rules to fill each field in this file are described in the sections 8.2 and 8.2.1.1.
1. Perform an UPDATE BLOCK using the ***eep_crc*** IWS tool (refer to RD(18)) which calculates BLOCK CRC also; the generated file (with an extension **.crc**) contains the UPDATE BLOCK in accordance to the EEPROM format (i.e. only LSByte is meaningful, the MSByte is filled with 0x00).
1. Assign the location of the parameter will be loaded in EEPROM. Remember to follow the rule shows in the section 8.1.2. Anyhow, it must be taken into account the EEPROM configuration at the moment of the loading (e.g. the first free EEPROM address).
1. Divide the already formatted UPDATE BLOCK (file with extension .crc) into a sequence of the Memory Load TC by means of ***tc*** IWS tool providing the EEPROM address (refer to the previous step) and the TC type code (refer to RD(18)). The tool generates two sequences of command file: one for the CDMU-A and the other for the CDMU-B. The tool does not calculate the command CRC (last word in the command files is always 0x0000). **Remark**: each command is a unique TC which includes the EEPROM address where the first command word will be loaded and the number of command word.
1. Send to the HASI experiment the complete TC sequence on both the two CDMU chain using the rules reported in the section 3.4. Each command must be repeated three times on each CDMU. An example of these HASI command rules is reported in the sect. 10.1.2.3.7.

Remark: using the Memory address and number of Word in the ML command, the HASI-S/W writes the TC content to the successive memory locations. Therefore a EEPROM loading or a RAM loading cannot be distinguished by the HASI-S/W. However, to perform a successful completed EEPROM loading it must follow the above rules.

8.4 Software patch generation and loading procedure

A procedure is the following:

1. Design the program code and data according the following rules
   - **<u>Program code</u>**: The program code must be contained into a single module. The use of existing routines and/or variables (refer to Annex 1) is allowed;
   - **<u>Program code starting address</u>**: the program start address must be 'SEGMENT' aligned (i.e. the start address Offset must be the hexadecimal value 0x0000H);
   - **<u>Program data</u>**: the program data must take into account the HASI memory map constraint (e.g. the size of unused RAM memory, the Operating System regions usage and definition, names of existing variables, etc.)
1. Compile the program code and data.
1. Link the obtained object code together with the existing HASI software objects considering that:
   - <u>the new linker's command file must not modify the original object layout</u>.
1. Perform a memory dump of the linked object. This memory dump becomes the UPDATE BLOCK body of the software patch.
1. Prepare the following information:
   - **<u>ParSize</u>**: the 'SIZE' of the Software patch;
   - **<u>ParType</u>**: is equal to 1 (i.e. 'PROG' type, refers also to section 8.2);
   - **<u>ParAddress</u>**: read the 'ADDRESS' in the table reported in sect. 8.5.4.
1. Assign to the **<u>ParNumber</u>** the next free number according to the actual software configuration; it is suggested to use an unique number for each parameter.
1. Write into an ascii file, with the extension '**.txt**', all the above information using a common editor; the rules to fill each field in this file are described in the example reported in the sections 8.2 and 8.2.1.1.
1. Perform an UPDATE BLOCK using the ***eep_crc*** IWS tool (refer to RD(18)) which calculates the Block CRC also; the generated file (with an extension **.crc**) contains the UPDATE BLOCK in accordance to the EEPROM format (only LSByte is meaningful, the MSByte is filled with 0x00).
1. Assign the location of the parameter will be loaded in EEPROM. Remember to follow the rule shows in the section 8.1.2. Anyhow, it must be taken into account the EEPROM configuration at the moment of the loading (e.g. the first free EEPROM address).
1. Divide the already formatted UPDATE BLOCK (file with extension .crc) into a sequence of the Memory Load TC by means of ***tc*** IWS tool providing the EEPROM address (refer to the previous step) and the TC type code (refer to RD(18)). The tool generates two sequences of command file: one for the CDMU-A and the other for the CDMU-B. The tool does not calculate the command CRC (last word in the command files is always 0x0000). **Remark**: each command is a unique TC which includes the EEPROM address where the first command word will be loaded and the number of command word.
1. Send to the HASI experiment the complete TC sequence on both the two CDMU chain using the rules reported in the section 3.4. Each command must be repeated three times on each CDMU. An example of these HASI command rules is reported in the sect. 10.1.2.3.7.

8.5 HASI parameters

8.5.1 PRE parameters

The table pp reports the allowed PRE parameters (refer to section 3.8.1). According to the HASI system tests, the modification of the Normal and Heath Check session table have been already tested. A available patch is also tested during Probe system tests. In the following it is reported the information to change the PREssure parameters.

Tmid: is the HASI Mission Time (HMT) when the HASI change from LOW to MEDIUM NORMAL Session tables (refer to 3.8.1.2). It is expressed in BCP count (1 BCP = 125 msec in HASI NOMINAL while it is 180 msec in case of BCP absence) starting from the T0 transition.

Thigh: is the HASI Mission Time (HMT) when the HASI change from MEDIUM to HIGH NORMAL Session tables (refer to 3.8.1.2). It is expressed in BCP count starting from the T0 transition.

NormSessMap: it stores the three NORMAL Session tables: HIGH (Session **A**), MEDIUM (Session **B**) and LOW (Session **C**) PREssure table (refer to 3.8.1.1.1). Each table contains 36 elements that indicate a sequence of the PPI channels. The physical channels allocation is reported in the table . The corresponding software number (i.e. each table element) is shown in the third column of the same table. The pressure measurements of a session element i and i+1 are performed in couples sharing the Reference channels. This fact restricts the freedom of channel selection: both elements in one pair has to belong to the same block (refer to table f).

HCSessMap: it stores the two HEALTH CHECK Session tables: Session '**G**' and Session '**H**' (refer to 3.8.1.1.2). Each table contains 37 elements that indicate a sequence of the PPI channels. The physical channels allocation is reported in the table f. The corresponding software number (i.e. each table element) is shown in the third column of the same table.

RefChannelMap: it stores the Reference channel number for each PPI physical channel. The table is used to perform the NORMAL Session measure. In-fact in the Normal session table is reported only the elements to be measured without regard to the Reference channel number. The table allows to modify, if necessary, the Reference channel for each physical PPI channel. The Reference channel physical allocation is reported in the table f. The corresponding software number (i.e. each table element) is shown in the third column of the same table.

Table PP: PRE Parameters (part#1)

NAME	TYPE	DATA TYPE	SIZE	ADDRESS	DEFAULT	MEMORY DUMP
Tmid	TABLE	Unsigned long	4	0040:0C26	36000 75 min	E0 C4 00 00

Thigh	TABLE	Unsigned long	4	0040:0C2A	50400 105 min	A0 8C 00 00

Table QQ: PRE Parameters (part#2)

NAME	TYPE	DATA TYPE	SIZE	ADDRESS	DEFAULT	MEMORY DUMP
NormSessMap [3,36] Where: **3** are the type of the PPI Normal sessions. **36** are the numbers of the raw data in each session.	TABLE	Byte	108	0040:0C2E	SESSION **A** 1 8 23 24 3 6 23 24 1 8 23 24 11 9 23 24 1 8 23 24 19 17 23 24 1 8 23 24 15 16 23 24 1 8 23 24 SESSION **B** 15 16 1 8 3 6 1 8 15 16 1 8 11 9 1 8 15 16 1 8 19 17 1 8 15 16 1 8 23 24 1 8 15 16 1 8 SESSION **C** 1 8 15 16 3 6 15 16 1 8 15 16 11 9 15 16 1 8 15 16 19 17 15 16 1 8 15 16 23 24 15 16 1 8 15 16.	00 07 16 17 02 05 16 17 00 07 16 17 0A 08 16 17 00 07 16 17 12 10 16 17 00 07 16 17 0E 0F 16 17 00 07 16 17 0E 0F 00 07 02 05 00 07 0E 0F 00 07 0A 08 00 07 0E 0F 00 07 12 10 00 07 0E 0F 00 07 16 17 00 07 0E 0F 00 07 00 07 0E 0F 02 05 0E 0F 00 07 0E 0F 0A 08 0E 0F 00 07 0E 0F 12 10 0E 0F 00 07 0E 0F 16 17 0E 0F 00 07 0E 0F
HcSessMap [2,37] Where: **2** are the type of the PPI Health Check sessions. **37** are the numbers of the raw data in each session.	TABLE	Byte	74	0040:0C9A	SESSION **G** 5 1 8 2 1 8 5 1 13 15 16 10 15 16 13 15 16 21 23 24 18 23 24 21 23 3 4 6 7 9 11 12 14 17 19 20 22 SESSION **H** 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24.	04 00 07 01 00 07 04 00 0C 0E 0F 09 0E 0F 0C 0E 0F 14 16 17 11 16 17 14 16 02 03 05 06 08 0A 0B 0D 10 12 13 15 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13 14 15 16 17

RefChannelMap [24,2] Where: **24** are the channels number. **2** are reference channel for each channel.	TABLE	Byte	48	0040:0CE4	**1st block** 5 2, 5 2, 5 2, 5 2, 5 2, 5 2, 5 2, 5 2, **2nd block** 13 10,13 10,13 10,13 10 13 10,13 10,13 10,13 10 **3rd Block** 21 18,21 18,21 18,21 18 21 18,21 18,21 18,21 18	04 01 04 01 04 01 04 01 04 01 04 01 04 01 04 01 0C 09 0C 09 0C 09 0C 09 0C 09 0C 09 0C 09 0C 09 14 11 14 11 14 11 14 11 14 11 14 11 14 11 14 11

8.5.1.1 Normal Table Parameter change

The following section describes an example to change the default value of all the Normal Session tables. This patch has been used during the HASI system test in order to perform a checkout for all the PREssure channels.

figure t shows the completed **Normal session** parameter UPDATE BLOCK. The data should be sequentially read line by line from the first to the last word. The ML commands which are needed to load this block into the EEPROM memory are not hereafter reported. figure u lists the content of the VMS command file to generate the needed ML commands.

Figure T: ppins.crc file - NORMAL SESSION UPDATE BLOCK

```
0048 0041 0053 0049 0020 0046 004d 0020 0031 002e 0030
0000 0040 0000 006c 0000 0002 0000 002e 000c 0040 0000      ; UPDATE LIST

0000 0002 0003 0005 0006 0007 0008 000a 000b 000d 000e
000f 0010 0012 0013 0015 0016 0017 0016 0017 0012 0010
0016 0017 0000 0007 0016 0017 000e 000f 0016 0017 0000
0007 0016 0017                                              ; NORMAL SESSION #0

0000 0002 0003 0005 0006 0007 0008 000a 000b 000d 000e
000f 0010 0012 0013 0015 0016 0017 0000 0007 0012 0010
0000 0007 000e 000f 0000 0007 0016 0017 0000 0007 000e
000f 0000 0007                                              ; NORMAL SESSION #1

0000 0002 0003 0005 0006 0007 0008 000a 000b 000d 000e
000f 0010 0012 0013 0015 0016 0017 000e 000f 0012 0010
000e 000f 0000 0007 000e 000f 0016 0017 000e 000f 0000
0007 000e 000f                                              ; NORMAL SESSION #3

0084 0001                                                   ; CRC
```

```
$
$ pu
$ del/log ppinsfm0.a;*
$ del/log ppinsfm0.b;*
$ del/log ppinsfm1.a;*
$ del/log ppinsfm1.b;*
$ del/log ppinsfm2.a;*
$ del/log ppinsfm2.b;*
$ del/log ppi_fm.crc;*
$ eep_crc ppi_fm.txt ppi_fm.crc
$
$ tc 4 f400 0000 ppi_fm.crc
$
$ rename/log  TC_0.A ppinsfm0.a
$ rename/log  TC_0.b ppinsfm0.b
$
$ rename/log  TC_1.A ppinsfm1.a
$ rename/log  TC_1.b ppinsfm1.b
$
$ rename/log  TC_2.A ppinsfm2.a
$ rename/log  TC_2.b ppinsfm2.b
$
```

Figure U: ppins.com - VMS Command File

8.5.2 ACC parameters

The table rr reports the ACC parameters. The meaning is explained in the sect. 3.8.2. During the Software Validation, it has been tested the mechanism to change each parameter, but a full assessment has been not done (e.g. it is not sure to maintain the actual software performance). In the following it is reported the list of useful information that can be used to change the parameters.

TaccSample: it is the HASI Mission Time (HMT) when HASI starts to sample the ACC (both in nominal and backup sub-mode). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the Probe power-On. Because the T0 transition is a separated flag, moving the **TaccSample**, the ACC sampling cannot be switched-ON after T0. It has impacts on the duration of Entry state and thus it increases number of packets stored in the RAM (refer to section 3.6).

TabXservo: it is a vector which contains two values. It defines the two threshold values to select which Xservo channel has to be transmitted in the TM packets. The used method is described in the sect. 3.8.2.1.2. These thresholds are the same for all the HASI mission states. The first value is used to pass from LOW gain to HIGH gain, while the second is used to pass from HIGH gain to LOW gain. Each value is a percentage of the ADC Full Scale and it is expressed in ADC digit. The following formula can be used to calculate each value:
For example if the LOW to HIGH threshold is set to 5% of the ADC Full Scale

ThValue = INT ((2048 * x) / 100)

where **X** is wanted percentage value.
INT is the integer function which truncates the result value

Formula N: Xservo channel selection threshold

(which corresponds at 0.5V having a 10V full scale), the threshold value has to be set to 102. When only one value changes, it must be loaded both the two values.

RangeThr: this defines the threshold value, used by the method described in the sect. 3.8.2.1.1, to change the Xservo range from HIGH to LOW resolution. The value is a percentage of the ADC Full Scale and it is expressed in ADC digit. The formula n is used to calculate the parameter.

ScdsETab:
ScdsDTab:
ScdsRTab: The tables change the Xservo production rate and consequently the HASI data rate belonging the HASI states. The first defines the production rate till DESCENT 1st state, the second till the DESCENT 3rd state and the last for the remaining time of the mission. The first two tables have directly impacts on the HASI TM queues capacity: a higher production rate means more packets stored in the TM queues. Each table is an C language structure with the following layout:

```
Begin
   int                      Npick
   int                      Nsum
   enum DATA_FORMATS        DataFormat
   INTEGDATA *              Data
   FLAGS                    PhaseAllocTable[6]
   int                      OutShift
End.
```

where:

Npick: is the sampling frequency. According to the sect. 3.8.2, the sampling frequency of the raw data base is fixed at 100Hz. The software picks up one sample (from the raw data base) every Npick sample. Therefore the frequency of the Xservo sampling is equal to 100 Hz / Npick. The PROM default value is 1.

Nsum: is the number of sample to be integrated. The parameter establishes the production rate. For example using raw data at 100Hz and assuming an average of 32 samples, the frequency of each data is 3.125 Hz. Therefore, being the number of the data in one TM packet is fixed at 56 for Xservo, the corresponding production rate is 1 packet every 16.64 sec.

DataFormat: is TM packet Data Format (refer to sect. 5.3) where the integrated samples are stored and later transmitted:
for ACC.SCDSE is 32 (decimal value)
for ACC.SCDSD is 33 (decimal value)
for ACC.SCDSR is 34 (decimal value).

Data: is the address at the RAM buffer that contains the current average value and information to perform the integration over the selected period. The buffer has the following C language structure:

```
INTEGDATA is :
   long int            Value
   int                 Counter
   GAIN_SELECTION      BestSel
   int                 Npick
END.
```

The PROM default values are:

Addr_ScdsE 0040:0988
Addr_ScdsD 0040:0992
Addr_ScdsR 0040:099C

PhaseAllocTable: is a table of flags indicate in which HASI states the item is sampled. The table is six bytes length. Each byte records the status **T**' (i.e. true, 0xFF) or '**F**' (i.e. false, 0x00) belonging the HASI states: Entry, Descent 1st, Descent 2nd, Descent 3rd, Impact and Surface.

OutShift: the TM data size is fixed to 16 bits signed integer, the parameter shows the number of required (right) shift to reduce the calculated average to a single signed word. For example, assuming an average of 32 raw data (12 bits signed value each), the obtained data is 17 bits signed integer. One right shift is required to fill it into the TM data size.

ImpactFun: it is the RAM address (Base and Offset) of the anchor for the function used to detect the Probe Impact and then to enter in the Surface state. The default address indicates the HASI-S/W default routine contained into the PROM memory (refer to 3.8.2.4).

QfA
QfB
QfC: these are the coefficients of the LP pass filter of the actual routine which is used in the Impact detection (refer to 3.8.2.4). **QfA**, **QfB** and **QfC** are signed integer numbers which are scaled according the following formula:

QfA = **int (round (value / 32767))** where value is in the range [-1.0 .. +1.0];
QfB = **int (round (value / 32767))** where value is in the range [-1.0 .. +1.0];
QfC = **int (round (value / 32767))** where value is in the range [-1.0 .. +1.0];

each Value represents the filter coefficient in floating point (for example, **QfA** = 0.1 ⇒ **QfA** = 3278)

QfT: is the threshold used to detect the Impact (refer to 3.8.2.4). **QfT** is a signed integer expressed in 16 bits ADC unit. The formula to calculate it from voltage value is the following:

QfT = int ((value * 32767) / 10) where value is expressed in Volt with the range [-10.0 .. +10.0];

the Value represents the threshold in Volts (for example, Value = +5Volt a ⇒ **QfT** = 1024). In order to convert the value in acceleration refers to section 3.8.2.5.

Table RR: ACC Parameters

NAME	TYPE	DATA TYPE	SIZE	ADDRESS	DEFAULT	MEMORY DUMP
TaccSample	TABLE	Unsigned integer	4	0040:0A16	5520 (21.5 min)	50 28 00 00
TabXservo[2]	TABLE	integer	4	0040:0A1A	143 7% of FS 1842 90% of FS	8F 00 32 07
RangeThr	TABLE	integer	2	0040:0A1E	1946	9A 07
ScdsETab	TABLE	DATAPRODTAB(1)	18	0040:0A20	1 32 ACC_SCDSE Addr_ScdsE T, F, F, F, F, F 1	01 00 20 00 20 00 88 09 40 00 FF 00 00 00 00 00 01 00
ScdsDTab	TABLE	DATAPRODTAB(1)	18	0040:0A32	1 24 ACC_SCDSD Addr_ScdsD F, T, T, F, F, F 1	01 00 18 00 21 00 92 09 40 00 00 FF FF 00 00 00 01 00
ScdsRTab	TABLE	DATAPRODTAB(1)	18	0040:0A44	1 57 ACC_SCDSR Addr_ScdsR F, F, F, T, F, T 2	01 00 39 00 22 00 9C 09 40 00 00 00 00 FF 00 FF 02 00
ImpactFun	PROG	far pointer	4	0040:0A56	FCF8:0004 (2)	See note (2)
QfA	TABLE	integer	2	0040:0A5A	3277	CD 0C
QfB	TABLE	integer	2	0040:0A5C	6553	99 19
QfC	TABLE	integer	2	0040:0A5E	22937	99 59
QfT	TABLE	integer	2	0040:0A60	1024	00 04

Note: (1) Refer to information given above.
(2) The default ImpactFun is a routine memorised in the PROM.

8.5.2.1 TaccSample parameter change

The following section describes an example to reload the **TaccSample** parameter with the default value (i.e. 21.5 min). When the Entry duration increases (e.g. **TaccSample** is set early then the default value or the T0 transition is delayed), the number of stored packets increases and therefore reaches the maximum number (i.e. 130 packets). In order to maintain almost constant the packets number, it must decrease the sampling rate of the Xservo (**ScdsETab** ACC parameter, refer to table rr).

The **TaccSample** is expressed in BCP count (i.e. 125msec in case of BCP presence) starting from the Probe power ON. The HASI-S/W considers the **TaccSample** before the T0 transition. In the example the 21.5min is equal to (21.5*60*8) BCP = 10320 BCP count. Since the **TaccSample** parameter is a long integer the new value is 0x00002850H (4bytes long).

Figure V: TaccSample.txt file - TaccSample UPDATE BLOCK

```
48 41  53  49  20  46   4d  20   31  2e  30  00   ; ParHeader
51 00                                             ; ParNumber
04 00                                             ; ParSize
02 00                                             ; ParType
16 0A                                             ; ParAddress offset of ACC  time sampling
40 00                                             ; ParAddress segment
50 28 00 00                                       ; Content  (Default: 21.5 min, New: 21.5 min
                                                  ; 0x00002850H)
00 00                                             ; CRC
```

figure v reports the file **TaccSample.txt** used to calculate the UPDATE BLOCK. The completed **TaccSample** parameter UPDATE BLOCK is shown in the figure w (i.e. **.crc** file). The content of the ML command is not shown.

Figure W: TaccSample.crc file - TaccSample UPDATE BLOCK

```
0048
0041
0053
0049
0020
0046
004d
0020
0031
002e
0030
0000
0051
0000
0004
0000
0002
0000
0016
000a
0040
0000
0050
0028
0000
0000
0089
0097
```

8.5.3 TEM Parameters

The table ss reports the TEM parameters such as the TEM sampling sequence along the Mission states (HMT greater than **Tdata**), the threshold and gradient to change from LOW to HIGH resolution and viceversa.

TemThreshold: it is a vector which indicates the threshold to pass from HIGH gain to LOW gain and viceversa (refer to 3.8.3.1). The first is used to change from LOW gain to HIGH gain, while the second changes channel from HIGH gain to LOW gain. Each entry is a unsigned long integer expressed in K. The default is 105K for **TemThreshold LOW** and 105K for **TemThreshold HIGH**.

TemGrad: it is a vector which indicates the scale factor to calculate the temperature starting from the formula k. When the measure is performed in the LOW gain (refers to section 3.8.3.1), the first parameter converts the RRX value in a temperature expressed in K. Viceversa, the second parameter converts the RRX value in a temperature (expressed in K) when is HIGH gain. Each parameter is unsigned long and is calculated taking into account the following:

TemGradient LOW = (value *256)

TemGradient HIGH = (value *256)

where: **value** is a temperature scale factor expressed in K. The default is 27.3K for **TemGradient LOW** and 7.32K for **TemGradient HIGH**

Note that the scale factor expressed in temperature has been calculated taking into account the different gain and reference resistance in the two analogue channels.

TemSequence: it indicates the sampling sequence of the four TEM sensors from the start of TEM acquisition (i.e. Entry state with HMT greater than **Tdata**) till the end of the mission (i.e. loss of the Probe link to the Orbiter). A complete readout is composed by four sensor readings in 5sec. The table is organised in six lines of 4 bytes. Each line indicates a different HASI state: the Entry state (from **Tdata**), the Descent 1st state, the Descent 2nd state, the Descent 3rd state, the Impact state and the Surface state. Each byte represents the sensor head that will be read during the relevant mission state. Each sensors head is coded by a number: 0 for F1, 1 for C1, 2 for F2 and 3 for C2. In the default, the **TemSequence** table is filled in such a way that the sampling sequence is the same except for the Impact state. During that state, only F1 and F2 and alternatively sampled.

Table SS: TEM parameters

NAME	TYPE	DATA TYPE	SIZE	ADDRESS	DEFAULT	MEMORY DUMP
TemThreshold [2]	TABLE	Unsigned long	8		105 (**TemThreshold LOW**) 105 (**TemThreshold HIGH**)	69 00 00 00 69 00 00 00
TemGrad [2]	TABLE	Unsigned long	8	0040:0BF8	18739 (**TemGradient LOW**) 6988 (**TemGradient HIGH**)	33 49 00 00 4C 1B 00 00
TemSequence [6,4] Where: **6** are the HASI states. **4** is the number of the TEM sensors.	TABLE	Byte	24	0040:0C00	F1 C1 F2 C2, F1 C1 F2 C2, F1 C1 F2 C2, F1 C1 F2 C2, F1 F2 F1 F2, F1 C1 F2 C2.	00 01 02 03 00 01 02 03 00 01 02 03 00 01 02 03 00 02 00 02 00 01 02 03

8.5.3.1 TEM sequence parameter change

The following example changes the default TEM scanning table (**TemSequence**) in order to use (i.e. to read) TEM F1 sensor along the Titan mission (HASI states). The effect is to increase the sampling frequency of TEM from 1 sample every 5sec to 1 sample every 1.25 sec. The other TEM sensors are not sampled and the relevant TM packet types will be not sent.

According to the previous section, the TEM F1 code is ‘0’ and therefore the TEM sequence table is filled with all zeros. figure x reports the ‘**tem.txt**’ input file for the ‘***eep_crc***’ IWS tool. The output file is in figure y.

Figure X: tem.txt file - TemSequence UPDATE BLOCK

```
48 41 53  49 20 46 4d  20  31 2e  30  00   ; ParHeader
30 00                                      ; ParNumber
18 00                                      ; ParSize
02 00                                      ; ParType
00 0c                                      ; ParAddress offset of TEM sequence
                                           Table
40 00                                      ; ParAddress segment
00 00 00 00                                ; TEM sequence table
00 00 00 00
00 00 00 00
00 00 00 00
00 00 00 00
00 00 00 00
00 00                                        ; CRC
```

Figure Y: tem.crc file - TemSequence UPDATE BLOCK

```
0048 0041 0053 0049 0020 0046 004d 0020 0031 002e
0030 0000 0030 0000 0018 0000 0002 0000 0000 000c
0040 0000                                          ; UPDATELIST

0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000                                ; TemSequence

00fa 0073                                          ; CRC
```

8.5.4 General parameters

The table tt reports the HASI general parameters such as the Experiment Timeline and the anchor to load an software memory patch. In the following it is reported the list of useful information that can be used to change the parameters.

Timeline: it contains the major time events that drive the Experiment Timeline in both nominal and backup sub-mode (refer to section 3.2).
The table is an C language structure with the following layout:

```
Begin
   unsigned long    Thasi
   unsigned long    Tdata
   unsigned long    Td1
   unsigned long    Td1w
   unsigned long    Td2
   unsigned long    TdataH
   unsigned long    Tradar
   unsigned long    Predicted T0
   unsigned long    Tproximity
End.
```

where:

Thasi: is the DDBL Time when the HASI should be switched-ON during Titan Descent (refer to the table i). It is used in the HASI-S/W to perform the Time tag of the DPU START-UP packets and all the data and events acquired during START-UP mode. It is expressed in BCP count (1 BCP = 125 msec) from the Probe switch-ON.

Tdata: is the HASI Mission Time (HMT) when the HASI enters in the Descent 1st state in both Nominal and back-up sub-mode (refer to table i and table j). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the T0 transition.

Td1: is the HASI Mission Time (HMT) when starts the window to perform the first attempt of Boom deployment in both Nominal and back-up sub-mode (refer to section 3.2 and 3.7.1). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the T0 transition.

Td1w: is the HASI Mission Time (HMT) of end of the window where the first attempt of Boom deployment can be issued. The parameter is valid for both Nominal and back-up sub-mode (refer to section 3.2 and 3.7.1). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the T0 transition.

Td2: is the HASI Mission Time (HMT) when starts the window to perform the second attempt of Boom deployment in both Nominal and back-up sub-mode (refer to section 3.2 and 3.7.1). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the T0 transition.

TdataH: is the HASI Mission Time (HMT) when the HASI enters in the Descent 2nd state in both Nominal and back-up sub-mode (refer to table i and table j). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the T0 transition.

Tradar: is the HASI Mission Time (HMT) when the HASI enters in the Descent 3rd state in both Nominal and back-up sub-mode (refer to section 3.2). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the T0 transition.

Predicted T0: is the HASI Mission Time (HMT) when the HASI recognises the T0 transition in Back-up sub-mode (refer to section 3.2). it is not used in Nominal mode. It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the Probe power-ON.

Tproximity: is the HASI Mission Time (HMT) when the HASI enters in the Impact state in back-up sub-mode (refer to section 3.2). It is expressed in BCP count (1 BCP = 125 msec or 180 msec if BCP is absent) starting from the T0 transition.

PatchFun: it is the RAM address (Base and Offset) of the anchor for the software patch. The default address indicates the HASI-S/W default routine contained into the PROM memory.

Table TT: HASI Parameters

NAME	TYPE	DATA TYPE	SIZE	ADDRESS	DEFAULT	MEMORY DUMP
Timeline	TABLE	Unsigned long	36	0040:04F6	8528 1066 sec (**Thasi**) 480 60 sec (**Tdata**) 480 60 sec (**Td1**) 800 100 sec (**Td1w**) 1120 140 sec (**Td2**) 1200 150 sec (**TdataH**) 15360 32 min (**Tradar**) 13440 28 min (**Predicted-T0**) 57129 119 min (**Tproximity**)	50 21 00 00 E0 01 00 00 E0 01 00 00 20 03 00 00 60 04 00 00 B0 04 00 00 00 3C 00 00 80 34 00 00 20 DF 00 00
PatchFun	PROG	Far pointer	4	0040:000C	F843:0002 (Stub function in PROM)	(see note #2)

8.5.4.1 Example of Timeline parameter change

The following section describes an example to change the default value of **Thasi** time (from 17 min and 46 sec to 18 min). Since is part of the **Timeline** table, it must be re-loaded the complete table.

The **Thasi** is expressed in BCP count (i.e. 125msec) starting from the Probe power ON. The HASI-S/W considers the **Thasi** before the T0 transition. In the example the 18min is equal to (18*60*8) BCP = 8640 BCP count. Since **Thasi** is a long integer the new value is 0x000021C0H (4bytes long).

Figure Z: *time.txt* file - Timeline UDATE BLOCK

48 41 53 49 20 46 4d 20 31 2e 30 00	; ParHeader		
50 00	; ParNumber		
24 00	; ParSize		
02 00	; ParType		
f6 04	; ParAddress offset of Timeline Table		
40 00	; ParAddress segment		
C0 21 00 00	; Thasi	(Default: 18 min,	New: 18 min 0x000021C0)
E0 01 00 00	; Tdata	(Default: 60 sec,	New: 60 sec 0x000001E0)
E0 01 00 00	; Td1	(Default: 60 sec,	New: 60 sec 0x000001E0)
20 03 00 00	; Td1w	(Default: 100 sec,	New: 100 sec 0x00000320)
60 04 00 00	; Td2	(Default: 140 sec,	New: 140 sec 0x00000460)
B0 04 00 00	; TdataH	(Default: 150 sec,	New: 150 sec 0x000004B0)
00 3C 00 00	; Tradar	(Default: 32 min,	New: 32 min 0x00003C00)
80 34 00 00	; Predicted-T0	(Default: 18 min,	New: 28 min 0x00003480)
20 DF 00 00	; Tproximity	(Default: 119 min,	New: 119 min 0x0000DF20)
00 00	; CRC		

Figure AA: *time.crc* file - Timeline UPDATE BLOCK

0048	0041	0053	0049	0020	0046	004d	0020	0031	002e
0030	0000	0050	0000	0024	0000	0002	0000	00f6	0004
0040	0000	00c0	0021	0000	0000	00e0	0001	0000	0000
00e0	0001	0000	0000	0020	0003	0000	0000	0060	0004
0000	0000	00b0	0004	0000	0000	0000	003c	0000	0000
0080	0034	0000	0000	0020	00df	0000	0000	00cb	003d

Note that the **time.crc** (refer to figure aa) file has been compressed, the UPDATE BLOCK words are read line by line from the first word to the last word in each line.

9 NOT FLIGHT ITEM LIST

The list of 'Remove Before Flight' items and their location is the following section. Each items refers to the relevant removal instruction (if any) written in this User Manual document.

9.1 STUB sub-system

Item 1: - Kiel Probe assembly RED COVER;
Item 2: - TEM 1 RED COVER (refer to 7.2.4);
Item 3: - TEM 2 RED COVER (refer to 7.2.4).

9.2 DBS sub-system

Item 4: - DBS 1 RED COVER;
Item 5: - DBS 1 GROUNDING Wires (refer to 7.2.5);
Item 6: - DBS 1 RED TAPE FLAG on RELaxation Probe;

Item 7: - DBS 2 RED COVER;
Item 8: - DBS 2 GROUNDING Wires(refer to 7.2.5);
Item 9: - DBS 2 RED TAPE FLAG on RELaxation Probe.

10 ESOC OPERATION INPUT

Refer to the sect 4 of the HASI User Manual for the Status Word Bits (HASI-SW) description and evolution. In the following sections are reported the Procedure Inputs to ESOC Verification Test.

10.1 TEST PROCEDURE INPUT

The HASI behaviour (in Flight Configuration) and the relevant Status Word (HASI-SW) evolution is checked performing a Simulated Descent. The Telecommands (TCs) are required only for special investigation or memory patches.

The procedures verify the HASI-SW content respect to the expected cases. Unfortunately additional HASI internal and/or external conditions can modify the expected ones. These new HASI-SW content may be nominal and only a later HASI-SW check (i.e. not performed in real time) will provide the explanation. The test scenario (e.g. un-expected delay time between the TC reception and the SW check) may introduce further problems that are not taken into account in the following procedures.

10.1.1 Cruise Check-out #1 and #2 Mission simulation

10.1.1.1 Purpose

The aim of the test is to check the HASI in Flight Configuration and the relevant Status Word (HASI-SW) evolution. In both the two mission scenario (#1 and #2) according to the ESA fax (PY/2.0/MV/6252/sp dated 30 Sep. 96), HASI is powered ON at T0-5' and it is switched-OFF at T0+140'. The most important functions will be fully tested, except for the BOOM opening. The simulated mission goes through all the HASI states (Entry, Descent and Impact). The HASI SURFACE state will be not reached due to the Probe configuration.

10.1.1.2 Set-up

The Probe (i.e. the Experiment platform) must be in Vertical Position with +Yaxis vertical respect to the clean room floor; the Experiment platform vertical position has to be measured with a precision better then 1°. All HASI RED not flight items must be removed following the relevant instruction. It is also required to measure the temperature and pressure of the clean room with a precision of the standard clean room instrumentation.

10.1.1.3 Test Procedure

1. After HASI Power-ON (T0-5'), check the HASI-SW A and B against the following value
   0xFFFFH HASI is powered OFF.
   0x0H HASI is powered ON.
   0x8000H HASI START-UP mode.
   0xFE54 HASI START-UP mode is successfully finished and the Entry state is entered.

2. Wait for 1' and then check the HASI-SW A and B against the value 0xFE54 (Entry state).

3. Check the HASI power Consumption (≤13W) and the BOOM micro-switches status (closed, i.e. in launch position).

4. Wait for DDBL time reaches (T0+2') and then check the HASI-SW A and B against the value 0xFE55H (Descent state).

5. Check the HASI power Consumption (≤17W) and the BOOM micro-switches status (closed, i.e. in launch position).

6. Wait for DDBL altitude reaches the **last Km** and control that the HASI-SW A and B do not change value.

7. Check the HASI power Consumption (≤17W) and the BOOM micro-switches status (closed, i.e. in launch position).

8. Wait for 32'' and then check the HASI-SW A and B against the following value 0xFE56H (Impact state).

9. Control the HASI-SW A and B do not change till the HASI Power OFF.

10.1.2 HASI command test

10.1.2.1 Purpose

The aim of the test is to simulate a special troubleshooting of the HASI experiment during Cruise checkout. Four different failure cases have been supposed: a ML-TM failure, a RAM investigation, a PWA problem on ACU sensor and a PPI sensor failure. Then it has been prepared four procedures using each a different command sequence. Unfortunately the used commands were designed to perform on Ground investigation and therefore the real troubleshooting will require new TC (or sequences) to be created. Moreover an example of software patch is used to check the HASI in flight software maintenance. During all the tests the HASI Status Word (HASI-SW) is also verified. The following procedure are performed in sequence:

- **HASI ML and TM behaviour test:** sending the TC which sets the HASI-SW bit 5, it is possible to check at the same time the HASI-SW, ML and TM interfaces;
- **Memory Dump HASI capability test** sending a Memory Dump TC and waiting for the Memory Dump TM packets;
- **PWA special investigation on ACU sensor** sending a PWA test mode 1 and verifying the TM content;
- **PPI Normal table modification test**: loading a sequence of three TCs in the EEPROM it is possible, after a successive HASI START-UP (performed via a reset TC), to modify the PPI scanning table pertaining to the Normal Session;
- **HASI software patch capability**: loading a sequence of three TCs in the EEPROM it is possible, after a successive HASI START-UP (performed via a reset TC), to execute a software task which creates a message which is sent via the EVENT LOG TM packet;
- **EEPROM content reset test**.

10.1.2.2 Set-up

The Probe must be set in **FLIGHT CHECKOUT** mode with **TIME RUNNING** in the range T0+3’ up to T0+130’. Note that the start time can be done at any time in the above range, but it must remain sufficient time to complete the command sequences. Both CDMU A and B must be **SWITCHED-ON** and they must show the **same DDBL content** (i.e. CDMU-B channel is redundant of the CDMU-A channel).
All the HASI **Red Cover** must be removed according to the relevant instruction. The HASI Red cover are listed in the section 9 of the HASI User Manual.
HASI requires to know the Probe environment (i.e. Clean Room Temperature and Pressure, Experiment Platform orientation) with a precision of the standard clean room instrumentation.

10.1.2.3 Test procedure

REMARK: The **bold text line** (i.e. the relevant procedure step) are the instruction for the ESOC procedure, while the others are the input to fill the command sequence (i.e. HIR file) that will be supplied together.

10.1.2.3.1 HASI Power On

1. **Power-ON HASI.**

2. **After HASI Power-ON, the HASI-SW A and B can have the following sequence 0x0H and then 0x8000H. They may be set to 0x8000H only.**

3. **Check the HASI power consumption (£13W) and the BOOM micro-switches status (Closed, i.e. launch position).**

4. **Wait for 4’ before to check the HASI-SW A and B against the value 0xFE55H (if CDMU-A is selected by HASI) or 0xFED5H (if CDMU-B is selected by HASI).**

10.1.2.3.2 HASI ML-TM investigation

1. **Start the command sequence. Call T_{start} the start of the HIR command file.**

2. Wait for T_{start}.

3. Send to HASI through the CDMU-A ML line the 'HASI_TEST_MODE1_A.BIN' and through the CDMU-B ML line the 'HASI_TEST_MODE1_B.BIN'. This command sets the HASI-SW bit 5.

4. Wait for T_{start}+19'' and repeat step 3.

5. Wait for T_{start}+17'' and repeat step 3. The command has been sent three times.

6. **Wait for (T_{start} +2') before to check the HASI-SW A and B against the following values:**
   case 1: Last TC correctly received
   0xFE75H or 0xFEF5H.
   This means the last TC has been successfully received and executed.

   case 2: Last TC wrongly received, but at least one TC was successfully executed
   0xFE35H or 0xFEB5H.
   This means the last TC has been wrongly received, but at least one of the two other commands was successfully executed.

   case 3: All three TCs wrongly received
   0xFE15H or 0xFE95H.
   This means the three TCs have been wrongly received.

7. Wait for T_{start}+3'.

8. Send to HASI through the CDMU-A ML line the '*HASI_TEST_MODE0_A.BIN*' and through the CDMU-B ML line the '*HASI_TEST_MODE0_B.BIN*'. This command resets the HASI-SW bit.

9. Wait for (T_{start} +3':19'') and repeat step 8.

10. Wait for (T_{start} +3':36'') and repeat step 8. The command has been sent three times.

11. **Wait for (T_{start} +5') before to check the HASI-SW A and B against the following values:**
    case 1: Last TC correctly received
    0xFE75H or 0xFEF5H.
    This means the last TC has been successfully received and executed.

    case 2: Last TC wrongly received, but at least one TC was successfully executed
    0xFE35H or 0xFEB5H.
    This means the last TC has been wrongly received, but at least one of the two other commands was successfully executed.

    case 3: All three TCs wrongly received
    0xFE15H or 0xFE95H.
    This means the three TCs have been wrongly received.

10.1.2.3.3 HASI Memory Dump capability

1. Wait for (T_{start} +6’).

2. Send to HASI through the CDMU-A ML line the ‘*HASI_FM_MEM_DUMP_A.BIN*’ and through the CDMU-B ML line the ‘*HASI_FM_MEM_DUMP_B.BIN*’. This command performs a Memory Dump of the HASI memory.

3. **Wait for (T_{start} +6’:32’’) before to check the HASI-SW A and B against the following values:**

   <u>case 1</u>: Last TC correctly received
   0xFE75H or 0xFEF5H.
   This means the last TC has been successfully received and executed.

   <u>case 2</u>: Last TC wrongly received, but at least one TC was successfully executed
   0xFE35H or 0xFEB5H.
   This means the last TC has been wrongly received, but at least one of the two other commands was successfully executed.

   <u>case 3</u>: All three TCs wrongly received
   0xFE15H or 0xFE95H.
   This means the three TCs have been wrongly received.

4. **Wait for (T_{start} +10’) before to check the HASI-SW A and B against the following values:**

   <u>case 1</u>: *Last TC correctly received*
   0xFE55H or 0xFED5H.
   The last TC has been successfully received and executed.

   <u>case 2</u>: *Last TC wrongly received*
   0xFE15H or 0xFE95H.
   The last TC has been wrongly received.

10.1.2.3.4 HASI PWA special investigation

1. Wait for (T_{start} +11’).

2. Send to HASI through the CDMU-A ML line the ‘*HASI_TEST_PWA1_A.BIN’* and through the CDMU-B ML line the ‘*HASI_TEST_PWA1_B.BIN’*. This command verifies the PWA Acoustic sensor.

3. Wait for (T_{start} +11’:19’’) and repeat step 2.

4. Wait for (T_{start} +11’:36’’) and repeat step 2. The command has been sent three times.

5. **Wait for (T_{start} +12’) before to check the HASI-SW A and B against the following values:**

   case 1: ***Last TC correctly received***
   0xFE55H or 0xFED5H.
   The last TC has been successfully received.

   case 2: ***Last TC wrongly received***
   0xFE15H or 0xFE95H.
   The last TC has been wrongly received.

6. Wait for (T_{start} +15’:32’’).

7. Send to HASI through the CDMU-A ML line the ‘*HASI_TEST_PWA0_A.BIN’* and through the CDMU-B ML line the ‘*HASI_TEST_PWA0_B.BIN’*. This command resets the PWA to Science Mode.

8. Wait for (T_{start} +15’:51’’) and repeat step 7.

9. Wait for (T_{start} +16’:08’’) and repeat step 7. The command has been sent three times.

10. **Wait for (T_{start} +18’) before to check the HASI-SW A and B against the following values:**

    case 1: ***Last TC correctly received***
    0xFE55H or 0xFED5H.
    The last TC has been successfully received.

    case 2: ***Last TC wrongly received***
    0xFE15H or 0xFE95H.
    The last TC has been wrongly received.

10.1.2.3.5 PPI Normal session table modification

1. Wait for (T_{start} +20’).
2. Send to HASI through the CDMU-A ML line the ‘*HASI_FM_PA_PPINS0_A.BIN’* and through the CDMU-B ML line the ‘*HASI_FM_PA_PPINS0_B.BIN’*. This command loads in the EEPROM memory the first part of the PPI Normal table patch created to modify the PPI scanning sequence.
3. Wait for (T_{start} +20’:19’’) and repeat step 2.
4. Wait for (T_{start} +20’:36’’) and repeat step 2. The command has been sent three times.
5. **Wait for (T_{start} +21’) before to check the HASI-SW A and B against the following values:**

   <u>case 1</u>: ***Last TC correctly received***
   0xFE55H or 0xFED5H.
   The last TC has been successfully received.

   <u>case 2</u>: ***Last TC wrongly received***
   0xFE15H or 0xFE95H.
   The last TC has been wrongly received.

6. Wait for (T_{start} +21’:10’’).
7. Send to HASI through the CDMU-A ML line the ‘*HASI_FM_PA_PPINS1_A.BIN’* and through the CDMU-B ML line the ‘*HASI_FM_PA_PPINS1_B.BIN’*. This command loads in the EEPROM memory the second part of the PPI Normal table patch created to modify the PPI scanning sequence.
8. Wait for (T_{start} +21’:29’’) and repeat step 6.
9. Wait for (T_{start} +21’:46’’) and repeat step 6. The command has been sent three times.
10. **Wait for (T_{start} +22’:20’’) before to check the HASI-SW A and B against the following values:**

   <u>case 1</u>: ***Last TC correctly received***
   0xFE55H or 0xFED5H.
   The last TC has been successfully received.

   <u>case 2</u>: ***Last TC wrongly received***
   0xFE15H or 0xFE95H.
   The last TC has been wrongly received.

11. Wait for (T_{start} +22’:30’’).
12. Send to HASI through the CDMU-A ML line the ‘*HASI_FM_PA_PPINS2_A.BIN’* and through the CDMU-B ML line the ‘*HASI_FM_PA_PPINS2_B.BIN’*. This command loads in the EEPROM memory the third part of the PPI Normal table patch created to modify the PPI scanning sequence.

13.Wait for (T_{start} +22':49'') and repeat step 11.

14.Wait for (T_{start} +23':06'') and repeat step 11. The command has been sent three times.

15.Wait for (T_{start} +24':00'') before to check the HASI-SW A and B against the following values:

case 1: ***Last TC correctly received***
0xFE55H or 0xFED5H.
The last TC has been successfully received.

case 2: ***Last TC wrongly received***
0xFE15H or 0xFE95H.
The last TC has been wrongly received.

10.1.2.3.6 PPI table patch verification

Now the EEPROM content is verified via 'Soft Reset' command.

1. Wait for (T_{start} +25':00'').

2. Send to HASI through the CDMU-A ML line the *'HASI_SOFT_RESET_A.BIN'* and through the CDMU-B ML line the *'HASI_SOFT_RESET_B.BIN'*.

3. **Wait (T_{start} +27':00'') before to check the HASI-SW A and B against the value 0xFE55H or 0xFED5H. The HASI has executed a new START-UP and the EEPROM has been loaded.**

10.1.2.3.7 HASI Memory patch loading

1. Wait for (T_{start} +35':00'').

2. Send to HASI through the CDMU-A ML line the '*HASI_FM_PA_EV0_A.BIN'* and through the CDMU-B ML line the '*HASI_FM_PA_EV0_B.BIN'*. This command loads in the EEPROM memory the first part of the patch created to check the HASI software patching.

3. Wait for (T_{start} +35':19'') and repeat step 2.

4. Wait for (T_{start} +35':36'') and repeat step 2. The command has been sent three times.

5. **Wait for (T_{start} +37':00'') before to check the HASI-SW A and B against the following values:**

   <u>case 1</u>: *Last TC correctly received*
   0xFE55H or 0xFED5H.
   The last TC has been successfully received.

   <u>case 2</u>: *Last TC wrongly received*
   0xFE15H or 0xFE95H.
   The last TC has been wrongly received.

6. Wait for (T_{start} +37':20'').

7. Send to HASI through the CDMU-A ML line the '*HASI_FM_PA_EV1_A.BIN'* and through the CDMU-B ML line the '*HASI_FM_PA_EV1_B.BIN'*. This command loads in the EEPROM memory the second part of the patch created to check the HASI software patching.

8. Wait for (T_{start} +37':39'') and repeat step 7.

9. Wait for (T_{start} +37':56'') and repeat step 7. The command has been sent three times.

10. **Wait for (T_{start} +38':30'') before to check the HASI-SW A and B against the following values:**

    <u>case 1</u>: *Last TC correctly received*
    0xFE55H or 0xFED5H.
    The last TC has been successfully received.

    <u>case 2</u>: *Last TC wrongly received*
    0xFE15H or 0xFE95H.
    The last TC has been wrongly received.

11. Wait for (T_{start} +39':00'').

12. Send to HASI through the CDMU-A ML line the '*HASI_FM_PA_EV2_A.BIN'* and through the CDMU-B ML line the '*HASI_FM_PA_EV2_B.BIN'*. This command loads in the EEPROM memory the last part of the patch created to check the HASI software patching.

13. Wait for (T_{start} +39':19'') and repeat step 12.

14. Wait for (T_{start} +39':36'') and repeat step 12. The command has been sent three times.

15.Wait for (T_{start} +41':00'') before to check the HASI-SW A and B against the following values:

<u>case 1</u>: *Last TC correctly received*
0xFE55H or 0xFED5H.
The last TC has been successfully received.

<u>case 2</u>: *Last TC wrongly received*
0xFE15H or 0xFE95H.
The last TC has been wrongly received.

10.1.2.3.8 Software patch verification

Now the EEPROM content is verified via 'Soft Reset' command.

1. Wait for (T_{start} +41':00'').
2. Send to HASI through the CDMU-A ML line the *'HASI_SOFT_RESET_A.BIN'* and through the CDMU-B ML line the *'HASI_SOFT_RESET_B.BIN'*.
3. **Wait (T_{start} +44':00'') before to check the HASI-SW A and B against the value 0xFE55H or 0xFED5H. The HASI has executed a new START-UP and the EEPROM has been loaded.**

10.1.2.3.9 EEPROM reset

1. Wait for (T_{start} +50':00'').
2. Send to HASI through the CDMU-A ML line the '*HASI_FM_PA_RST_A.BIN*' and through the CDMU-B ML line the '*HASI_FM_PA_RST_B.BIN*'. This command overrides the EEPROM content.
3. Wait for (T_{start} +50':19'') and repeat step 2.
4. Wait for (T_{start} +50':36'') and repeat step 2. The command has been sent three times.
5. **Wait for (T_{start} +52':00'') before to check the HASI-SW A and B against the following values:**

   case 1: *Last TC correctly received*
   0xFE55H or 0xFED5H.
   The last TC has been successfully received.

   case 2: *Last TC wrongly received*
   0xFE15H or 0xFE95H.
   The last TC has been wrongly received.

10.1.2.3.10 HASI power OFF

1. **Wait for (T_{start} +54':00'') and then send trough CDMS the 'Deactivation flag'.**
2. **Wait for (T_{start} +55':00'') and then perform HASI Power-OFF.**

10.1.3 HASI EEPROM Override capability

10.1.3.1 Purpose

The aim of the test is to check the HASI in Flight EEPROM Override capability: the EEPROM content is not loaded and consequently a TC sequence can be uploaded to EEPROM override. During the test is monitored the Status Word (HASI-SW) evolution. The test is divided in two parts: the first (executed before T0) which resets the EEPROM content (refer to 10.1.3.3.2) and the second (executed after T0) which re-loads the EEPROM (refer to 10.1.3.3.3). The EEPROM content is re-loaded with an TCs sequence. The TC sequence is composed by 5 TCs. Each TC is repeated three times. The sequence simulates a 250 bytes long memory patch. In the test procedure, the sequence is composed by the same TC. The command name is *'HASI_FM_MCARST_A/B.BIN'* (where A/B it means CDMU-A and B). At START-UP, the command initialises the MCA control register. The HASI EEPROM configuration at the end of the test is checked (refer to 10.1.3.3.5) respect to the expected one: the EEPROM must contain the MCA Memory Patch to initialise the MCA control register. The test could be a reference for in flight special checkout test.

10.1.3.2 Set-up

The Probe must be set in **FLIGHT CHECKOUT** mode with **TIME RUNNING** and the SPIN RATE =0xFFH. Both CDMU A and B must be **SWITCHED-ON** and they must show the **same DDBL content** (i.e. CDMU-B channel is redundant of CDMU-A channel). The HASI shall be powered according to the input given in the procedure.
All the HASI **Red Cover** must be removed following the relevant instruction. The HASI Red cover are listed in the section 9 of the HASI User Manual.

10.1.3.3 Test procedure

REMARK: The **bold text line** (i.e. the relevant procedure step) are the instruction for the ESOC procedure, while the others are the input to fill the command sequence (i.e. HIR file) that will be supplied together.

10.1.3.3.1 HASI Power On

1. **Power-ON HASI at 5' Pre-T0 (DDBL time).**

2. **After HASI Power-ON, the HASI-SW A and B can have the following sequence 0x0H and then 0x8000H. They may be set to 0x8000H only.**

3. **Check the HASI power consumption (£13W) and the BOOM micro-switches status (Closed, i.e. in launch position).**

4. **Wait for 3' before to check the HASI-SW A and B against the value 0xFE54H (if CDMU-A is selected by HASI) or 0xFED4H (if CDMU-B is selected by HASI).**

10.1.3.3.2 EEPROM reset

1. **Start the command sequence. Call T_h the start of the HIR command file.**
2. Send to HASI through the CDMU-A ML line the '*HASI_FM_PA_RST_A.BIN*' and through the CDMU-B ML line the '*HASI_FM_PA_RST_B.BIN*'. This command overrides the EEPROM content.
3. Wait for (T_h +00':19'') and repeat step 2.
4. Wait for (T_h +00':36'') and repeat step 2. The command has been sent three times.
5. **Wait for (T_h +01':00'') before to check the HASI-SW A and B against the following values:**

<u>case 1</u>: ***Last TC correctly received***
0xFE54H or 0xFED4H.
The last TC has been successfully received.

<u>case 2</u>: ***Last TC wrongly received***
0xFE14H or 0xFE94H.
The last TC has been wrongly received.

10.1.3.3.3 Time Resume after T0

1. **Wait for T0 transition.**
2. **Wait for (T0+2':00'') before to check the HASI-SW A and B against the following values:**

<u>case 1</u>: ***Last TC correctly received***
0xFE55H or 0xFED5H.
The last TC has been successfully received.

<u>case 2</u>: ***Last TC wrongly received***
0xFE15H or 0xFE95H.
The last TC has been wrongly received.

10.1.3.3.4 EEPROM re-loading

1. **Start the command sequence. Call T_{e2} the start of the HIR command file.**

2. Send to HASI through the CDMU-A ML line the *'HASI_FM_MCARST_A.BIN'* and through the CDMU-B ML line the *'HASI_FM_MCARST_B.BIN'*.

3. **Wait for (T_{e2} +00':32'') before to check the HASI-SW A and B against the following values:**

   case 1: *TC correctly received*
   0xFE5DH or 0xFEDDH.
   The TC has been successfully received and is in execution.

   case 2: TC correctly received and PWA time-out
   0xEE5DH or 0xEEDDH.

   The TC has been successfully received and is in execution. During TC execution mode the PWA link may be Not OK (i.e. PWA task is stopped).
   case 3: *TC wrongly received*
   0xFE15H or 0xFE95H.
   The TC has been wrongly received.

   case 4: *TC wrongly received and in HASI in Back-up sub-mode*
   0xFE11H or 0xFE91H.
   The TC has been wrongly received and HASI changed to Back-up sub-mode.

4. Wait for (T_{e2} +00':41'') and repeat step 2.

5. **Wait for (T_{e2} +01':00'') before to check the HASI-SW A and B against the following values:**

   case 1: *TC correctly received*
   0xFE5DH or 0xFEDDH.
   The TC has been successfully received and is in execution.

   case 2: TC correctly received and PWA time-out
   0xEE5DH or 0xEEDDH.
   The TC has been successfully received and is in execution. During TC execution mode the PWA link may be Not OK (i.e. PWA task is stopped).
   case 3: *TC wrongly received*
   0xFE15H or 0xFE95H.
   The TC has been wrongly received.

   case 4: *TC wrongly received and in HASI in Back-up sub-mode*
   0xFE11H or 0xFE91H.
   The TC has been wrongly received and HASI changed to Back-up sub-mode.

6. Wait for (T_{e2} +01':00'') and repeat step 2. . Note the TC has been sent three times on both CDMU channels.

7. **Wait for (T_{e2} +01':32'') before to check the HASI-SW A and B against the following values:**

   case 1: *TC correctly received*

0xFE5DH or 0xFEDDH.
The TC has been successfully received and is in execution.

case 2: **TC correctly received and PWA time-out**
0xEE5DH or 0xEEDDH.
The TC has been successfully received and is in execution. During TC execution mode the PWA link may be Not OK (i.e. PWA task is stopped).

case 3: ***TC wrongly received***
0xFE15H or 0xFE95H.
The TC has been wrongly received.

case 4: ***TC wrongly received and in HASI in Back-up sub-mode***
0xFE11H or 0xFE91H.
The TC has been wrongly received and HASI changed to Back-up sub-mode.

8. Wait for (T_{e2} +02':00'').

9. Send to HASI through the CDMU-A ML line the *'HASI_FM_MCARST_A.BIN'* and through the CDMU-B ML line the *'HASI_FM_MCARST_B.BIN'*.

10. Wait for (T_{e2} + 02':17'') and repeat step 9.

11. Wait for (T_{e2} + 02':36'') and repeat step 9. The command has been sent three times.

12. Wait for (T_{e2} + 03':00'') before to check the HASI-SW A and B against the following values:

case 1: ***Last TC correctly received***
0xFE55H or 0xFED5H.
The last TC has been successfully received.

case 2: ***Last TC wrongly received***
0xFE15H or 0xFE95H.
The last TC has been wrongly received.

13. Wait for (T_{e2} +03':00'').

14. Send to HASI through the CDMU-A ML line the *'HASI_FM_MCARST_A.BIN'* and through the CDMU-B ML line the *'HASI_FM_MCARST_B.BIN'*.

15. Wait for (T_{e2} + 03':17'') and repeat step 14.

16. Wait for (T_{e2} + 03':36'') and repeat step 14. The command has been sent three times.

17. Wait for (T_{e2} + 04':00'') before to check the HASI-SW A and B against the following values:

case 1: ***Last TC correctly received***
0xFE55H or 0xFED5H.
The last TC has been successfully received.

case 2: ***Last TC wrongly received***
0xFE15H or 0xFE95H.

The last TC has been wrongly received.

18.Wait for (T_{e2} +04':00'').

19.Send to HASI through the CDMU-A ML line the *'HASI_FM_MCARST_A.BIN'* and through the CDMU-B ML line the *'HASI_FM_MCARST_B.BIN'*.

20.Wait for (T_{e2} + 04':17'') and repeat step 19.

21.Wait for (T_{e2} + 04':36'') and repeat step 19. The command has been sent three times.

22.Wait for (T_{e2} + 05':00'') before to check the HASI-SW A and B against the following values:

<u>case 1</u>: ***Last TC correctly received***
0xFE55H or 0xFED5H.
The last TC has been successfully received.

<u>case 2</u>: ***Last TC wrongly received***
0xFE15H or 0xFE95H.
The last TC has been wrongly received.

23.Wait for (T_{e2} +05':00'').

24.Send to HASI through the CDMU-A ML line the *'HASI_FM_MCARST_A.BIN'* and through the CDMU-B ML line the *'HASI_FM_MCARST_B.BIN'*.

25.Wait for (T_{e2} + 05':17'') and repeat step 24.

26.Wait for (T_{e2} + 05':36'') and repeat step 24. The command has been sent three times.

27.Wait for (T_{e2} + 06':00'') before to check the HASI-SW A and B against the following values:

<u>case 1</u>: ***Last TC correctly received***
0xFE55H or 0xFED5H.
The last TC has been successfully received.

<u>case 2</u>: ***Last TC wrongly received***
0xFE15H or 0xFE95H.
The last TC has been wrongly received.

10.1.3.3.5 Software patch verification

Now the EEPROM content is verified via ‘Soft Reset’ command.

1. Wait for (T_{e2} +10’:00’’).

2. Send to HASI through the CDMU-A ML line the *‘HASI_SOFT_RESET_A.BIN’* and through the CDMU-B ML line the *‘HASI_SOFT_RESET_B.BIN’*.

3. **Wait (T_{start} +14’:00’’) before to check the HASI-SW A and B against the value 0xFE55H or 0xFED5H. The HASI has executed a new START-UP and the EEPROM has been loaded.**

10.1.3.3.6 HASI power OFF

1. **Wait for (T_{e2} +15’:00’’) and then send trough CDMS the ‘Deactivation flag’.**

2. **Wait for (T_{e2} +16’:00’’) and then perform HASI Power-OFF.**

FIGURES